University of Niš
Faculty of Mechanical Engineering

PROCEEDINGS

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

October 09 - 10, 2014, Niš, Serbia

Publisher

Faculty of Mechanical Engineering Niš
Prof. Vlastimir Nikolić, Dean

Editor

Prof. Dušan Stamenković
Prof. Miloš Milošević

Reviewers

Prof. Dušan Stamenković
Prof. Miloš Milošević
Prof. Zdenka Popović

Technical preparation

Milan Banić
Aleksandar Miltenović
Nikola Petrović

Cover design

Prof. Miloš Milošević

Number of copies

160

Printing

UNIGRAF, Niš

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

629.4(082)
656.2(082)
625.1(082)
338.47(497.11)(082)

SCIENTIFIC-Expert Conference of Railways (16th ; 2014 ; Niš)
Proceedings / XVI Scientific-Expert Conference on Railways - RAILCON '14, October 09-10, 2014, Niš ; [organized by] University of Niš, Faculty of Mechanical Engineering ; [editor Dušan Stamenković]. - Niš : Faculty of Mechanical Engineering, 2014 (Niš : Unigraf). - XXI, 282 str. : ilustr. ; 25 cm

Tiraž 160. - Napomene uz tekst. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-6055-060-8

1. Faculty of Mechanical Engineering (Niš)
a) Железничка возила - Зборници b) Железнички саобраћај - Зборници c) Железничке пруге - Зборници d) Србија - Саобраћајна политика

COBISS.SR-ID 210153228

ISBN 978-86-6055-060-8

Ministry of Education, Science and Technological Development of the Republic of Serbia has participated in printing costs of the Proceedings of the XVI International Scientific-expert Conference on Railways - **RAILCON 2014**

University of Niš

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

Faculty of Mechanical Engineering

Program Committee

Prof. Dušan Stamenković, President, Faculty of Mechanical Engineering Niš, SRB
Prof. Boban Anđelković, Faculty of Mechanical Engineering Niš, SRB
Prof. Dobrinka Atmadžova, VTU Todor Kableškov Sofia, BG
Prof. Branislav Bošković, Faculty of Traffic Engineering Belgrade, SRB
Prof. Dragan Đurđanović, University of Texas at Austin, USA
Prof. Miroslav Đurđanović, Faculty of Mechanical Engineering Niš, SRB
Prof. Ratko Đuričić, Faculty of Traffic Engineering Doboj, R. Srpska
Prof. Eberhard Hohnecker, Karlsruhe Institute of Technology, GER
Prof. Daniel Kalinčak, University of Žilina, SK
Prof. Dragutin Kostić, Faculty of Traffic Engineering Belgrade, SRB
Prof. Stjepan Lakušić, Faculty of Civil Engineering Zagreb, HR
Prof. Vojkan Lučanin, Faculty of Mechanical Engineering Belgrade, SRB
Prof. Dragomir Mandić, Faculty of Traffic Engineering Belgrade, SRB
Prof. Dragan Marinković, Technical University of Berlin, GER
Prof. Dragan Milčić, Faculty of Mechanical Engineering Niš, SRB
Prof. Vojislav Miltenović, Faculty of Mechanical Engineering Niš, SRB
Rešad Nuhodžić, PhD, Ministry of Transport and Maritime Affairs, MNE
Nena Tomović, MSc, Serbian Railways, SRB
Prof. Nenad T. Pavlović, Faculty of Mechanical Engineering Niš, SRB
Prof. Snežana Pejčić Tarle, Faculty of Traffic Engineering Belgrade, SRB
Prof. Dragan Petrović, Faculty of Mechanical and Civil Engineering Kraljevo, SRB
Prof. Mihaela Popa, University Politehnica of Bucharest, RO
Prof. Zdenka Popović, Faculty of Civil Engineering Belgrade, SRB
Privatdoz. Andreas Schoebel, Technical University of Vienna, AUT
Prof. Kiril Velkov, Technical University of Sofia, BG
Prof. Radisav Vukadinović, The Railway College of Vocational Studies Belgrade, SRB

Organizing Committee

Prof. Miloš Milošević, President
Aleksandar Miltenović, PhD
Miroslav Mijajlović, PhD
Srđan Stojičić, MSc
Milan Banić
Srđan Mladenović
Nikola Petrović
Predrag Milić
Dušanka Nikolić
Vesna Grozdanović

Patrons

Ministry of Education, Science and Technological Development of the Republic of Serbia
JSC SERBIAN RAILWAYS
MIN Lokomotiva a.d.

Cofinanciers

STADLER
ALTPRO
STRAIL
MIN DIV Svrljig
THALES
OPEN TRACK

CONTENTS

Plenary Session

- PRECEDENT-FREE FAULT LOCALIZATION FOR HIGH SPEED TRAIN DRIVE SYSTEMS I
  Asad UL HAQ, Dragan ĐURĐANOVIĆ
  University of Texas at Austin, Austin, USA
- IMPROVING SERBIAN RAILWAYS: POLICY OPTIONS AND STRATEGIC DIRECTIONS XI
  Nena TOMOVIĆ,
  JSC Serbian Railways, Belgrade, Serbia
  Snežana PEJČIĆ TARLE
  Faculty of Transport and Traffic Engineering, Belgrade, Serbia
- IMPORTANCE OF COTIF TO INTERNATIONAL TRAFFIC XVII
  Bas LEERMAKERS, Dragan NEŠIĆ
  OTIF, Bern, Switzerland

Rolling stock

1.1. EXPERIMENTAL RESEARCH OF CHARACTERISTICS OF IMPROVED TYPE OF COMBINED TUBE ENERGY ABSORBER 1
Jovan TANASKOVIĆ, Dragan MILKOVIĆ, Vojkan LUČANIN, Žarko MIŠKOVIĆ
Faculty of Mechanical Engineering, Begrade, Serbia

1.2. HYBRIDIZATION- THE WAY OF DECREASING CARBON DIOXIDE EMISSION AND FUEL ECONOMY 5
Martin MIKOLAJČÍK, Daniel KALINČÁK
Univerzity of Žilina, Slovakia

1.3. NEW STADLER “FLIRT3” EMU’S FOR SERBIAN RAILWAYS 9
Fadi KHAIRALLAH
Stadler Bussnang AG, Bussnang, Switzerland

1.4. REQUIREMENTS FOR CUSTOMER FRIENDLY RAILWAY INTERIORS 13
Bernhard RÜGER
Vienna University of Technology, Vienna, Austria

1.5. EXPERIMENTAL MEASUREMENTS AND NUMERICAL SIMULATIONS OF THE WHEEL-RAIL ANGLE OF ATTACK 17
Dragan MILKOVIĆ, Goran SIMIĆ, Jovan TANASKOVIĆ, Živana JAKOVLJEVIĆ
Faculty of Mechanical Engineering, Belgrade, Serbia

1.6. DETERMINATION OF FRICTION HEAT GENERATION IN CONTACT OF WHEEL-RAIL SET USING FEM 21
Aleksandar MILTENOVIĆ, Milan BANIĆ, Dušan STAMENKOVIĆ, Miloš MILOŠEVIĆ, Miša TOMIĆ
Faculty of Mechanical Engineering, Niš, Serbia

1.7. ANALYSIS OF THE RESULTS OF THEORETICAL AND EXPERIMENTAL STUDIES OF FREIGHT WAGON FALS 25
Svetoslav SLAVCHEV, Kalina GEORGIEVA, Valeri STOILOV, Sanel PURGIĆ
Technical University, Sofia, Bulgaria

1.8. ABOUT THE PROCESS OF BRAKED WEIGHT LOSS IN THE FREIGHT TRAINS 29
Kiril VELKOV, Oleg KRASTEV, Sanel PURGIĆ
Technical University, Sofia, Bulgaria

1.9. ISSUES OF WAGON MODELLING WITH SHELL ELEMENTS 33
Svetoslav SLAVCHEV, Kalina GEORGIEVA, Valeri STOILOV
Technical University, Sofia, Bulgaria

1.10. FRICTION CHARACTERISTICS OF THE FRICTION PAIRS IN DISC BRAKES 37
Vasko NIKOLOV
Todor Kableshkov University of Transport, Sofia, Bulgaria

1.11. ENERGY ANALYSIS OF FRACTIONAL ORDER OSCILLATIONS OF A COMPOSITION OF THE TRAIN BY A CHAIN MODEL OF FRACTIONAL ORDER PROPERTIES 41
Katica R. (Stevanović) HEDRIH
Department for Mechanics of Mathematical Institute SANU, Belgrade and Faculty of Mechanical Engineering, Niš, Serbia

1.12. BAGGAGE TRANSPORT SYSTEM – NEW SOLUTION 45
Bernhard RÜGER
Vienna University of Technology, Vienna, Austria

1.13. PESA 122NASF SWING - THE NEW TRAMS IN SOFIA 49
Zornitsa EVLOGIEVA, Emil M. MIHAYLOV
Todor Kableshkov University of Transport, Sofia, Bulgaria

1.14. HYBRID INTELLIGENT VIBRATION CONTROL OF RAIL CAR BODY WITH PIEZO ACTUATORS 53
Emina PETROVIĆ, Ivan ĆIRIĆ, Žarko ĆOJBAŠIĆ, Vlastimir NIKOLIĆ, Ivan PAVLOVIĆ
Faculty of Mechanical Engineering, Niš, Serbia

1.15. 30 YEARS OF THE EXPLOITATION OF LOCOMOTIVES TYPE DVM12 57
Marko ĐUKIĆ
JSC Serbian Railways, Belgrade, Serbia

1.16. THE INFLUENCE OF THE RAILWAY FLEET MODERNIZATION ON THE ENERGY EFFICIENCY 61
Igor KORUNOSKI, Kire DIMANOSKI, Gligorche VRTANOSKI
Macedonian Railways Transport JSC, Skopje, Macedonia

1.17. MEASURING ACCELERATIONS FRAME TRAM BOGIES T81 IN ORDER TO ESTABLISH THE REASONS FOR THE EMERGENCE AND DEVELOPMENT OF CRACKS 65
Emil M. MIHAYLOV, Emil IONTCHEV, Dobrinka ATMADZHOVA
Todor Kableshkov University of Transport, Sofia, Bulgaria

1.18. THE BULGARIAN STATE RAILWAYS EXPERIENCE IN DETERMINING FATIGUE STRENGTH OF ROLLING STOCK STRUCTURES 69
Dobrinka ATMADZHOVA
Todor Kableshkov University of Transport, Sofia, Bulgaria

Traffic and Transport

2.1. ASSESSING ACCIDENT SEVERITY RISK AT RAILWAY CROSSINGS IN SERBIA BY USING A MULTINOMIAL LOGIT MODEL 73
Sandra KASALICA, Dušan JEREMIĆ, Marko BURSAĆ, Goran TRIČKOVIĆ
The Railway College of Vocational Studies, Belgrade, Serbia

2.2. ANALYSIS OF RAIL AND ROAD INFRASTRUCTURE FOR POSSIBLE USE OF CAR HANDLING SYSTEMS 77
Vladimir REDŽOVIĆ
WAM Planer und Ingenieure AG, Solothurn, Switzerland

2.3. MODELLING AND DESIGN FACILITIES FOR DEALING WITH DANGEROUS GOODS ON RAILWAY 81
Slavko VESKOVIĆ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia
Goran MAKSIĆ
JSC Serbian Railways, Belgrade, Serbia
Marko VASILJEVIĆ
Faculty of Traffic and Transport Engineering, Doboj, Bosnia and Herzegovina
Gordan STOJIĆ
Faculty of Technical Sciences, Novi Sad, Serbia
Snježana RAJILIĆ
Municipal Novi Grad, Novi Sad, Serbia

2.4. RAILWAY TRAFFIC IN SUSTAINABLE ENVIRONMENTAL DEVELOPMENT AND ENERGY EFFICIENCY 85
Predrag PETROVIĆ, Marija PETROVIĆ, Slobodan VUKMIROVIĆ
Institute "Kirilo Savić", Belgrade, Serbia
Živojin PETROVIĆ
Faculty of Mechanical Engineering, Belgrade, Serbia

2.5. SELECTION OF RAILWAY LEVEL CROSSINGS FOR INVESTING IN SECURITY EQUIPMENT USING HYBRID DEMATEL-MARIC MODEL 89
Dragan PAMUČAR, Ljubislav VASIN, Vesko LUKOVAC
Military academy, Belgrade, Serbia

2.6. ON VALIDITY OF INTRODUCING THE ENERGY METERS ON ELECTRIC TRACTION UNITS 93
Slobodan ROSIĆ
JSC Serbian Railways, Belgrade, Serbia
Dragutin KOSTIĆ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia

2.7. A COMPARISION OF DRIVER BEHAVIOR AT RAILWAY CROSSING WITH PASSIVE AND ACTIVE PROTECTION SYSTEMS 97
Sandra KASALICA, Goran TRIČKOVIĆ, Dušan JEREMIĆ, Marko BURSAĆ
The Railway College of Vocational Studies, Belgrade, Serbia

2.8. RANKING OF HEADWAYS PRIORITY IN RAILWAY TIMETABLE 101
Predrag JOVANOVIĆ, Dragomir MANDIĆ, Dragan IVANOVIĆ
Faculty of Traffic and Transport Engineering, Belgrade, Serbia

2.9. APPLICATION OF OPENTRACK AT RAILWAY PROJECTS IN AUSTRIA 105
Andreas SCHÖBEL
OpenTrack Railway Technology GmbH, Vienna, Austria

2.10 SIMULATION MODELLING OF TECHNOLOGICAL PROCESSES IN SUBWAY STATION 109
Svetla STOILOVA, Veselin STOEV
Technical University, Sofia, Bulgaria

2.11. MULTICRITERIA SUSTAINABILITY EVALUATION OF TRANSPORT MODES 113
Nikola PETROVIĆ, Vesna JOVANOVIĆ
Faculty of Mechanical Engineering, Niš, Serbia
Jelena PETROVIĆ, Mladen MITROVIĆ
Faculty of Science and Mathematics, Niš, Serbia

Infrastructure

3.1. THE ORGANIZATION OF CONSTRUCTION WORKS UNDER TRAFFIC ON OVERHAUL OF RAILWAY SECTION DOBOJ – KM 103+500 117
Ljuban JEROSIMIĆ, Tatjana MIKIĆ, Tatjana SIMIĆ
CeS COWI, Belgrade, Serbia

3.2. WATERPROOFING OF CONCRETE BRIDGE – GENERAL CHARACTERISTICS AND REQUIREMENTS 121
Snejana VALKOVA, Nikolina POROJANOVA
Todor Kableshkov University of Transport, Sofia, Bulgaria

3.3. EXTENSION OF ARCHITECTURAL CONTENT ON PASSENGER STATIONS AND SPECIAL REQUIREMENTS IN CIVIL ENGINEERING AND INFRASTRUCTURE PLANNING 125
Tomasz REMUS
WAM Planer und Ingenieure AG, Solothurn, Switzerland

3.4. DESIGN SOLUTION OF CONTAINER TERMINAL WAREHOUSE CASE OF FREE ZONE CITY OF NIŠ 129
Vojislav TOMIĆ, Miloš MADIĆ, Boban NIKOLIĆ
Faculty of Mechanical Engineering, Niš, Serbia

3.5. MODULAR MICROPROCESSOR LEVEL CROSSING PROTECTION SYSTEM TYPE RLC23 FOR SAFETY INTEGRITY LEVEL SIL4 133
Zvonimir VIDUKA, Darko BARIŠIĆ
ALTPRO, Zagreb, Croatia

3.6. TOOLS FOR TRANSITION CURVE DESIGN - APPLICATION FOR RAILWAY RECONSTRUCTION 137
Luka LAZAREVIĆ, Zdenka POPOVIĆ, Milica VILOTIJEVIĆ
Faculty of Civil Engineering, Belgrade, Serbia
3.7. AUTHORISATION FOR PLACING IN SERVICE OF STRUCTURAL SUBSYSTEMS PRESENTED ON THE EXAMPLE OF THE SUBSYSTEM “INFRASTRUCTURE” 141
Mirjana DŽUDOVIĆ, Milan POPOVIĆ
Directorate for Railways, Belgrade, Serbia
Dragana JOKANOVIĆ
JSC Serbian Railways, Belgrade, Serbia

Vehicle and infrastructure maintenance

4.1. REPAIRING OF BROKEN LAMINATED SPRINGS OF FREIGHT WAGONS BY WELDING 145
Dragan PETROVIĆ, Milan BIŽIĆ
Faculty of Mechanical and Civil Engineering, Kraljevo, Serbia
4.2. DATABASE TO SUPPORT OPTIMIZATION OF ROLLING STOCK MAINTENANCE IN SERBIAN RAILWAYS 149
Slađana JANKOVIĆ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia
Života ĐORĐEVIĆ
JSC Serbian Railways, Belgrade, Serbia
Irina BRANOVIĆ
IEEE Member
Snježana RAJILIĆ
Municipal Novi Grad, Novi Sad, Serbia
Slavko VESKOVIĆ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia
4.3. FIRST RESULTS OF THE CHANGE OF THE CRITERIA FOR REGULAR REPAIRS OF SERIES 441 TRACTION VEHICLES 153
Dragan B. RAJKOVIĆ
JSC Serbian Railways, Novi Sad, Serbia
4.4. METHODOLOGIES OF EXPERIMENTAL DETERMINATION OF WHEEL-RAIL CONTACT FORCES 157
Milan BIŽIĆ, Dragan PETROVIĆ
Faculty of Mechanical and Civil Engineering, Kraljevo, Serbia
4.5. DAMAGES OF RAILWAY INFRASTRUCTURE INDUCED BY CORROSION 161
Dušan PETKOVIĆ, Goran RADENKOVIĆ
Faculty of Mechanical Engineering, Niš, Serbia
Jelena DIMITRIJEVIĆ
Faculty of Civil Engineering, Niš, Serbia
4.6. MEASUREMENT OF WIRE PRESTRESSING FORCE TO QUALITY OF CONCRETE SLEEPERS 165
Slobodan JOVANOVIĆ, Dragan S. JOVANOVIĆ
Faculty of Mechanical Engineering, Niš, Serbia
Slaviša PLANIĆ
DIV Concrete sleepers LTD. Svrljig, Serbia
4.7. THE THERMAL ELASTIC BEHAVIOR OF THE CYLINDRICAL ROLLER BEARING FOR RAILWAY VEHICLES 169
Vladimir BLANUŠA, Milan ZELJKOVIĆ, Aleksandar ŽIVKOVIĆ
Faculty of Technical Sciences, Novi Sad, Serbia

Strategy and Policy

5.1. QUANTIFYING LANDSCAPE FRAGMENTATION DUE TO RAIL INFRASTRUCTURE 173
Nataša BOJKOVIĆ, Marijana PETROVIĆ, Snežana PEJČIĆ TARLE
Faculty of Transport and Traffic Engineering, Belgrade, Serbia

5.2. IMPROVING QUALITY OF SERVICE FOR PEOPLE WITH DISABILITIES IN RAILWAY TRANSPORT 177
Dragan ĐORĐEVIĆ
Institute of Transportation CIP, Belgrade, Serbia
5.3. DATA DRIVEN MODEL FOR PREDICTION OF RAIL TRAFFIC 181
Luka LAZAREVIĆ, Miloš KOVAČEVIĆ, Zdenka POPOVIĆ
Faculty of Civil Engineering, Belgrade, Serbia
5.4. HOW TO EVALUATE BODIES FOR RAILWAY MARKET REGULATION 185
Branislav BOŠKOVIĆ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia
Danijela ĐORIĆ
Serbia
Nataša CEROVIĆ
Directorate for Railways, Belgrade, Serbia
5.5. APPLICATION OF GROUP DECISION MAKING APPROACH FOR RESTRUCTURING RAILWAYS TOWARDS SUSTAINABILITY 189
Boban ĐORĐEVIĆ, Tanja PAREZANOVIĆ, Snežana PEJČIĆ TARLE
Faculty of Transport and Traffic Engineering, Belgrade, Serbia
Nena TOMOVIĆ
JSC Serbian Railways, Belgrade, Serbia
Nikola PETROVIĆ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia
5.6. SELECTION OF THE LOCOMOTIVE SERIES APPROPRIATE FOR MODERNIZATION BASED ON MULTI-CRITERIA ANALYSIS 193
Oleg KRASTEV, Kiril VELKOV, Mario KRASTEV
Technical University, Sofia, Bulgaria

Other Railway aspects

6.1. RISK MANAGEMENT CAPABILITIES IN RAIL TRANSPORT UNDER SEVERE WEATHER CONDITIONS 197
Dragutin JOVANOVIĆ, Vujadin VEŠOVIĆ
Faculty of Transport, Communications and Logistics, Berane, Montenegro
Branko BABIĆ
Technical College of Vocational Studies, Novi Sad, Serbia
Nebojša ĆURČIĆ
College of Vocational Studies - Belgrade Polytechnics, Belgrade, Serbia
6.2. DISCUSSION ON AUCTIONS AND POSSIBILITY OF THEIR APPLICATION IN RAILWAY 201
Nikola STOJADINOVIĆ, Branislav BOŠKOVIĆ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia
6.3. RAILWAY ENGINEERING EDUCATION 205
Dušan STAMENKOVIĆ
Faculty of Mechanical Engineering, Niš, Serbia
Dragomir MANDIĆ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia
6.4. THE ROLE AND COMPETENCIES OF REGULATORY BODY ACCORDING TO THE LAW ON RAILWAYS 209
Branka NEDELJKOVIĆ, Zorica RADOVIĆ
Directorate for Railways, Belgrade, Serbia
6.5. CURRENT PROBLEMS OF CROSSING THE RAILWAY DURING THE CONSTRUCTION AND OPERATION OF THE HIGHWAYS ON CORRIDOR 10 213
Aleksandar NAUMOVIĆ
"Corridors of Serbia", Belgrade, Serbia
Sinisa MARIĆ
JSC Serbian Railways, Belgrade, Serbia
Predrag ATANASKOVIĆ
Faculty of Technical Sciences, Novi Sad, Serbia

6.6. IMPORTANCE OF PASSENGER RAILWAY TRAFFIC IN DEFINING CRITERIA TRANSPORT ACCESSIBILITY OF THE AREAS OF DANUBE DISTRICTS 217
Ana VULEVIĆ, Dragan ĐORĐEVIĆ
Institute of Transportation CIP, Belgrade, Serbia
6.7. ACTIONS TAKEN ON RAILWAYS IN STIMULATING OF TRANSPORT OF PASSENGERS WITH SPECIAL NEEDS 221
Zoran PAVLOVIĆ
JSC Serbian Railways, Belgrade, Serbia
6.8. RAILWAY LINES FOR FAST TRAINS IN JAPAN 225
Jelena DIMITRIJEVIĆ
Faculty of Civil Engineering, Niš, Serbia
Dušan PETKOVIĆ
Faculty of Mechanical Engineering, Niš, Serbia
6.9. REMOVING OF RELEASING PROBLEM OF FREIGHT CARS OPERATING IN SS REGIME WITH INSTALLING OF BY/PASS 229
Erdinč RAKIPOVSKI
Skopje, Macedonia
Dragan MILČIĆ
Faculty of Mechanical Engineering, Niš, Serbia
6.10. ANALYSIS OF LIFE CYCLE COSTS AND PROFITS OF TRAMS IN SLOVAKIA 233
František RUMAN, Juraj GRENČÍK
Univerzity of Žilina, Slovakia
6.11. DESIGN OF A DISTRIBUTED SYSTEM FOR MONITORING ENERGY CONSUMPTION OF ELECTRIC-TRACTION VEHICLES BASED ON GPRS-INTERNET 237
Nenad JEVTIĆ, Dragutin KOSTIĆ, Slobodan MITROVIĆ, Petar MARKOVIĆ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia
6.12. APPLICATION OF THE MOBILE MACHINES IN RAILWAY TRANSPORT 241
Dragoslav JANOŠEVIĆ, Jovan PAVLOVIĆ, Vesna JOVANOVIĆ
Faculty of Mechanical Engineering, Niš, Serbia
6.13. INVESTIGATING THE GROUND BASE ALONG A DEFORMED SECTION OF THE SILISTRA-ALFATAR RAILWAY (BULGARIA) 245
Vanushka PETROVA
Geological Institute – Bulgarian Academy of Sciences, Sofia, Bulgaria
Zornitsa EVLOGIEVA
Todor Kableshkov University of Transport, Sofia, Bulgaria
6.14. A PROPOSAL OF LED MODULE DESIGN IN RAILWAY SIGNALS 249
Ranko BABIĆ
The Railway College of Vocational Studies, Belgrade, Serbia
6.15. APPLICATIONS OF FBG SENSOR SYSTEM FOR TRAIN AXLE COUNTING IN RAILWAY 253
Ivan STANKOVIĆ, Nenad T. PAVLOVIĆ
Faculty of Mechanical Engineering, Niš, Serbia

Poster presentations

7.1. TESTING OF THE DYNAMICAL BEHAVIOUR IN RUNNING CONDITION OF THE NEW DMU FOR THE SERBIAN RAILWAYS 257
Milutin KRIVOKAPIĆ, Marija VUKŠIĆ-POPOVIĆ, Saša RADULOVIĆ, Borisav BOGDANOVIĆ
Institute "KiriloSavić", Belgrade, Serbia
7.2. THE POSSIBILITY OF USING A SUPPLEMENTARY COMPONENT FOR THE COMBUSTION EFFICIENCY OF LOCOMOTIVE DIESEL ENGINES 261
Miloš MILOŠEVIĆ, Boban NIKOLIĆ, Vojislav TOMIĆ
Faculty of Mechanical Engineering, Niš, Serbia
Jovica PEŠIĆ
Linex, Pirot, Serbia
Ljubiša TJUPA
ETŠ Mija Stanimirović, Niš, Serbia

7.3.	COMPARISON OF THE OPERATING PROPERTIES OF COMPOSITE ORGANIC RAILWAY BRAKE BLOCKS WITH CAST IRON BRAKE BLOCKS P10 Daniel KALINČÁK, Rudolf ŘEZNÍČEK, Martin MIKOLAJČÍK University of Žilina, Slovakia	265
7.4.	RISK ANALYSIS OF DELAY OF PASSENGER TRAINS IN THE RAIL NETWORK Svetla STOILOVA Technical University, Sofia, Bulgaria	267
7.5.	INFRASTRUCTURE OF URBAN RAIL SYSTEMS Ivana VICENTIĆ EnCon doo, Belgrade, Serbia Zdenka POPOVIĆ Faculty of Civil Engineering, Belgrade, Serbia	271
7.6.	THE ISSUE OF PERFORMANCE MANAGEMENT SUCCESS IN SERBIAN RAILWAYS COMPANY Aleksandar BLAGOJEVIĆ JSC Serbian Railways, Novi Sad, Serbia Radmila ČURĆIĆ High School of Professional Studies for Traffic Management, Niš, Serbia	275
7.7.	THE EFFECT OF AGING TEMPERATURE ON SILICA REINFORCED POLYISOPRENE/ CHLOROSULPHONATED POLYETHYLENE RUBBER BLEND IN RAILWAY INDUSTRY Gordana MARKOVIĆ Tigar, Pirot, Serbia Milena MARINOVIC-CINCOVIĆ Institute of Nuclear Science Vinča, Belgrade, Serbia Vojislav JOVANOVIĆ, Suzana SAMARŽIJA-JOVANOVIĆ Faculty of Natural Science and Mathematics, Priština (Kosovska Mitrovica), Serbia Jaroslava BUDINSKI-SIMENDIĆ Faculty of Technology, Novi Sad, Serbia	279

Index of Authors

Plenary Session

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

PRECEDENT-FREE FAULT LOCALIZATION FOR HIGH SPEED TRAIN DRIVE SYSTEMS

Asad Ul HAQ [1]
Dragan ĐURĐANOVIĆ [2]

Abstract *– In this paper, a framework for localization of sources of unprecedented faults in the drive train system of high speed trains is presented. The framework utilizes distributed anomaly detection, with anomaly detectors based on the recently introduced Growing Structure Multiple Model Systems (GSMMS) models. Physics-based model of the drive train of a well-known high-speed train was developed using first principles and was calibrated using data from several actual trips on the train. Simulations based on the physics based model as the data source demonstrate the ability of GSMMS based distributed anomaly detection to localize faults within various parts of the drive train system without the need for models of the underlying faults.*

Keywords – Immunity inspired diagnostics, high speed trains, Growing Structure Multiple Model Systems.

1. INTRODUCTION

A growing concern with the environmental impact of air traffic has contributed to the success and growth of high speed rail as a more sustainable transport medium. Consequently, in recent years the European and Japanese markets have seen a significant transition of traffic from airplanes to high speed rail, especially for journeys up to a few hundred miles long [1]. Studies have also been carried out that underline the benefits of high speed rail as a transport system [2].

The growing popularity of high speed rail has inevitably led to investment in the development of the resources required to ensure reliability of the train systems [3], which is critical to the ability of high speed rail to compete with alternative modes of transport. As such, there is a need to develop systems for condition monitoring that would enable detection of faults and localization of their root causes within the system[1]. The increasing complexity of trains running at higher speeds has led to greater challenges in the tasks of detecting faults that cascade through the system, and finding their sources. The first and foremost factor driving the need for such reliable and efficient monitoring systems derives from the safety requirements for high speed trains. In addition to this, there is a two-fold financial significance. First, ensuring reliability is critical as it prevents delays, which becomes a factor in retaining passengers. Second, accurate fault localization contributes to the reduction of wastage of resources on ineffective maintenance.

Unfortunately, monitoring systems based on the classical framework are restricted in their diagnostic abilities, due to their reliance on fault models for these tasks. Namely, the classical diagnostic paradigm requires models of the relevant faults in order to detect their occurrence. Furthermore, these models need to be adequate throughout the operating space which the system experiences. Therefore, a monitoring system under the classical framework is not able to deal with faults that have not been foreseen, or for systems in operating regimes for which diagnostic models were not trained. This is of particular significance for highly complex system operating under highly variable operating regimes, such as the drive train of a high speed train. For such systems, it becomes unfeasible to build models of all possible faults, under all operating conditions. This strongly implies the need for a precedent-free fault detection and isolation approach.

In this paper, the method for precedent-free fault detection and localization introduced in [4],and

[1] *Reliably and efficiently determining which part of the system is at fault*

[1] Asad Ul HAQ, Teaching Assistant, The University of Texas at Austin, Austin, TX 78712, USA, asadulhaq@utexas.edu
[2] Dragan ĐURĐANOVIĆ, Associate Professor, The University of Texas at Austin, Austin, TX 78712, USA, dragand@me.utexas.edu

further developed in [5], is employed to facilitate monitoring of high speed train drive systems. More specifically, the aforementioned novel diagnostic paradigm was applied to models and data corresponding to the platform of the Trains a Grand Vitesse (TGV), developed by ALSTOM [6] and operated by SNCF in France [7].

The methodology presented in [4] spans the tasks of fault detection, localization and identification in complex systems of interacting dynamic subsystems. Anomalous behavior of the system is detected as a statistically significant departure of its behavior from the normal one. The detection of a fault triggers the distribution of anomaly detectors (ADs) across the subsystems of the faulty system, spreading into increasingly granular levels of subsystems that exhibit deviation from their own models of normal behavior. This process of AD proliferation continues as each AD that detects a fault is replaced by multiple ADs monitoring the constituent subsystems of the faulty system. Thus, the source(s) of the fault(s) is(are) localized, as part(s) of the system surrounded by alarming ADs, in a hierarchical manner once the highest possible level of granularity of subsystems is reached. This distributed anomaly detection based on an a priori known structure of the monitored system[2] has been shown to enable precedent-free fault root cause localization [8]. The entire process is based solely on models of normal behavior, thereby bypassing the need for fault models, which, as previously mentioned, is a major constraining factor in the applicability of traditional diagnostic methods.

After faulty subsystem(s) is (are) located, the natural next step is fault diagnosis, which involves identification of corresponding fault models so that such behavior may be recognized in the future, and possibly remedied via fault-tolerant controller adaptation or maintenance intervention. This obviously amounts to the traditional diagnostic paradigm of recognizing known faults based on their models, or building new fault models when the currently observed behavior of the monitored system does not match any existing fault model. Such fault models can be built based on knowledge about system physics, as well as historical experience and observations of system operation.

The novel diagnostic framework briefly described above has previously been successfully implemented for fault detection, localization and diagnosis in the electronic throttle and crankshaft systems of an automotive internal combustion (IC) engine [4] [9], Exhaust Gas Recirculation System of an automotive diesel engine [5] and most recetly, distributed thermo-fluidic systems [10]. In this paper, this approach is employed for monitoring the drive system of a high speed train. A drive system in a high speed train is a complex system which incorporates linear and non-linear subsystems with continuous as well as discrete inputs and outputs. These factors contribute to a tremendously increased complexity for the monitoring task at hand[3].

The remainder of this paper is organized as follows. Section 2 describes the Growing Structure Multiple Model Systems (GSMMS) modeling approach, which was used as the foundation of the ADs in this work. It also describes the GSMMS-based anomaly detection and isolation procedures. Section 3 describes the physics based and data driven modeling of the system and Section 4 goes on to describe the implementation of the framework to the system in question and the results thereof. Finally, the conclusions and suggested future work are presented in Section 5.

2. DIAGNOSTIC FRAMEWORK

The diagnostic framework described in the previous section does not require fault models for localization of the sources of abnormal behavior of the monitored system. Instead, it only requires models of normal behavior for all the relevant subsystems, which form the basis of the ADs distributed across the system. The recently introduced GSMMS approach for modeling nonlinear dynamic systems [4] is exploited to create the aforementioned models and this section will briefly look into the motivation for the use of this modeling paradigm, as well as summarize methodological traits of the GSMMS model. Further, this section will also discuss how the distributed anomaly detection framework can be used to facilitate precedent-free localization of culprit subsystems causing anomalous behavior of the monitored system.

2.1 Modeling of Dynamic Behavior

Traditional anomaly detection methods, based on global models of system behavior, focus on characterizing probability distributions of behavioral features and detecting anomalies as changes in those distributions. For systems that do not involve interactions between various constituent subsystems, such anomaly detection approaches are appropriate. However, interactions with other subsystems mean that shifts in the dynamic behavior of a constituent subsystem may not occur solely due to changes in the system dynamics (i.e. real faults), but also due to changes in the operating regime (which should not be seen as anomalies). Namely, changes in the upstream

[2] *Knowing what subsystems constitute it and what their respective inputs and outputs are*

[3] *Requiring the use of more distributed ADs and a higher level AD hierarchy than the cases reported in the literature on precedent-free diagnostics so far*

subsystems, whose behavior affects the monitored system, cause shifts in the operating regime of the monitored system, potentially leading to changes in the behavior of the modeling residuals of the relevant anomaly detector and, consequently, false alarms.

Such a situation necessitates the use of modeling and anomaly detection approaches that have the potential to separate abnormalities caused by unusual operating conditions (which are not truly anomalies) and true anomalies due to changes in the internal dynamics of the monitored system. To that end, one can utilize "divide and conquer" approaches, pursued in e.g. [4] [5] [9] [11] [12], where the operating space of the monitored system is indexed using features from other systems affecting it. Divide and conquer models decompose the operating space into regimes of similar dynamic behavior, permitting the diagnostic framework to deal with regime-switching induced behavioral shifts. By postulating relatively tractable models in each operating regime, a set of region-specific anomaly detectors can be utilized. The behavior can then be considered independently in each operating regime and the presence of a fault can be detected as unusual behavior of modeling residuals within any of those operating regimes (i.e. corresponding to any of the local models within the divide and conquer modeling framework).

Within the GSMMS framework, the regionalization of operating regimes of a system is conducted via unsupervised clustering of its inputs and initial conditions using a Kohonen Self-Organizing Map (SOM) [13]. The use of such an unsupervised approach for partitioning the operating space overcomes the drawbacks associated with ad-hoc or variable-by-variable approaches [14] - [16]. In addition, growing mechanisms, such as those reported in [17] - [19], enable the determination of the number of local models required to approximate the underlying nonlinear dynamics, with a desired accuracy.

The Growing Structure Multiple Model System can be seen as a collection of local models, with a local model capturing the dynamic behavior in each operating regime. The simple and tractable linear ARX type models were used for the work presented in this paper,allowing easy parameter estimation and interpretation of local models. Essentially such a GSMMS formulation casts the problem of representing the system dynamics into the framework of interconnected, analytically tractable linear dynamic models. Even more simply stated, it approximates a curved surface (non-linear) with a set of appropriately shaped and sized flat tiles (linear models), where the number, shape, size and location of the tiles is determined via a growing SOM. This structure enables the modeling of complex systems, such as the drive system of a high speed train, while maintaining analytical tractability and an operating regime decomposition that enables regionalized anomaly detection. The GSMMS approach has been used successfully for modeling an electronic throttle system in a gasoline engine [11], automotive crankshaft dynamics [9], diesel engine Exhaust Gas Recirculation (EGR) system and its subsystems [5], electrical portion of an alternating current generator [12] and a distributed thermo-fluidic system [10].

Further details, including the mathematical details and graphical representations, of this modeling approach can be found in [20].

2.2 Method for Detection, Isolation and Diagnosis of an Anomaly

Anomalous behavior can be seen as a statistically significant departure of the current dynamics of the target subsystem away from the normal one. Once a GSMMS model of normal behavior is built for each system to be monitored, anomaly detection can be accomplished through comparison of the statistical characteristics of its residuals displayed during normal behavior with characteristics of the most recent modeling residuals. Since the operating space is decomposed into regions within which a linear model describes the system dynamics, each GSMMS region can be equipped with its own decision making scheme that quantifies how close the current residual pattern is to the normal pattern. Following [11], the performance within each operating region will be described in this paper using the concept of regional confidence values (CVs), defined as the area of overlap of the probability density function (PDF) of the modeling residuals displayed during normal behavior and the PDF of the residuals corresponding to the current behavior, in that region. Based on their universal approximation ability, Gaussian Mixture Models (GMMs) were used to approximate the PDFs [21], which allows efficient recursive updating of the PDFs during operation to obtain the most recent distributions [22], as well as analytical and thus, fast calculation of the distribution overlaps (CVs).

With the above definition, one can see that the CV will be close to 1 when there has not been significant change in the local dynamics of the monitored system, while any notable shift in the local system dynamics will result in lower CVs, with 0 being the lower bound. Following [11] the global CV for the monitored system is then quantified as the geometric mean of the local CVs. This choice of global CV prevents the masking of a fault that is apparent only in certain operating regimes. Namely, a low CV in any given operating regime will force a low global CV for the system, even if the performance is not affected in other operating regimes.

Isolation of the anomaly source can be conducted by proliferating anomaly detectors (ADs) to monitor subsystems of the anomalous system, all of which utilize only models of normal behavior of the system they monitor. Effectively, once an anomaly is detected, the proliferation of the ADs monitoring the pertinent subsystems of that target system is initiated, enabling monitoring and anomaly detection in subsystems of ever finer granularity. Such distributed anomaly detection leads to progressively finer localization of the fault through the hierarchy of the overall monitored system, until the finest feasible granularity is reached.

Once the fault is localized to a subsystem, the next step is to recognize the underlying fault (if the model of that fault exists) or recognize that the underlying fault is unknown. A diagnoser for a specific fault can be constructed following essentially the same approach pursued for the purpose of anomaly detection. Signatures emitted in the presence of the fault that the diagnoser needs to recognize can be utilized to estimate the PDFs of the modeling residuals of that diagnoser in the presence of that fault (residuals of the GSMMS corresponding that fault). Proximity of the most recent system behavior to that fault can then be evaluated via the overlap between the PDF characterizing the most recent residuals of the fault model and that corresponding to the residuals of the fault model observed in the presence of the fault it is supposed to recognize. Whenever this CV-like value for a specific fault model is close to 1, it can be concluded that the corresponding fault is present and a value of this CV-like index close to 0 would imply the absence of that fault. If for none of the existing diagnosers this CV-like overlap happens to be close to 1, the presence of an unknown fault can be inferred and a new fault model must be developed to enable recognition of this fault in the future.

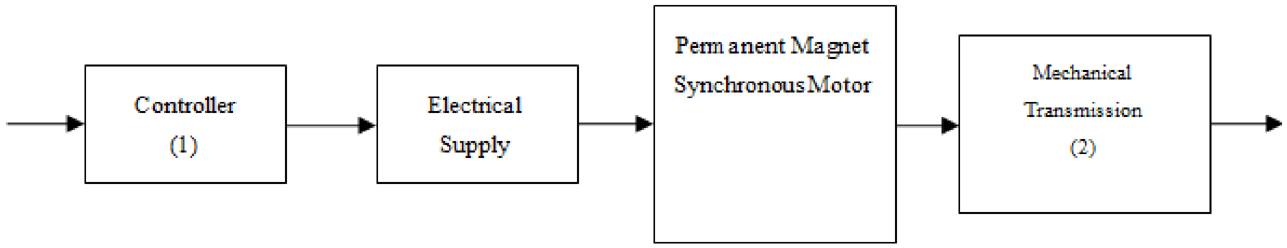


Figure 1: High speed drive train system

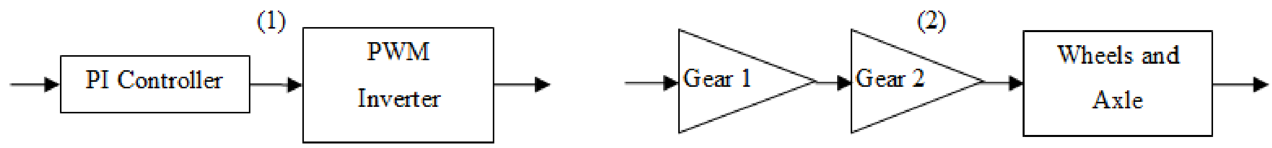


Figure 2: Components of controller and mechanical transmission systems

3. MODELING THE HIGH SPEED TRAIN DRIVE SYSTEM

In order to implement the distributed anomaly detection to the drive system of a high speed train, GSMMS models for the system and its pertinent subsystems must be developed. To this end, a physics based model was first built based on a combination of expert advice and available literature. The model was built in Simulink® and simulated using velocity profiles collected from actual TGV train journeys between Paris and Metz, in France. The simulations generated data for the inputs and outputs of each of the subsystems of interest, which was then used to develop the relevant GSMMS based ADs.

The overall system receives a reference velocity as the input, while the actual velocity generated by the drive system is the output. It is composed of a controller, electrical supply, drive motor and mechanical transmission, as illustrated in Figs. 1 and 2. These figures show the major components of the Simulink® model utilized. In addition, it was assumed that sensors were available to collect the input and output data pertaining to each of these subsystems, as well as their component subsystems.

The drive motor was taken to be a permanent magnet synchronous motor (PMSM), as per expert advice received from ALSTOM engineers and relevant literature [23]. PMSM modeling has been tackled in the literature in various ways, commonly using a transition of the electrical component from the physical 3-phase structure to an equivalent 2-phase right-angled structure, enabled by the Clark Transformation [24]. In this paper, we used model of PMSM dynamics developed in [25]. Following [26], the controller was taken to be a simple proportional-integral (PI) controller, with a pulse width modulating inverter. Finally, the mechanical transmission subsystem consists of two gears and a wheel and axle combination [23], each of which was modeled simply as a proportional gain. The wheel size required for the gain of the wheel and axle was set as per the information available in [27].

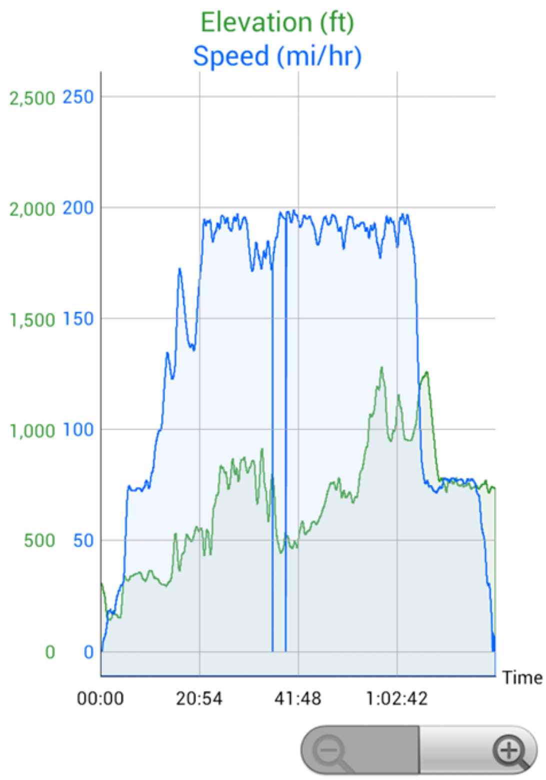


Figure 3: Example reference velocity trajectory

In order to make the data generated as representative of the real world conditions as possible, the reference velocity profiles were collected during actual high speed train journeys between Paris and Metz. Four such profiles were collected, one of which was used for training and the other three for testing of the proposed diagnostic approach. These profiles were gathered using a mobile phone based Android application called 'My Tracks' [28], which tracks position, velocity and height using GPS signals. The measurement of interest here is the velocity profile, an example of which is provided in Fig. 3 as a screenshot from the mobile phone.

Once the physics based model was built, data collected from the simulations was used to build the required GSMMS based ADs for all the relevant subsystems of the drive train. The orders of the local ARX models within the GSMMS, were set ad hoc, although techniques for the automated selection of these parameters can be found in [29].

4. SIMULATION OF DISTRIBUTED ANOMALY DETECTION

With the GSMMS based ADs available to monitor each subsystem, the distributed anomaly detection approach was put to the test. The hierarchy of the AD distribution is shown in Figs. 4 and 5, displaying the AD associated with each monitored system and subsystem. The fault localization process commences at AD1 which monitors the overall drive train system. Once a fault is detected by AD1, AD2 - AD4 are activated and begin to monitor the controller, PMSM and mechanical transmission systems respectively. The fault is then localized to one of these subsystems and, depending on which system is faulty, either AD5 and AD6 or AD7, AD8 and AD9 are activated. AD5 monitors the PI controller within the controller, hence it and AD6 would be activated if the fault had been signalled by AD2. If the fault had been signalled by AD4, AD7 - AD9 would be activated respectively monitoring gear 1, gear 2 and the wheel and axle combination.

The faults considered in this paper were limited to the controller and mechanical transmission systems, and were introduced approximately 8 minutes into the journey.

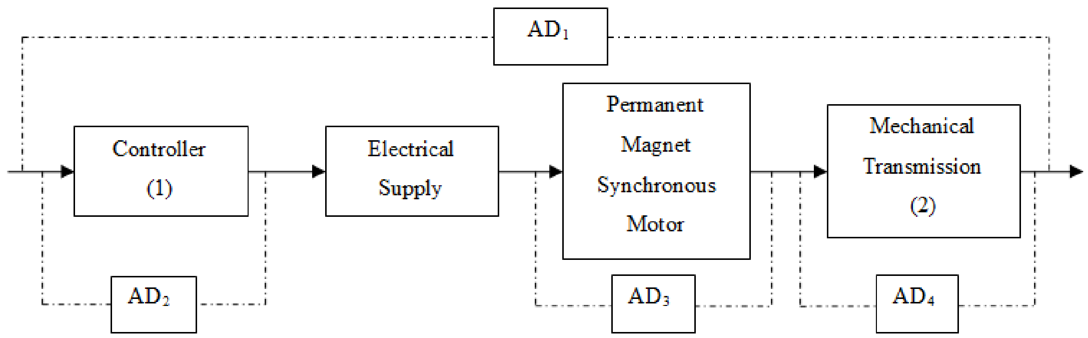


Figure 4: Levels 1 and 2 of the anomaly detector distribution hierarchy

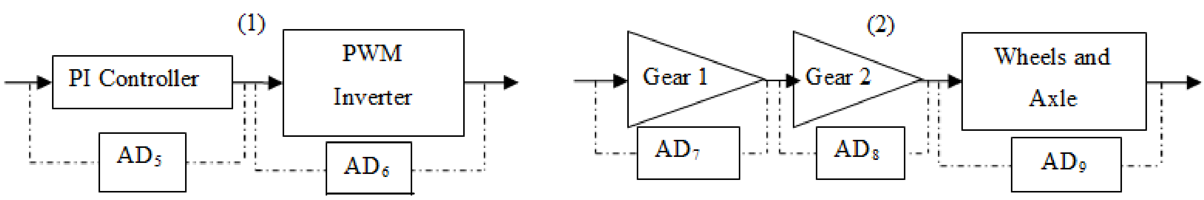


Figure 5: Level 3 of the anomaly detector distribution hierarchy

4.1 Localization of a Fault in the Controller

The fault in the controller was introduced in the form of a delay in its output, with delays of 0.7 seconds and 1.4 seconds being inserted in 2 different simulations. The results are presented in the form of the CVs associated with each AD and shown in Figs. 6, 7 and 8. The fault is detected by AD1 as is highlighted in Fig. 6 by the drop in the associated CV. From Fig. 7 one can see that, of the 3 ADs monitoring the first level of subsystems, only AD2 exhibits a drop in CV. Hence, the fault can at this stage be localized to the controller subsystem. Finally, it is observed in Fig. 8 that the CV associated with AD5 drops significantly, while that associated with AD6 remains high. These results show the fault being tracked through the levels as being local first to the overall system, then the controller subsystem and finally the PI controller. The approach has hence been able to localize the fault without having any signatures or models associated with the fault in question. In addition, it is noted that no fault was signalled at any of the subsystems that were not faulty, including those interacting with the faulty subsystem. With the anomaly detectors having been set up beforehand, the distributed anomaly detection framework is able to detect the fault online.

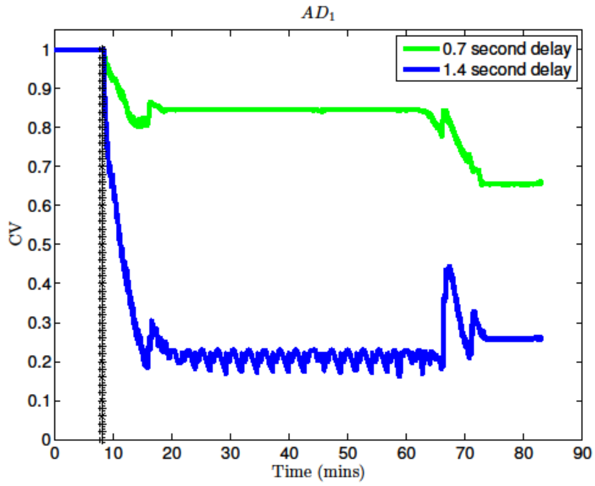


Figure 6: Controller fault detection response of the AD monitoring the overall system

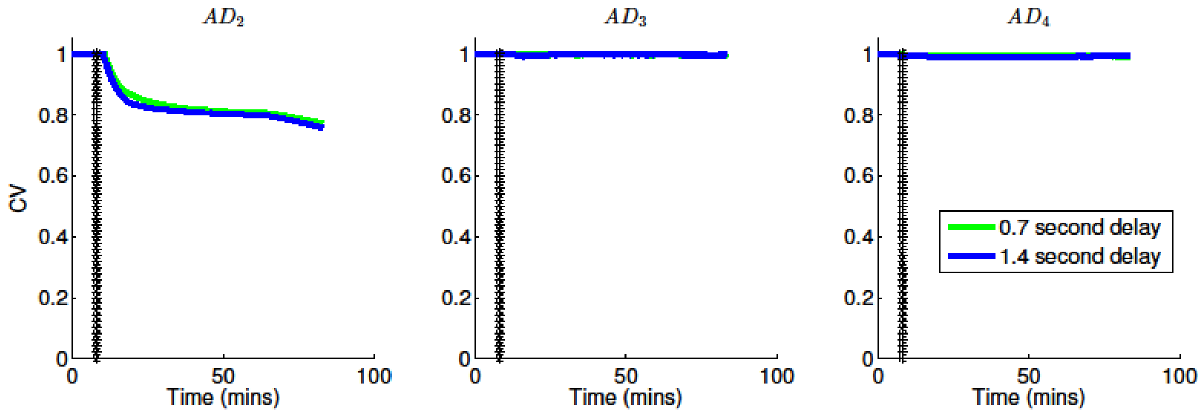


Figure 7: Controller fault localization at first level of subsystems

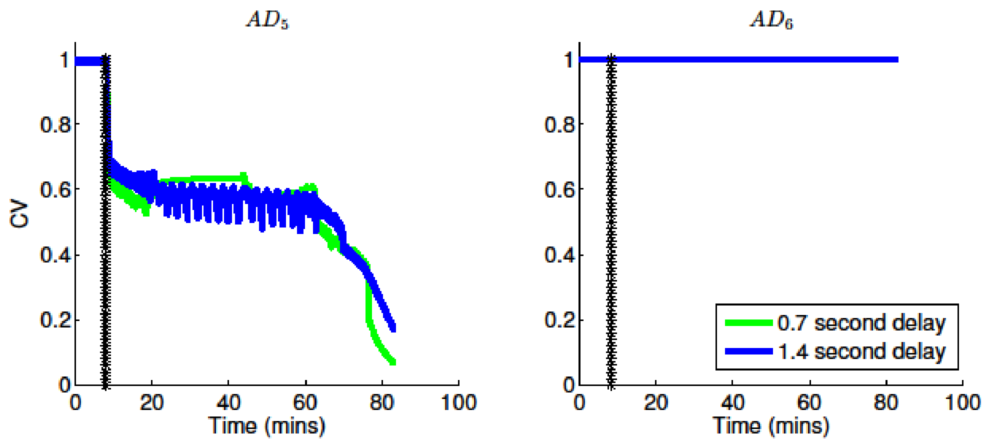


Figure 8: Fault localization within the Controller system

4.2 Localization of a fault in the Mechanical Transmission

A fault in the mechanical transmission was modeled in the form of added noise to the output from gear 2 to simulate a chattering type fault. Once again, the fault was introduced about 8 minutes into the journey and 2 simulations were conducted with added noise at 6% and 10% of the signal, respectively. The resulting CVs for the relevant ADs are shown in Figs. 9 - 11.

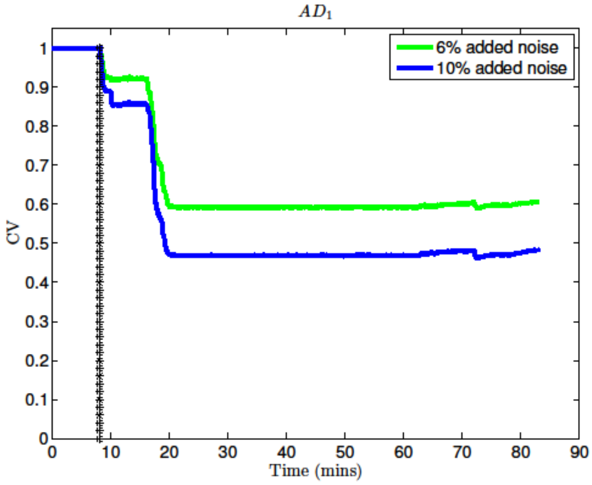


Figure 9: Gear fault detection response of the AD monitoring the overall system

arrives the maintenance team will know exactly which component requires their attention, thereby saving time on inspection and offline fault localization.

5. CONCLUSIONS AND FUTURE WORK

A recently introduced distributed anomaly detection framework is utilized for precedent-free fault localization in the drive system of a high speed train. The framework uses Growing Structure Multiple Model System (GSMMS) models of the monitored system to describe its dynamics and a statistical measure of departure away from normal behavior for fault detection. GSMMS-based anomaly monitors distributed across the system were then used to localize the sources of anomalous behavior without the need for signatures or models of the underlying faults.

The plant was simulated using a physics based model, which was tuned using data collected from several actual TGV journeys. Simulations of that

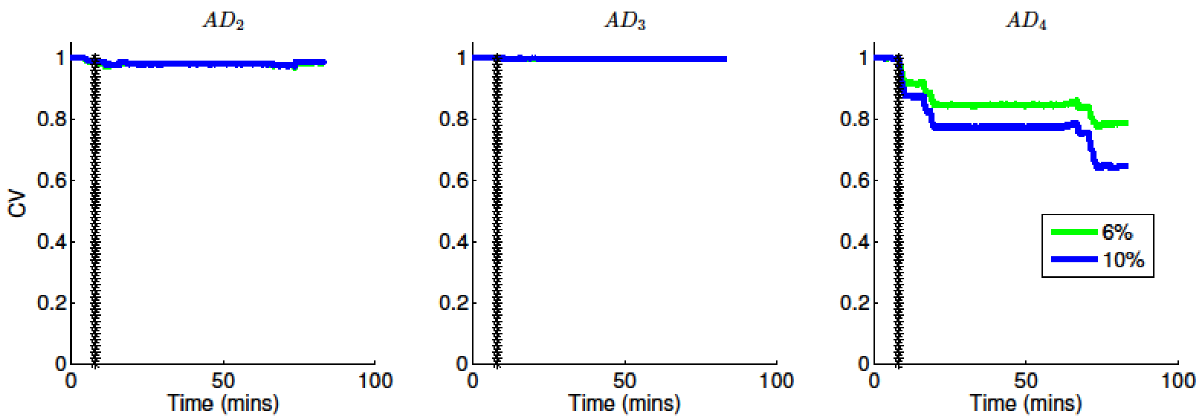


Figure 10: Gear fault localization at the first level of subsystems

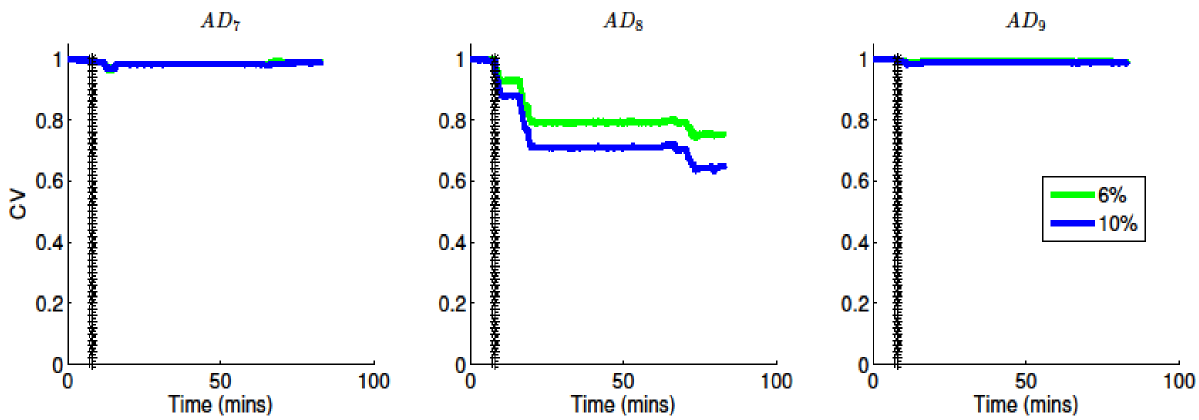


Figure 11: Gear fault localization within the mechanical transmission system

The CVs shown in Fig. 9 provide clear indication of the presence of a fault in the overall system. Then, the ADs whose CVs are shown in Fig. 10 localize the fault to the mechanical transmission, implicated by the falling CVs in AD4. Finally, in Fig. 11 the CVs of AD7 - AD9 isolate gear 2 as the source of the faulty behavior. Whenever the next maintenance opportunity

model were used to generate the data needed to build GSMMS based anomaly detectors for the drive train system and its subsystems. The results of the fault detection and localization accomplished using these ADs show that distributed anomaly detection successfully localizes the faulty subsystems, without any prior information regarding the underlying fault.

The results found here provide several directions for possible future work. Firstly, data generated in the presence of the faults can be used to build GSMMS models of the system behavior in the presence of those faults, based on which the faults could be positively recognized, thus accomplishing traditional fault diagnosis. Another natural extension of the work presented in this paper is the implementation of the precedent-free fault diagnostic approach to hardware-in-the-loop testing environments. Further, the local tractability of the GSMMS modeling approach may be exploited to develop a fault tolerant control scheme for performance recovery. The aforementioned problems are outside the scope of this paper, but are worth pursuing in future research.

ACKNOWLEDGMENT

This work was supported in part by the National Science Foundation (NSF) grant no. OISE 1157699. The authors also wish to thank Mr. Daniel Cadet and his team at Alstom in Paris, France for their support and help during the execution of this project. Finally, the authors thank Prof. Kondo Adjallah from Ecole Nationale d'Ingenieurs de Metz (ENIM) and Prof. Imed Kacem from the University of Lorraine in Metz, France, for their help and support during the research that led to this paper.

REFERENCES

[1] A. Jehanno, "High Speed Rail and Sustainable Mobility: A focus on environment and social issues," in International Practicum on Implementing High Speed Rail in the United States, Paris, France, 2011.

[2] US High Speed Rail Association, "Economic Benefits of High Speed Rail," US High Speed Rail Association, 2013. [Online]. Available: http://www.ushsr.com/benefits/economic.html. [Accessed December 2013].

[3] People's Daily Overseas Edition, "China to develop faster high-speed trains," People's Daily, April 2012. [Online]. Available: http://english.people.com.cn/90882/7800974.html. [Accessed November 2013].

[4] J. Liu, D. Djurdjanovic, K. Marko and J. Ni, "Growing structure multiple model system for anomaly detection and fault diagnosis," ASME Journal of Dynamic Systems, Measurement and Control, vol. 131, no. 5, pp. 051001-1 - 051001-13, 2009.

[5] M. Cholette and D. Djurdjanovic, "Precedent-free fault isolation in a diesel engine exhaust gas recirculation system," ASME Journal of Dynamic Systems, Measurement and Control, vol. 134, no. 3, 2012.

[6] The Infrastructurist, "JSC: High Speed Rail Lines," 2007. [Online]. Available: http://www.eng.hsrail.ru/abouthsr/trains/alstom/. [Accessed November 2013].

[7] SNCF, "SNCF TGV," [Online]. Available: http://www.tgv.com. [Accessed June 2013].

[8] D. Djurdjanovic, J. Liu, K. Marko and J. Ni, "Immune systems inspired approach to anomaly detection and fault diagnosis for engines," in International Joint Conference on Neural Networks, Orlando, FL, 2007.

[9] J. Liu, P. Sun, D. Djurdjanovic, K. Marko and J. Ni, "Growing structure multiple model system based anomaly detection for crankshaft monitoring," in Proceedings of the 2006 International Symposium on Neural Networks (ISNN), Chengdu, China, 2006.

[10] K. Carpenter, D. Djurdjanovic and A. Da Silva, "Fault detection and precedent-free localization in numerically discretized thermal-fluid systems," Expert Systems with Applications: An International Journal, vol. 39, no. 17, pp. 12858-12868, 2012.

[11] J. Liu, D. Djurdjanovic, K. Marko and J. Ni, "A novel method for anomaly detection, fault localization and fault isolation for dynamic control systems," Mechanical Systems and Signal Processing, vol. 23, no. 8, pp. 2488 - 2499, 2009.

[12] D. Djurdjanovic, C. Hearn and Y. Liu, "Immune systems inspired approach to anomaly detection, fault localization and diagnosis in a generator," in Proceedings of the 2010 Conference on Grand Challenges in Modeling and Simulation (GCMS), Ottawa, ON, 2010.

[13] T. Kohonen, "Self-organized formation of topologically correct feature maps," in Biological Cybernetics, The MIT Press, 1988.

[14] J. Principe, L. Wang and M. Motter, "Local dynamic modeling with self-organizing maps and applications to nonlinear system identification and control," Proceedings of the IEEE, vol. 86, no. 11, pp. 2240 - 2258, 1998.

[15] T. Johanssen and B. Foss, "Identification of non-linear system structure and parameters using regime decomposition," Automatica, vol. 31, no. 2, pp. 321 - 326, 1995.

[16] G. Barreto and A. Araujo, "Identification and control of dynamical systems using the self-organizing map," IEEE Transactions on Neural Networks, vol. 15, no. 5, pp. 1244 - 1259, 2004.

[17] B. Fritzke, "A growing neural gas network learns topologies," Advances in Neural Information Processing Systems, vol. 7, pp. 625 - 632, 1995.

[18] B. Fritzke, "Growing cell structures - a self-organizing network for unsupervised and supervised learning," Neural Networks, vol. 7, no. 9, pp. 1441 - 1460, 1994.

[19] D. Alahakoon, S. Halgamuge and B. Srinivasan, "Dynamic self-organizing maps with controlled growth for knowledge discovery," IEEE Transacitons on Neural Networks, vol. 11, no. 3, pp. 601 - 614, 2000.

[20] M. Cholette, J. Liu, D. Dhurdjanovic and K. Marko, "Monitoring of complex systems of interacting dynamic systems," Applied Intelligence, vol. 17, no. 1, pp. 60 - 79, 2012.

[21] G. McLachlan and D. Peel, Finite Mixture Models, Joh Wiley & Sons, Inc., 2000.

[22] Z. Zivkovic and F. van der Heijden, "Recursive unsupervised learning of finite mixture models," IEEE Transactions on Pattern Analysis and Machine Learning, vol. 26, no. 5, pp. 651 - 656, 2004.

[23] R. Kemp, "Drive systems for high speed trains," Transport Research Board, 1998.

[24] N. Urasaki, T. Senjyu and K. Uezato, "An accurate modeling for permanent magnet synchronous motor drives," in Applied Power Electronics Conference and

Exposition, New Orleans, LA, 2000.
[25] I. Guney, Y. Oguz and F. Serteller, "Dynamic behaviour model of permanent magnet synchronous motor fed by PWM inverter and fuzzy logic controller for stator hase current, flux and torque control of PMSM," in Electric Machines and Drives Conference, Cambridge, MA, 2001.
[26] K. Boby, A. Kottalil and N. Ananthamoorthy, "Mathematical modelling of pmsm vector control," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 2, no. 1, pp. 689 - 695, 2013.
[27] J. McKey, "Super high speed trains - TGV and AGV," September 2013. [Online]. Available: http://4rail.net/ref_fast_tgvagv.php. [Accessed September 2013].
[28] My Tracks, [Online]. Available: http://www.google.com/mobile/mytracks/. [Accessed June 2013].
[29] L. Jiang, E. Latronico and J. Ni, "A novel method for input selection for the modeling of nonlinear dynamic systems," in ASME Dynamic Systems and Control Conference, Ann Arbor, MI, 2008.
[30] R. Isermann, Fault-Diagnosis Systems, Springer Science & Business Media, 2006. 2013.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

IMPROVING SERBIAN RAILWAYS: POLICY OPTIONS AND STRATEGIC DIRECTIONS

Nena TOMOVIĆ [1]
Snežana PEJČIĆ TARLE [2]

Abstract *– Long term development policy of "Serbian Railways" is oriented toward faster development and modernization, reaffirmation of the role of railway traffic, using technical and technological balancing of railway resources and resources of railway networks of neighbour European railway governments through identification, planning and realization of developing projects. According to that, continuous and basic task is creation of conditions for safe, reliable and economically acceptable transport of users of transport services, including the mostly efficient use of available resources and lowest cost. Achieving of these objectives hindered during many years due to unfavourable financial position of the Enterprise and insufficient investment in infrastructure, transport capacities and informatics equipment over many years. Most of problems, which are financial by their nature, Serbian Railways are not capable to solve without more active involvement of state and governing ministry departments who should keep in mind that railway is a pillar of the development, economic progress and one of the strongest generators of economic recovery and employment of economy of every state. Therefore, main developing tasks of Serbian Railways for the period 2014-2018 are following: continuing of restructuring process; processes of revitalization and modernization of infrastructure, especially of Corridor X; repairing and modernization of driving vehicles; promotion of technology and working effectivity in all segments; alignment of regulations with UIC and EU standards; rationalization of number of employees and use of human resources; development of adequate informational systems as support for enterprise business. Conduction of these tasks would create conditions for increasing of involvement of Serbian Railways on transport market of Serbia and Europe, which could increase profitability.*

Keywords – Serbian Railways, modernization, profitability.

1. INTRODUCTION

Continuous and main task of Serbian Railways is to provide safe, reliable and economically acceptable transport for users, with mostly efficient use of available resources and lowest costs. Achieving of these objectives hindered during many years due to unfavorable financial position of the Enterprise and insufficient investment in infrastructure, transport capacities and informatics equipment over many years.

During previous period, Serbian Railways made efforts on system promoting. Some of results of Serbian railway sector, which are achieved during previous period can be reflected through following:

- New legal framework is aligned with EU directives;
- Analytical basis for long term Agreement on infrastructure, Agreement on obligation of public transport and Fee for accessing railway infrastructure was made;
- Restructuring program is in preparation. Predicted solutions for restructuring originate from need to focus on main activity, market orientation and rationalization in all areas.

Since strategic plan of Serbian Railways is to be respectable participant in transport and economic market, it is necessary to provide certain activities during next period in order to create conditions for involvement of our railway system in transport and economic system of Serbia and in European transport system.

It can be noted that the high level of transport services is a part of the culture of quality of contemporary society. In this society, intermodal and

[1] Nena TOMOVIĆ, M.Sc., Serbian Railways, Nemanjina 6, Beograd, nena.tomovic@srbrail.rs
[2] Snežana PEJČIĆ TARLE, PhD, Faculty of Transport and Traffic Engeneering, University of Belgrade, Vojvode Stepe 305, s.tarle@sf.bg.ac.rs

acceptable transport service is the right answer for social and economic demands for mobility.

Railway system suffers consequences due to small commercial speed, insufficient capacities, long keeping on national boundaries. All of that create lack of quality in service for passenger and cargo traffic. Small scope of traffic is specific for Serbian Railways business during previous period which provided poor business and financial results. The intensity of traffic in railway network of Serbian Railways is about 30% of the average intensity of such traffic in EU [1].

Short term strategic objective of Serbian Railways is conducting of numerous activities in business of railway in order to provide financial balance which is possible to achieve by decreasing of losses, providing planned transport, needed resources for maintaining of mobile capacities and infrastructural objects and activating of priority investments.

Basic development tasks for period 2014-2018 are following:

- Continuing of restructuring process in order to make Serbian Railways more oriented to users and competitive in markets within individual business wholes;
- Revitalization and modernization of railway infrastructure, especially of Corridor X;
- Repairing of driving vehicles;
- Promotion of technology and working effectivity in all segments;
- Alignment of regulations with UIC and EU standards;
- Rationalization of number of employees and use of human resources;
- Development of adequate informational systems as a support for enterprise business.

Conduction of these tasks would create conditions for increasing of involvement of Serbian Railways on transport market of Serbia and Europe, which could increase profitability.

Also, efficient and sustainable transport provides economic growth and new jobs. In order to realize that, global action including intensive international cooperation is needed [2].

Long term development policy of railway is oriented to faster development and modernization, reaffirmation of railway traffic role, using technical and technological balancing of railway resources with resources of railway networks of neighbor European railway governments through identification, planning and realization of development projects. According to aspect of development of infrastructural capacities, it is important for "Serbian Railways" to provide development and modernization of railways on Corridor X (railway defined by international agreements of SEECP, AGC, AGTC). Corridor X is a part of strategic infrastructure of Europe and strategic benchmark of development of national traffic infrastructure. On the other hand, it is important to develop, reconstruct and modernize network of regional railways regarding economy system of Serbia.

Modernization of towing and transportation capacities needs to be aligned with market demands (in cargo traffic using modern technologies and kinds of transported goods, in passenger traffic – higher speeds of transport, comfort and additional services) and international standards and norms which defined possibility of involvement into European traffic system.

By analyzing of position of Serbian Railways regarding environment, this work will especially highlight importance of finalizing of restructuring process and recovery and modernization of infrastructure capacities in order to increase productivity indicators as main strategic objectives of Serbian Railways by 2018.

2. STARTING ELEMENTS OF RAILWAY DEVELOPMENT

All railways of developed European states plan objectives, methods and speed of development in long term condition. Their most important strategic objective is increasing of scope and efficiency of railway transport on key transit directions that connect Europe and Asia [3].

During next 10 to 15 years, the important part of European gross national product will be directed to development of Pan-European traffic infrastructure in order to provide development of efficient traffic network which could provide sustainable mobility in entire Europe [4].

Such strategy for development of European railways is a chance for Serbian Railways since conditions can be created for following:

- Achievement of higher efficiency in infrastructure development and faster connecting with Europe,
- Faster flow of passengers and goods on national boundaries and faster transport,
- Obtaining of credit and help from International community in order to develop infrastructure at the Corridor,
- Involvement into planning of development dynamic from aspect of Europe and achieving of strategic objectives.

The first step in realization of development objectives includes analysis of position of Serbian Railways position in relation to the environment (southeast Europe states) and to developed railway governments in Europe using analysis of success indicators which are related to obtained productivity of the system.

Table 1. Comparable review of productivity indicators

Indicator	Average EU	Serbia	Southeast Europe	SR* compared the South East Europe	SR* Compared Average EU
[1000 residents/km]	2,1	1,9	3,1	-	-
[employees/km]	5,4	4,7	4,7	=	-
[vehicle kilometers/km]	14760	4988,2	4700,9	+	-
[vehicle kilometers/locday]	500,5	153,1	113,6	+	-
[vehicle kilometers/ employee]	3237,7	1055,6	1161,9	-	-
[1000rtkm/km]	3523,4	910,7	1082,9	-	-
[1000rtkm/locomotive]	97,3	28,0	25,5	+	-
[1000rtkm/ employee]	755,4	192,7	241,5	-	-

* SR – Serbian Railway

Regarding European states, our transport system is incomplete, poorly developed, inefficient and expensive. It is characterized by insufficient social rationality, low technical level and technological lagging, economic exhaustion and insufficient market orientation.

Regarding these facts, first step should include analyzing of position of Serbian Railways in relationto the environment in order to take appropriate place with its railway network and mobile capacities and place real objectives for successful development in the region.

As their strategic objective, Serbian Railways should be oriented to average indicators of business productivity that are specific for European states with similar geographic and traffic properties.

Table 1 includes comparable review of average indicators of productivity that are realized in railway governments of EU, railways in southeast Europe and in Serbia.

Productivity indicators in the region explained that we do not lack behind other states. In other words, average condition in railways of southeast Europe is almost the same as in Serbia.

It is interesting to note that Serbia and southeast Europe region have a slightly better indicator of number of employees by railways, while the region significantly lacks behind EU regarding other qualitative indicators. According to operative data collected on main and other railways of I order, Table 2 presented average use of planned driving schedule of trains. Number of employees by railways significantly varies and some railways include significantly greater number in relation to average of the EU, southeast Europe and Serbia.

It is estimated that from 2018, Serbian Railways should become respectable subject of sustainable mobility by realization of planned infrastructural projects. It is expected that productivity indicators will follow European average according to these estimations. Increasing of the reliability and quality level of railway infrastructure in Serbian Railways and improvement of all performances included in these processes would provide safe and regular traffic flow.

Expected effects could be observed in several ways. Probably the most interesting way for observing is time of travelling of passenger trains. For the objective that trains could use average speed of 100 km/h on main railways, it is expected that commercial speed would increase also.

Therefore, time of trains travelling will significantly decrease which will promote competitiveness of Serbian Railways in national and international transport market. This hypothesis can be confirmed by Table 3. It includes estimation of infrastructure parameters on electrified railways in Corridor X, which could be expected in 2018.

These parameters are related to projected speed, highest allowed speeds and time of travelling for passenger trains. Five cases of target value of commercial speed were observed for 55 km/h, 60 km/h, 65 km/h, 70 km/h and 75 km/h.

Table 2. Review of use of planned driving schedule and number of employees by km of the railway

Railway / railroad stocks	Length of the line [km]	Use of planned driving schedule [%]	Number of employees by km
(Beograd) Stara Pazova - Subotica	177	49.6	18
Beograd – Šid	123.50	61.9	19
Beograd – Velika Plana - Niš – Preševo	400.50	46.5	9
Beograd Centar – Pančevo Glavna	102.40	53.5	17
Beograd - Vrbnica	287.50	55.7	5

Defined objective, which is related to increasing of average commercial speed of 55 km/h can be observed as value which is the minimum expectation of the realization of infrastructure projects.

Table. 3. Existing condition and estimation of infrastructure parameters in 2018

Number	**Railway / railroad stocks**	**Length of the line [km]**	**The projected speed (km / h)**		**The maximum permitted speed (km / h)**		**Travel time trains for passengers (hours)**					
			Current situation	**Evaluation after modernization**	**Current situation**	**Evaluation after modernization**	**Current situation**	**V_{kom}= 55 km/h**	**V_{kom}= 60 km/h**	**V_{kom}= 65 km/h**	**V_{kom}= 70 km/h**	**V_{kom} = 75 km/h**
1	2	3	4	5	6	7	8	9	10	11	12	13
1	(Beograd)S.Pazova -Subotica	177	85-120	80-160	40-80	80-140	4,00	3,22	2,95	2,72	2,52	2,36
2	Beograd-Šid	117	85-120	80-160	30-70	80-140	2,83	2,12	1,95	1,80	1,67	1,56
3	Beograd-Velika Plana-Niš	243	80-120	80-160	50-100	80-140	4,67	4,41	4,05	3,74	3,47	3,24
4	Niš-Preševo	149	75-120	80-160	30-100	80-140	2,92	2,71	2,48	2,29	2,13	1,98
Travel time Subotica-Preševo (1+3+4):							**11,59**	**10,34**	**9,48**	**8,75**	**8,12**	**7,58**
Travel time Šid-Preševo (2+3+4):							**10,42**	**9,25**	**8,48**	**7,83**	**7,43**	**6,78**

The importance of achieving of average commercial speed of 75 km/h is especially important since it demanded more significant changes in way of Serbian Railways business, respecting and application of principles which all market oriented organizations use for their business.

It would mean, among others, that Serbian Railways are capable to offer high level of transport services, which would be the right answer to social and economic demands for mobility.

In that case, the travelling time of passenger trains on Corridor X would significantly decrease, which would provide the possibility for Serbian Railways to take more active role in European market of transport services on which organizations with long tradition make businesses. Also, these organizations could be used as a model of successful business.

On the other hand, railways could enhance their competitive position regarding bus and truck traffic which are dominant during last years.

In order to observe possibilities which realization of certain commercial speed could provide, Table 4 presents the comparison review of travelling time of passenger train for five values of commercial speed: V_{kom}= 55 km/h, V_{kom}= 60 km/h, V_{kom}= 65 km/h, V_{kom}= 70 km/h, and V_{kom}= 75 km/h and travelling time of bus on relations Subotica – Presevo and Šid – Preševo.

It is proven that railway can be competitive to bus transport of passengers with the commercial speed of Vkom= 55 km/h since it has shorter driving times on all relations except on relation Belgrade – Niš. In that case, the travelling time of trains on relations Subotica – Preševo and Šid – Preševo would be an hour shorter than travelling time of buses.

Each increasing of commercial speed which is

Table. 4. Comparable review of travelling time of train and bus on Corridor 10 after railway modernization

Number	**Railway / railroad stocks**	**Travelling by train**						**Travelling by bus**	
		Length of the line [km]	**Travel time (hours)**					**Length of the line [km]**	**Travel time (hours)**
			V_{kom}= 55 km/h	**V_{kom}= 60 km/h**	**V_{kom}= 65 km/h**	**V_{kom}= 70 km/h**	**V_{kom} = 75 km/h**		
1	2	3		4				5	6
1	Beograd-S.Pazova-Subotica	177	3,22	2,95	2,72	2,52	2,36	182	3,25
2	Beograd -Šid	117	2,12	1,95	1,80	1,67	1,56	121	2,16
3	Beograd -V.Plana-Niš	243	4,41	4,05	3,74	3,47	3,24	236	3,33
4	Niš-Preševo	149	2,71	2,48	2,29	2,13	1,98	164	3.92
Travel time Subotica-Preševo (1+3+4):		**10,34**	**9,48**	**8,75**	**8,12**	**7,58**	**-**	**10,50**	
Travel time Šid-Preševo (2+3+4):		**9,25**	**8,48**	**7,83**	**7,43**	**6,78**	**-**	**9,41**	

used by trains on observed relations create higher effects. The objective is to increase commercial speed to Vkom= 75 km/h, by which travelling time of train on relation Subotica – Preševo would be smaller for 2,92 hours than travelling time of bus on that relation.

Regarding relation Šid – Preševo, this time would be smaller for 2,63 hours. It means that railway would increase its competitivenes on all relations of Corridor X regarding passenger transport by bus.

3. CONCLUSION

In order to achieve more efficient and more effective development and realization of strategic objectives, there is a need to realistically observe and use all advantages and opportunities, and to remove weaknesses within the system and to eliminate obstacles in the environment.

It is obvious that Serbian Railways are expecting a very tough period during which they will be obliged to accelerate reforms and adapt business to market conditions due to influence of numerous internal and external factors.

Unfortunately, the time is passing and differences between developed railway governments and Serbian railways are becoming more dramatic. The most difficult issue for management is how to find the best way to align with developed railway governments. Such burden is the largest in these complex processes. These processes demand great expert knowledge and capabilities.

Actual moment in which Serbian Railways are currently situated imposes need for conduction of serious analysis in order to make the best observation of current position of the enterprise, as a development strategy for the following period. However, it is possible to make following conclusions as guidelines for acceleration of activities for transforming of railway into sustainable system, on all levels of functioning. The most important conclusions are following:

Define development strategies relating to environment, within the enterprise in order to improve all vital functions, with defined concrete objectives related to:

- promotion of traffic security and reliability of driving schedule for trains,
- promotion of level and quality of services of railway structure and transport,
- promotion of application of EU standards for interoperability for conventional railways,
- promotion of accessibility of railway infrastructure and transport services,
- promotion of environmental protection by mass use of the railway,
- promotion of contribution of railway to the regional development,
- increasing of readability of enterprise management and state to apply agreed strategic objectives,
- investment of more efforts and energy into realization of started restructuring process,
- parallel conduction of repairing process and development of railway network with process of restructuring in line with Regulation EU No. 440/91 related to liberalization of market on railways,
- defining of responsibilities for financing of maintenance and development of infrastructure with obliged dividing of costs and revenues for infrastructure and transport,
- paying attention on decreasing of number of employees and following of obligations while avoiding tendency to use social program by highly qualified labor force, which can provide engagement of unprofessional employees without previous experience in work on railways,
- promoting of partnerships with users, business partners and all railway companies in the region,
- efficient and strong use of obtained financial resources for modernization of infrastructure and railway resources,
- defining of priorities in conditions of limited financial resources, while rehabilitation and maintenance of railways are providing parallel with modernization and construction,
- precise defining of desirable standards regarding availability, level of security and level of services of transport networks,
- aligning of harmful emissions with objectives placed by EU, increasing of efforts for application and stimulating of environmental sustainable transport systems,
- adaptation of development and maintenance of infrastructure to environmental demands, in order to provide balance with natural and cultural environment,
- providing of increased role of private sector and defining of regulations in public sector and institutions regarding integration with EU, through clearly defined responsibilities, professional management and staff, and efficient control procedures.

In front Serbian Railways are complex tasks and embodiments above mentioned objectives create the conditions for it to become productive, technologically and economically efficient transport system, which will, by putting emphasis on the quality of the service, to become competitive on the domestic and on the international transport market.

REFERENCES

[1] Europien Commision, White Paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system (2011)

[2] The EU in the world 2014, A statistical portrait, Eurostat Statistical books, EU 2014

[3] CER, "Reforming Europe's railways – an assessment of progress", Eurail press Tetzlaff-Hestra GmbH, 2005

[4] Transport 2050: 50 facts and figures, available on http://ec.europa.eu/transport/strategies/en.htm

IMPORTANCE OF COTIF FOR INTERNATIONAL RAIL TRAFFIC

Bas LEERMAKERS [1]
Dragan NEŠIĆ [2]

***Abstract** – More than any other mode of transport, rail transport depends on technical compatibility between the infrastructure and the vehicles running on it. Harmonisation is therefore indispensable to enable uninterrupted international rail traffic. Today, international rail traffic is organised according to two concepts: the traditional concept, i.e. the traditional exchange of wagons and coaches at border-crossing stations (still mainly applied by OTIF's non-EU Member States) and the interoperability concept, i.e. uninterrupted movement of whole trains across borders (the basis of EU railway policy). This paper will reflect on the compatibility achieved between COTIF and the EU railway regulations in terms of the authorisation of vehicles. The cornerstone for this compatibility was the introduction of the equivalence principle for COTIF and EU technical vehicle requirements, which enables the mutual recognition of admitted vehicles. In addition to the harmonised technical requirements, the separation of responsibilities between all the entities involved in rail traffic is also harmonised to the extent necessary for international traffic. As a result of the above, manufacturers can now design and build standard vehicles to be used in all OTIF States (including EU Member States) if they comply with the UTP rules (provided there are no specific cases/open points or national technical requirements).*

Keywords – COTIF, interoperability, admission of vehicles, equivalence principle, railway actors.

1. INTRODUCTION

Economic growth and international transport are inextricably linked. More than any other mode of transport, rail transport depends on technical compatibility between the infrastructure and the vehicles running on it. Harmonisation is therefore indispensable to enable international rail traffic.

International rail traffic traditionally consists of the exchange of wagons and coaches. The exchange of wagons and passenger coaches across borders required only the harmonisation of the technical characteristics of these wagons and coaches, not of locomotives and operational rules.

The challenge now and for the future is to achieve the right balance between regulations imposed by the authorities on the one hand, and harmonisation of technical solutions by the rail industry and operators on the other. The key is to create a regulated basis, which ensures cross-border technical compatibility for all railway vehicles, including locomotives, and train sets, whilst not imposing unnecessary technical solutions.

This paper will explain the basic principles of COTIF[1] [1] Appendices APTU [2] and ATMF [3]. It will also reflect on the compatibility that has been achieved with the EU rail regulations.

The first part of the paper will introduce OTIF; compare two models for organising international rail traffic, i.e. the traditional approach of the exchange of vehicles at border crossing stations, and the interoperability model, in which entire trains cross borders. The second part deals with OTIF's requirements for the admission and use of vehicles, and at the same time describes the legal equivalence that has been achieved between the OTIF and EU provisions. The third part highlights the roles, responsibilities and duties of the main actors in the process of verification, admission, operation and maintenance of vehicles. Lastly, the benefits for the main actors when they are using COTIF and its appendices are also highlighted.

[1] *COTIF stands for Convention concerning International Carriage by Rail*

[1] Bas LEERMAKERS, OTIF, Head of Technology Section, Gryphenhübeliweg 30, Bern, CH, Bas.Leermakers@otif.org
[2] Dragan NEŠIĆ, OTIF, First Officer in Technology Section, Gryphenhübeliweg 30, Bern, CH, Dragan.Nesic@otif.org

1.1 OTIF at a glance

The Intergovernmental Organisation for International Carriage by Rail (OTIF) was founded on 1 May 1985.

By ratifying COTIF, States become OTIF Member States. At the time of writing, 49 States are Member States of OTIF (Europe, Asia and North Africa) and the number is expected to increase. At present, international carriage by rail on rail infrastructure of around 270,000 km and the complementary carriage of freight and passengers on several thousand kilometres of shipping routes, inland waterways and (in domestic carriage) roads are concerned by the uniform law created by OTIF.

Member States of decide to which extend they wish to apply the Convention and may declare not to apply certain Appendices of COTIF. Member States that apply the technical Appendices APTU and/or ATMF are referred to as Contracting States. Currently 40 Member States are also Contracting States. Annex 1 illustrates how COTIF is applied throughout its geographical scope.

The headquarters of the Organisation are in Berne, Switzerland. The geographical scope of COTIF and its appendices is shown in Annex 1 of this paper.

2. THE LEGAL INTERFACE OF OTIF

One of OTIF's main tasks is to promote, improve, and facilitate international rail traffic. In order to achieve this, a uniform system of law has been established. These Uniform Rules are contained in the appendices to COTIF and cover the following fields of law:

- The contract of carriage of passengers and goods in international rail traffic by rail (Appendix A - CIV and Appendix B - CIM);
- The contract of use of vehicles as means of transport in international rail traffic (Appendix D - CUV);
- The contract of use of infrastructure in international rail traffic (Appendix E - CUI);
- Technical rules concerning vehicles for the carriage of dangerous goods (Appendix C - RID).
- The provisions on interoperability and technical harmonisation in the railway field and the technical approval of railway material intended for use in international rail traffic (Appendices F - APTU and G - ATMF).

Of the 49 Member States of OTIF, 26 are also EU Member State. The EU develops policy to establish a single, liberalised European railway market. The key element of the EU's policy is to bring about interoperability by harmonising technical parameters, rules and safety requirements.

On the other hand, the main tasks of OSJD, the international railway organisation of the Euro-Asian region, are the development of common international rail transport, the development of consentaneous transport policy as well as co-operation in economic, information, scientific, technological and ecological aspects of rail transport.

Despite different legal systems, what is common to all these organisations is that they deal with regulations on international rail transport, development of the rules for interoperability/dangerous goods and the regulation of transport contracts. As an intergovernmental organisation under international law, OTIF has the capacity to provide legal and technical support in overcoming differences. In COTIF 1999, and particularly since the EU acceded to COTIF in 2011, additional possibilities for closer cooperation and for some joint measures were created. Some good results/examples of such cooperation are:

- Creation of the common OTIF/OSJD consignment note, which allows goods to be carried from the Atlantic coast to the Pacific coast using a single document,
- Harmonisation (i.e. equivalence) of COTIF and EU regulations on the single admission of railway vehicles, which provide an interface between EU and non-EU States,
- Common registers between OTIF and ERA (EU), e.g. Vehicle Keeper Marking Register (VKM), Entity in Charge of Maintenance Register (ECM), National Vehicle Register (NVR), European Centralised Virtual Vehicle Register (ECVVR),
- Harmonisation between OTIF and OSJD on registration of vehicles in VKM Register,
- Administrative Arrangements between ERA, DG MOVE and OTIF to facilitate cooperation and formalise the exchange of information.

2.1 Interoperability vs. exchange of vehicles

As stated previously, EU railway policy promotes a liberalised railway market and aims to establish railway interoperability. This requires a harmonised definition of technical parameters, responsibilities of actors and operational requirements that apply within every EU Member State.

Most non-EU OTIF states organise international rail traffic according to a more traditional mode referred to as "exchange of vehicles". This model requires less harmonisation and is mainly used for fully integrated national rail railway companies, which manage infrastructure and are the monopolistic train operator. In the latter model, the national railway company (RU1) runs the vehicles on its network to the border where another state railway company

(RU2) takes these vehicles over and runs them on its own network. OTIF does not impose any model and therefore the challenge for OTIF is to develop regulations that are compatible with both the interoperability model as well as the exchange of vehicles model.

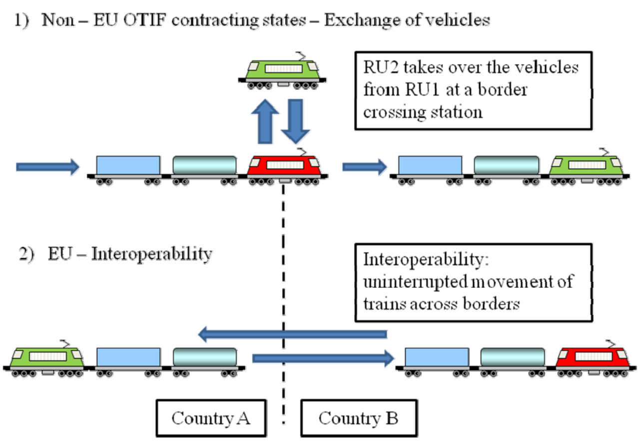


Figure 1: Exchange of vehicles (above) compared to interoperability (below)

2.2 Admission of vehicles - OTIF requirements in force

Before introducing APTU and ATMF, requirements for the technical admission of railway vehicles and the validation of technical standards applicable to rolling stock were mainly defined among rail companies through UIC (non-governmental union of railway companies). UIC developed the “Regolamento Internazionale Veicoli” (RIV) and “Regolamento Internazionale delle Carrozze” (RIC), which govern freight and passenger vehicles respectively. Rail companies which were members of UIC were competent (authorised) to legislate bindingly the admission of vehicles. The mutual recognition of homologation checks of passenger coaches (RIC) and freight wagons (RIV) between rail companies was based on UIC standards which, in essence, were a mix of technical and commercial requirements. Often these standards also described a technical solution. By doing so, innovative solutions for rolling stock could not be applied and consequently railways (manufacturers) were losing ground to technological progress.

With the introduction of APTU (technical requirements) and ATMF (admission procedures and use of vehicles), states (rather than railway companies) agree on minimum technical and safety requirements for rolling stock interoperability. All these minimum requirements are prescribed in Uniform Technical Prescriptions (UTP).

A full set of UTPs covering freight wagons has been in force since 1.12.2012 and a full set of UTPs covering locomotives and passenger rolling stock is foreseen to enter into force on 1.1.2015.

If the vehicle complies with UTPs, its admission will be recognised by all Contracting States. In practice, the principle of ATMF applies fully in each OTIF Contracting State, where the State takes responsibility for the admission of vehicles. At the same time rail companies and the railway industry may agree voluntarily on additional requirements.

Generally, APTU provides rules for the adoption of technical provisions applicable to vehicles intended to be used in international rail traffic. The aim is to create a set of requirements that will facilitate the admission of railway vehicles to international rail traffic. ATMF sets out the principles, objectives and procedures of technical admission of railway vehicles and the responsibilities in terms of using these vehicles.

A summary of the scopes of APTU and ATMF are shown in figure 2.

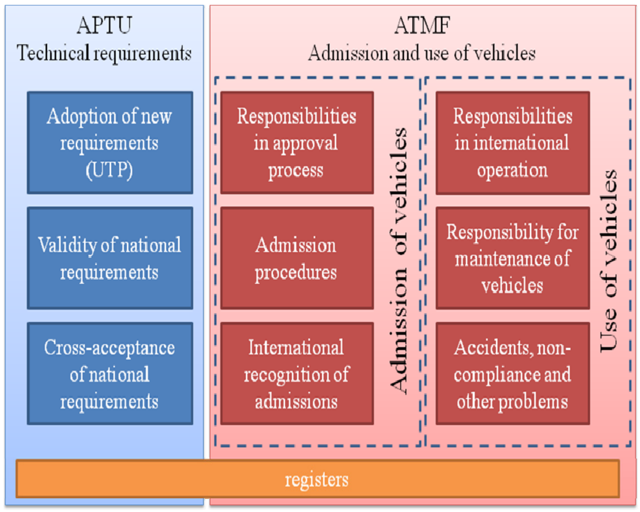


Figure 2: Scope of APTU and ATMF

2.3 OTIF Requirements in force and EU requirements they are based on

The UTP prescribes norms and essential requirements [4], which will provide uniform technical, operational and assessment rules for the rail system at international level.

Structural and functional UTPs are based on TSIs[2]. Although UTPs and TSIs have different formats practically their technical content is uniform, therefore by applying either UTPs or TSIs the same result will be obtained.

Instead of being equivalent to a TSI, some UTPs may be equivalent to (a set of) other EU regulations. Examples are UTP GEN-A and UTP GEN-B, which respectively are equivalent to Annex III and Annex II of the Interoperability Directive 2008/57/EC. Another

[2] *TSI stands for Technical Specification of Interoperability*

example is the UTP MARKING, which is equivalent to a combination of requirements taken from Appendix P of OPE TSI and Appendix 6 of the EU NVR Specification.

Annex 2 contains a list of all the OTIF requirements that are in force and the EU requirements on which they are based. All OTIF technical requirements are publicly available, free of charge, from the OTIF website http://www.otif.org/en/technology/regulations-in-force.html.

2.4 Equivalence principle of ATMF for fully UTP compliant vehicles

Free circulation of vehicles between OTIF Member States and Member States of the European Union and States which apply European Union legislation only works if there is legal equivalence between the OTIF and EU provisions..

In accordance with ATMF Art 3a, a railway vehicle admitted to operation in accordance with ATMF is deemed to be "authorised for placing in service" in the Member States of the European Union and in the States which apply European Union legislation as a result of international agreements with the European Union. The same applies *vice versa*, i.e. a railway vehicle placed into service in accordance with the applicable EU legislation and corresponding national legislation is deemed to be admitted to operation by all Contracting States according to ATMF (as illustrated in Figure 3). The conditions for these principles are:

a) full equivalence between the applicable UTP and the corresponding TSIs,
b) the set of applicable UTP/TSI against which the railway vehicle was authorised must cover all aspects of the relevant subsystems [5] that are part of the vehicle,
c) the UTP/TSI applied must not contain any open points in relation to technical compatibility with the infrastructure,
d) the vehicle must not be subject to derogation, and
e) the vehicle must not be subject to specific cases which limit the conditions of admission or "authorisation for placing in service".

If the conditions of a) to e) are not met, the vehicle is subject to authorisation according to the law applicable in the Member States. However, in such a case, the part of the vehicle which is compliant with the UTP has to be accepted by all Contracting States.

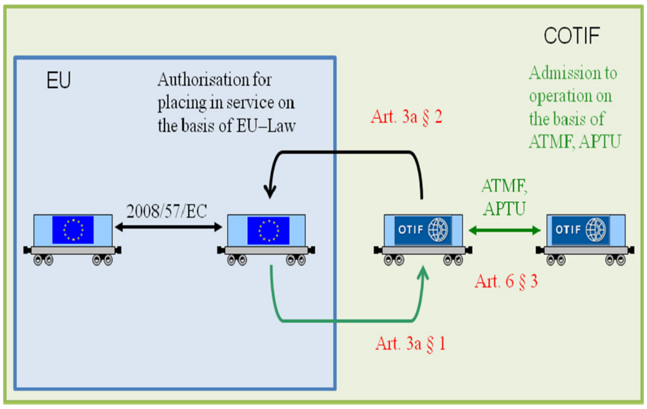


Figure 3: Equivalence principle of ATMF for fully UTP compliant vehicles

3. MAIN ACTORS IN CONFORMITY ASSESSMENT, ADMISSION AND OPERATION

3.1 Conformity assessment and admission

The competent authority is the national or international body which is competent and authorised by the State to carry out the technical admission of a vehicle.

The applicant is the entity (railway undertaking, manufacturer, or other entity) which requests a technical certificate, or the assessment of conformity of a subsystem or element of construction and therewith initiates the admission process.

Before a competent authority issues the first admission to operation, it must be ensured that the vehicle meets all the essential requirements. This is primarily done by ensuring compliance with UTPs.

UTP verification is the assessment procedure based on the assessment procedure modules (UTP GEN-D) [6], whereby an assessing entity or, depending on national law the competent authority, on the request of an applicant checks and certifies that the railway vehicle complies with the relevant UTPs and other applicable Regulations.

As the UTPs do not describe every detail of a vehicle, the first admission should also cover generic requirements in order to fulfil the applicable essential requirements[3]. For consecutive admissions these generic requirements have not to be checked again and therefore if there are no specific cases, open points or derogations, the (first) admission shall also be valid on the territories of other Contracting States[4].

Competent authorities are able to withdraw or suspend technical certificates in accordance with the provisions of ATMF Article 10a.

[3] *In accordance with ATMF Article 7 § 1*
[4] *In accordance with ATMF Article 6 § 3*

3.2 Operational responsibilities

The entities responsible for the vehicle after admission, i.e. the Keeper, the Railway Undertaking (RU) and the Entity in Charge of Maintenance (ECM), are responsible for ensuring that the vehicle is well maintained and kept in a compliance with the UTPs.

The Keeper is (usually) the owner of the vehicle. The Certificate of Operation relates to the vehicle and the keeper is the entity which holds this Certificate. In accordance with common practice in several Contracting States and in order to make more explicit the responsibilities of the keeper, the keeper is made responsible[5] for designating an ECM for his vehicles.

The RU is responsible for the correct use of the vehicle within its conditions and limits of use and other conditions of the admission. The RU must also ensure that the vehicle is operated only on compatible infrastructure. The operating RU must in due time, either directly or via the keeper, provide the ECM of the vehicle with information on the operation of the vehicle (including mileage, type and extent of activities, incidents/accidents).

The ECM must ensure, either directly or via the keeper, that reliable information about the vehicle concerning maintenance and restrictions affecting operations, which is necessary and sufficient to support safe operations, is available to the operating RU. The ECM (and not the keeper) must ensure that the vehicles for which it is in charge of maintenance are in a safe state of running by means of a system of maintenance.

Although all types of railway vehicles must have an ECM, the ECM certification system[6] need only be applied to freight wagons.

4. CONCLUSIONS

In order to serve its Member States, OTIF works closely together with other organisations working in the field of international railways. One of the major achievements is that OTIF technical rules provide a seamless interface between EU and non-EU railway systems, without imposing a particular market model.

By means of the COTIF Appendices APTU and ATMF, OTIF has also succeeded in introducing a clear separation of responsibilities between all the entities in charge of conformity assessment, admission and operation processes.

The application of COTIF enables States to create a legal environment that is favourable to both railway operations and the railway industry.

As the UTPs define minimum requirements, the level of uncertainty for manufacturers is also minimised. Based on the UTPs, manufacturers can design and build standard vehicles to be used in all OTIF States (including EU Member States). This broadens the potential market to a wider geographical area and provides good business opportunities for industry in both directions.

REFERENCES

[1] **COTIF** – Convention concerning International Carriage by Rail as amended by the Vilnius Protocol, in force from 1. July 2006 (link: COTIF 1999)

[2] **APTU** – Appendix F to COTIF 1999, in the revised version that entered into force on 1 December 2010. (Appendix F to COTIF 1999)

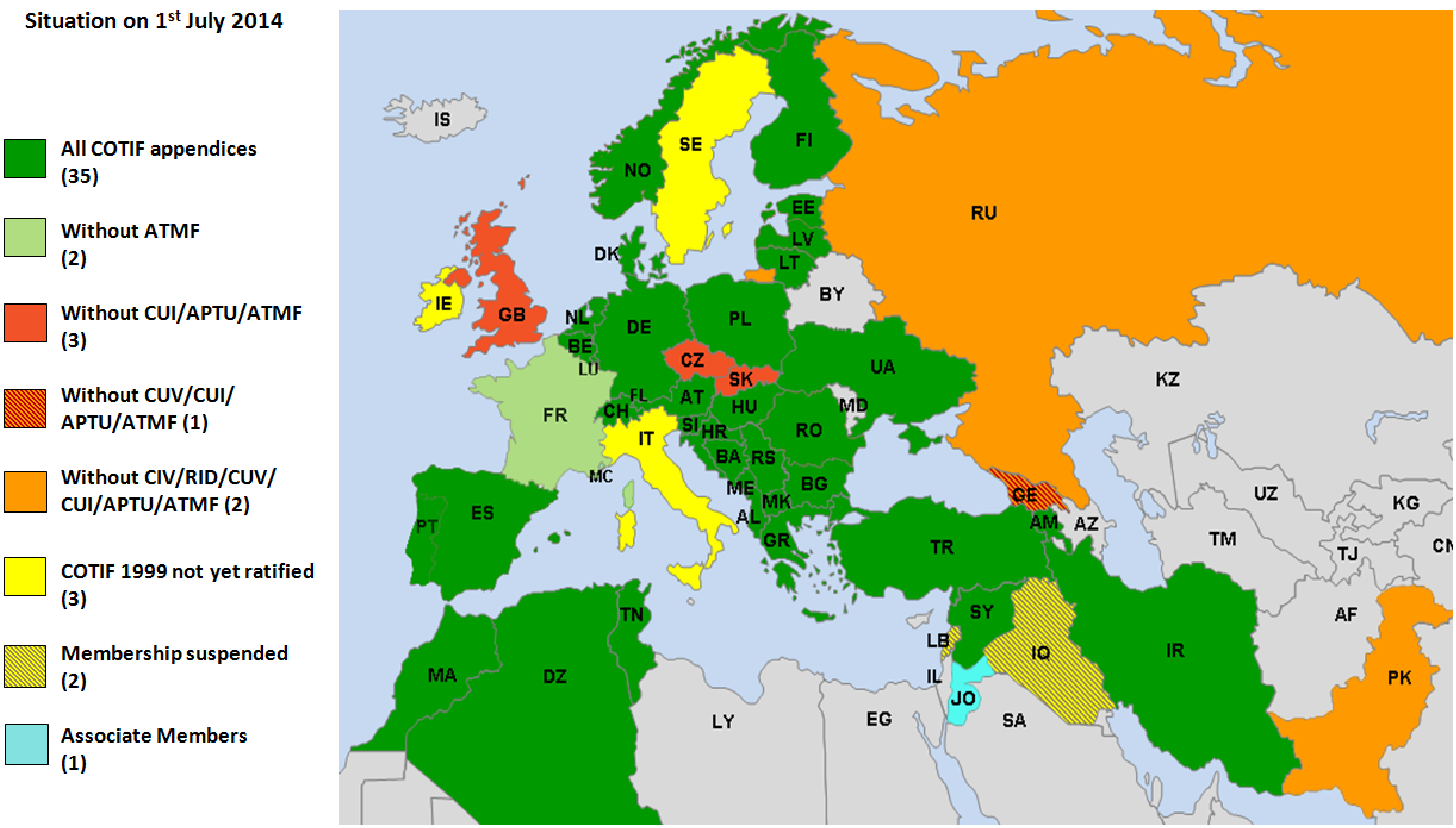
[3] **ATMF** – Appendix G to COTIF 1999, in the revised version that entered into force on 1 December 2010 (Appendix G to COTIF 1999)

[4] UTP GEN-A: General Provisions – Essential requirements, in force from 1. December 2011 (A 94-01A/1.2011 v.05)

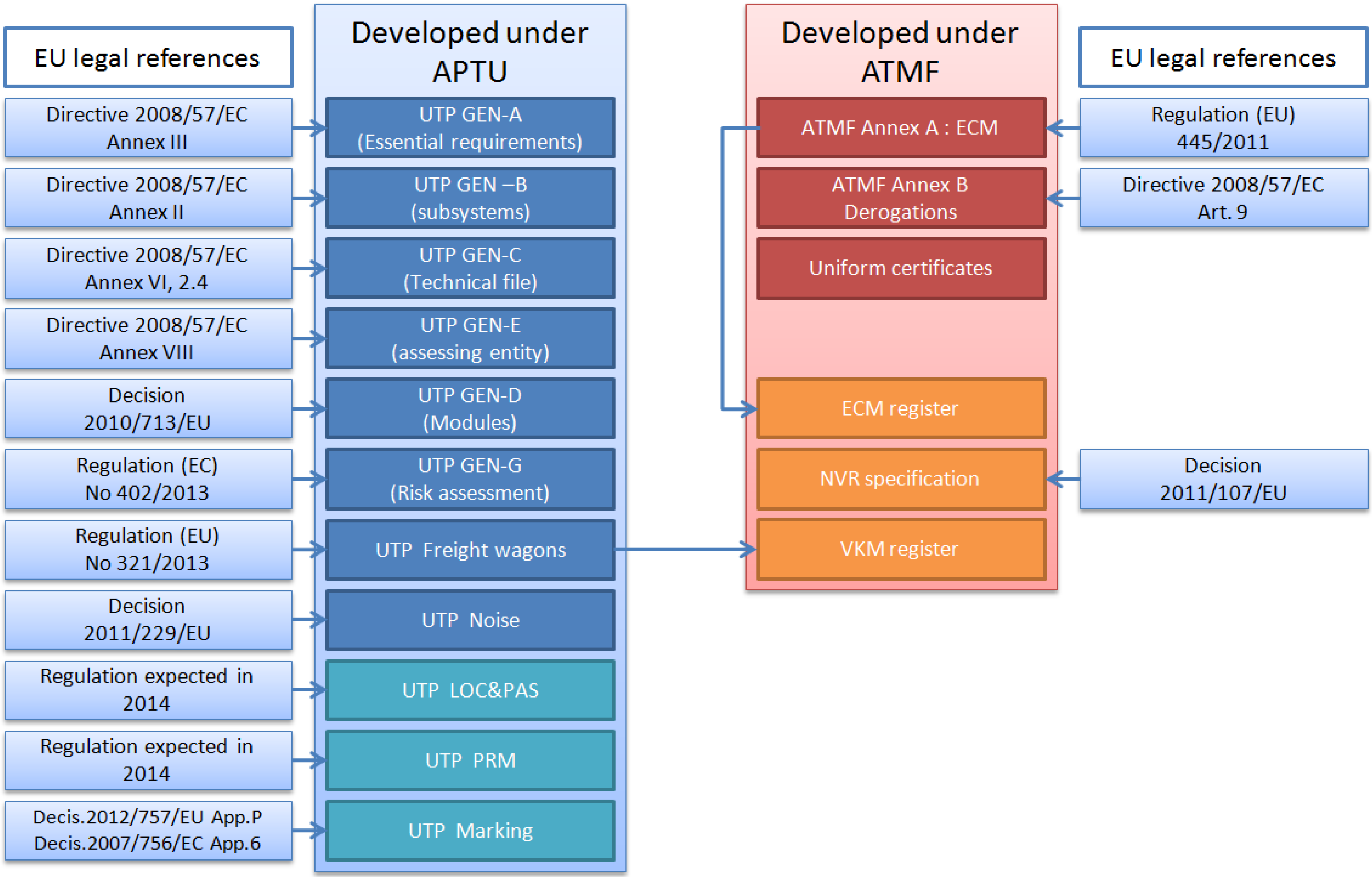
[5] UTP GEN-B: General Provisions – Subsystems, in force from 1. May 2012 (A 94-01B/1.2012 v.06)
UTP GEN-D: General Provisions – Assessment procedures (Modules), in force from 1. October 2012 (A 94-01D/3.2011)

[5] *As decided by the 25th Revision Committee. This responsibility will be included in the revised COTIF of 2015.*

[6] *Annex A to ATMF*



Geographical scope of COTIF and its appendices



OTIF requirements in force and EU requirements on which they are based

Rolling stock

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

EXPERIMENTAL RESEARCH OF CHARACTERISTICS OF IMPROVED TYPE OF COMBINED TUBE ENERGY ABSORBER

Jovan TANASKOVIĆ [1]
Dragan MILKOVIĆ [2]
Vojkan LUČANIN [3]
Žarko MIŠKOVIĆ [4]

Abstract *– Crash energy absorber represents one of the main and necessary elements of body structure of modern railway vehicles. Intensive research in the field of passive safety produced more different types of collision energy absorbers using different shapes of deformations to absorb as much kinetic collision energy as possible. Different combinations of the shape of deformations lead to compact dimensions of absorber. Subject of this paper is combined energy absorber which works on the principle of shrinking and splitting the seamless tube at the same time, using special tools. Using shrinking-splitting process energy absorption occurs by elastic-plastic deformations of the tube and friction between the tube and the cone bush, respectively friction between the tube and the splitting tool. Energy absorption starts in the tube which is compressed into cone bush. After exactly defined stroke in the process of energy absorption by shrinking the seamless tube, the simultaneous process of splitting of the tube starts, so tube deforms in parallel shrinking-splitting mode during the rest of the stroke. This type of combined process gives gradually increase of the force without undesirable peaks which characterizes second phase of deformation of shrinking-folding combined absorber. Experimental research was realized via quasi-static tests in the laboratory conditions. During tests, reaction force and stroke were measured. Results of the investigations of combined shrinking-splitting absorber and shrinking-folding absorber were compared.*

Keywords – Crash absorber, Passive safety, Shrinking, Splitting, Experimental researches.

1. INTRODUCTION

The subject of this paper is process of improving absorption characteristics of the combined tube absorber using different shapes of deformations. Experimental investigations of combined absorber described in this paper based on the tube absorber that works on the principle of compressing the seamless tube into a cone bush [1, 2]. This type of absorber characterizes gradual increase of the force, without peaks until reaching the maximal value, when the force remains approximately constant with minor deviations to the end of the deformation process. As an idea for combined energy absorption served experimental investigations obtained by axial pressure of the tube of circular and square cross sections with parallel analyzes of inversion and splitting processes were presented in the paper [3]. Folding of the tube characterizes jagged force versus stroke curve. Experimental investigations directed to the shrinking-folding combined process of seamless tube are showing that the folding process not the best solution in combination with shrinking process [4-6]. Results of investigations showed that combination of these two processes may increase absorption power with compact dimension of absorber, but it is not possible to eliminate force peaks at the start of deformation (folding process) of each segments of the tube wall. Using a larger number of folding segments in the tube

[1] Jovan TANASKOVIĆ, Asst. Professor, PhD, University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, jtanaskovic@mas.bg.ac.rs
[2] Dragan MILKOVIĆ, Asst. Professor, PhD, University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, dmilkovic@mas.bg.ac.rs
[3] Vojkan LUČANIN, Full Professor, PhD, University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, vlucanin@mas.bg.ac.rs
[4] Žarko MIŠKOVIĆ, Teaching Assistant, M.Sc., University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, zmiskovic@mas.bg.ac.rs

wall, could alleviate jagged effect on the force versus stroke diagram. Reduction of peaks does not mean their elimination, so the further investigations were directed toward research of other possible combinations. Experimental and theoretical analysis of splitting process of the tubes made by aluminum and mild steel were presented in the paper [7-9]. These investigations were realized on the samples with different wall thickness and lengths. Splitting tube, using different top angles of the special cone die, were realized. The angle of the top of cone die has direct influence on the correct flow of splitting tube, so appropriate design of angle is very important. Force vs. stroke diagram characterizes peak at the start of deformation process. After that, force value decreases to approximately half of the initial value and stays on that level with minimal deviations to the end of deformation process. Using above-mentioned facts, quasi-static tests were performed on two different types of combined tube energy absorber. Results obtained by these experimental investigations (shrinking-folding and shrinking-splitting the tubes) were analyzed and main differences between them are presented.

2. EXPERIMENTAL INVESTIGATIONS

Quasi-static tests were realized on servo-hydraulic machine ZWICK ROELL HB250 at the University of Belgrade Faculty of Mechanical Engineering, Fig. 1. Maximum load which can be realized on this machine is 250kN. Acquisition system may record up to 8 measurement channels with sampling frequency up to 10 kHz. During experimental investigations deformation resistance (reaction force) is measured on the defined stroke.

Fig.1. Testing machine Zwick Roell HB250

2.1. Shrinking-folding combined absorber

This type of combined tube absorber uses shrinking and folding processes to absorb kinetic collision energy. Working principle of combined absorber is shown in the Fig. 2. During the collision, process of energy absorption first starts mode of tube shrinking (Item 1) during the stroke of ≈ 63 mm. After the stroke of 63 mm, starts the second mode of energy absorption, using folding of the tube (Item 2). In that moment, energy absorption continues in parallel working mode, compressing and folding the tubes on the stroke of 40 mm (Item 1 and 2).

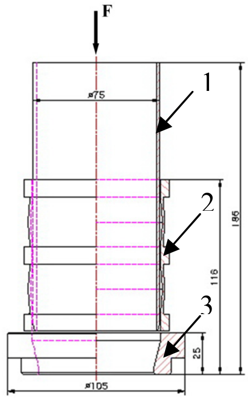


Fig.2. Working principle of shrinking-folding absorber

The following elements were used for this investigation: seamless tube (Item 1, material S355J2G3) with dimensions Ø75x2x160mm, segments tube (Item 2, material S355J2G3) with dimensions Ø86x90mm and the cone bush (Item 3) from quenched and tempered carbon steel (material C45E) with dimensions Ø105/68x13°, Fig. 2. Samples are separated in five groups: a) seamless tubes with two folding segments with cone walls (Item 1), b) seamless tubes with two folding segments with plane walls (Item 2), c) plane seamless tubes of length L = 160 mm (Item 3), d) plane seamless tubes of length L = 71 mm (Item 4) and e) cone bush (Item 5), Fig. 3. Different geometries of the folding tubes are created to show influence of the wall geometry on the starting values of the deformation resistance.

Fig.3. Samples

2.2. Shrinking-splitting combined absorber

This type of tube absorber uses shrinking and splitting processes for energy absorption. Working principle of combined absorber can be described using

Fig. 4. During collision, process of energy absorption first starts with the tube (Item 1) shrinking using cone bush (Item 2) at the stroke of ≈ 50 mm. After stroke of 50mm, second mode of energy absorption, i.e. splitting of the tube, starts with contact between predeformed tube and the die (Item 3). In that moment, energy absorption continues in parallel working mode, compressing and splitting tube at the stroke of 40mm. The absorber was installed in the special tool (Item 4) which was used as a support during the testing.

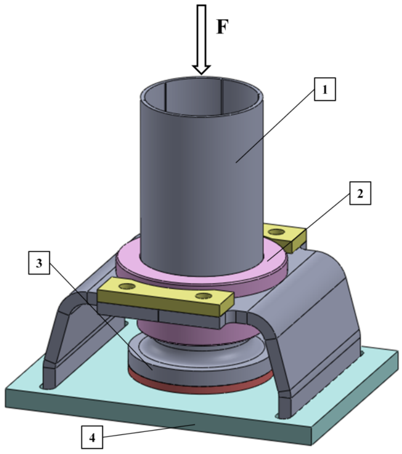


Fig.4. Working principle of shrinking-folding absorber

The following elements were used for this investigation: seamless tubes (Item 1 and 2) from low carbon steel (material P235T1), cone bush (Item 3) with dimensions ø75/68x13° and die (Item 4) with dimensions ø61/r8 from quenched and tempered carbon steel (material C45E), Fig. 5.

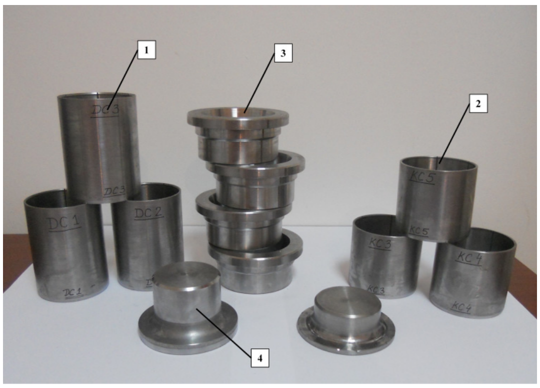


Fig.5. Samples shrinking-splitting absorber

Seamless tubes are separated in two groups according to the lengths: a) seamless tubes with dimensions ø75/70 of the length L = 100 mm (Item 1) and b) seamless tubes with dimensions ø75/70 of the length L = 70 mm (Item 2), Fig. 5. Shorter tubes were used for the control tests and for the check in shrinking process that was used as a base for evaluation of the combined process. Six grooves on the inner wall were made on all tube samples in the inner wall. These grooves were used as initial places for tube wall cracking during splitting process of deformation.

3. RESULTS

3.1. Shrinking-folding absorber

Deformed shrinking-folding absorber shown in the Fig. 6.

Fig.6. Deformed shrinking-folding absorber

Charateristic diagram obtained by experimental investigations is shown in Fig. 7. This diagram characterizes two clear separated phases. The first phase is compressing the tube into a cone bush at stroke of approximately 60 mm. The second phase characterizes parallel work of the shrinking tube and the folding tube at the stroke of approximately 35 mm.

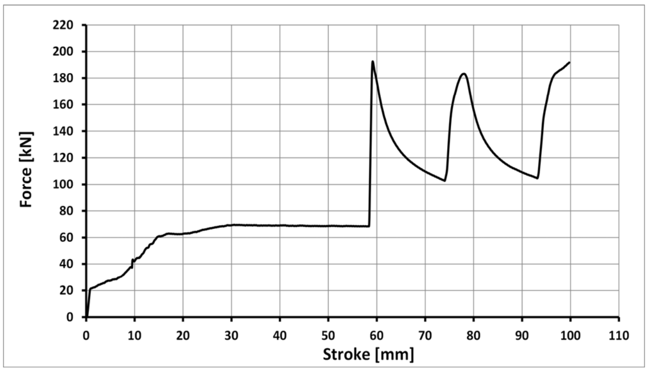


Fig.7. Force vs. stroke diagram: shrinking-folding absorber

3.2. Shrinking-splitting absorber

Fig. 8 shows the sample after deformation. Three samples were tested with the combined shrinking-splitting process and force-versus stroke diagrams obtained by these investigations are shown in Fig. 9. The diagram clearly shows two separate phases of deformation. The first phase of deformation process, until the stroke of ≈50 mm, has the characteristics of shrinking. After this phase, the splitting process starts on part of the tube that was plastically deformed during the first phase. Until the end of the test at a stroke of ≈90 mm, energy absorption occurs in parallel shrinking and splitting processes.

Fig. 8. Deformed shrinking-splitting absorber

At the moment the splitting process starts (there is a transition in the region 50-55 mm stroke) the force increases sharply from ≈100 kN to ≈194 kN. With the appearance of the first cracks at the end of the tube, along the inner grooves, the force drops to ≈150 kN at the stroke of 60 mm. After this, the splitting of the tube along the inner grooves is more controlled and the force again increases gradually to ≈210 kN at the stroke of 80 mm, remaining thereafter at this value until the test ends at 90 mm stroke.

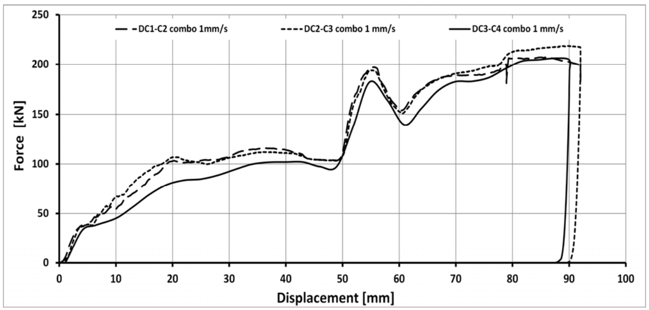


Fig. 9. Force vs. stroke diagram: shrinking-splitting absorber

These two diagrams (Fig. 8 and 9) show similar curves during analysing two clearly separately phases. Second phase serves as a base for the evaluation of characteristics of combined absorbers. The jagged part of diagram, which characterises folding process, was eliminated using splitting process of deformations. On the other side, absorbed energy given by shrinking-splitting process is higher than shrinking-folding absorber. This was the main improvement of the combined absorber.

Absorbed energy in the first and the second phase was calculated as the work of force at defined stroke (amount of absorbed energy is equal to area under curve):

$$W=F_{sr} \; x \; h$$

where: F_{sr} – average value of the force at defined stroke, h – stroke of deformation.

The average calculated value of the total absorbed energy was 11,52 kJ for the shrinking-splitting process and 8 kJ for the shrinking-folding process. The energy absorption of the improved absorber is increased by ≈ 40 %.

4. CONCLUSION

Using combined principle of energy absorption leads to better absorption characteristics. Improved type of absorber may absorb significantly higher amount of collision energy in comparison with using combined shrinking-folding process. Using shrinking-splitting process it is possible to eliminate jagged characteristic which is very important in terms of gradual introduction of the force in the vehicle structure.

ACKNOWLEDGEMENT

The research work is funded by the Ministry of Education, Science and Technological Development, Republic of Serbia, project TR 35045 and TR35006.

REFERENCES

[1] Simić G., Lučanin V., Tanasković J., Radović N., Experimental research of characteristics of shock absorbers of impact energy of passenger coaches, Journal of Experimental Techniques, Volume 33, Issue 4, 2009.
[2] Tanaskovic J., Lučanin V., Milkovic D., Simic G., Milos M., Experimental Research of Characteristics of Modified Tube Absorbers of Kinetic Collision Energy of Passenger Coaches, Journal of Experimental Techniques, Volume 38, Issue 3, page 37-44, 2014.
[3] Alghamdi A.A.A., Collapsible impact energy absorbers: an overview, Thin-Walled Structures, Volume 39, Issue 2, Pages 189-213, February 2001.
[4] Reid S.R., Plastic deformation mechanisms in axially compressed metal tubes used as impact energy absorbers, International Journal of Mechanical Sciences, Volume 35, Issue 12, 1993.
[5] Tanaskovic J., Milkovic D., Lucanin V., Miloradovic N., Experimental and numerical analysis of the characteristics of combined collision energy absorbers, Journal FACTA UNIVERSITATIS - Series Mechanical Engineering, Vol.10, No 2, 2012.
[6] Salehghaffari S., Rais-Rohani M., Najafi A., Analysis and optimization of externally stiffened crush tubes, Thin-Walled Structures, Volume 49, Issue 3, 2011.
[7] Huang X., Lu G., Yu T. X., On the axial splitting and curling of circular metal tubes, International Journal of Mechanical Sciences, Volume 44, Issue 11, 2002.
[8] Reddy T. Y., Reid S. R., Axial splitting of circular metal tubes, International Journal of Mechanical Sciences, Volume 28, Issue 2, Pages 111-131, 1986.
[9] Atkins A. G., On the number of crack in the axial splitting of ductile metal tubes, International Journal of Mechanical Sciences, Volume 29, Issue 2, 1987.

HYBRIDIZATION - THE WAY OF DECREASING CARBON DIOXIDE EMISSION AND FUEL ECONOMY

Martin MIKOLAJČÍK [1]
Daniel KALINČÁK [2]

Abstract *– This article analyzes the driving performance shunting locomotives with conventional internal combustion engine (ICE) and suitable substitutes of conventional ICE for ICE with lower performance combined with hybrid propulsion.*

Installed performance of the ICE in shunting locomotive is high, the maximum power is used only for minimum working time of locomotive and it´s leading to high fuel consumption and increasing operating costs and emission of carbon dioxide. Due to the introduction of stricter emission limits for rolling stocks are placed demands on more effective fuel efficiency and reducing greenhouse gases emissions.

For this reason, there is an effort to introduce hybrid propulsion into rail vehicles operating in a wide range of performances, which replace the ICE with high performance. Hybrid drive consists of ICE, which is more powerfull than average power of shunting (non hybrid) locomotive in shunting and hybrid system, which covers performance peaks. In this case, the ICE works most of the time in the optimal mode which results in a reduction in fuel consumption and emissions. It is also possible to recuperate kinetic energy of locomotive and subsequently stored it in a suitable storage of energy for later use and achieving high efficiency operation. A suitable storage of energy can be batteries, ultracapacitors, flywheel, pressure accumulator and their combination and the most suitable alternative should be chosen according to the power transmission of shunting locomotive (electric, hydraulic, mechanical).

Keywords – Hybrid traction drive of rail vehicles, Utilization power of ICE, Hybrid locomotives, Fuel utilization, Accumulation of energy.

1. INTRODUCTION

Railway systems always have been described as competitive, sustainable and environmentally friendly modes of transportation. However, diesel engines appear more and more like the weak point in this good picture. Fortunately, fast-growing technologies offer everyday new opportunities for improving such a technical domain as railway [1].

Most diesel locomotives used on railways using outdated types of ICE that do not meet today's emission limits for this type of vehicle and using of their installed power is low. As suitable and cheaper solution to this problem, instead of buying a new rail vehicle seems to use a hybrid system in upgraded diesel locomotives and it brings the desired reduction in fuel consumption and reduce emissions. For suitable design of a hybrid propulsion of specific rail vehicle, it is necessary to know the operating parameters and make the analysis of operating parameters to determine the most appropriate design of the hybrid system and accumulators of energy. Improper design of a hybrid system would be extended return of investment in rebuilding and hybrid system could not be fully utilized. It is best use hybrid systems in rail vehicles, which often stop and then starting up again. In the following paper we will present the possibility of using a hybrid system in shunting locomotives.

2. ANALYZATION OF SHUNTING LOCOMOTIV´S OPERATION PARAMETERS

It is known that the use of installed power capacity of ICE in motive power units (especially in shunting locomotives and locomotives for industrial transport) is very low. Average utilisation of engine power is

[1] Martin MIKOLAJČÍK, Department of Transport and Handling Machines, Faculty of Mechanical Engineering, Univerzity of Žilina, Univerzitná 1, SK-010 26 ŽILINA, SLOVAKIA, martin.mikolajcik@fstroj.uniza.sk
[2] Daniel KALINČÁK, Department of Transport and Handling Machines, Faculty of Mechanical Engineering, Univerzity of Žilina, Univerzitná 1, SK-010 26 ŽILINA, SLOVAKIA, daniel.kalincak@fstroj.uniza.sk

usually less than 20% of the installed power capacity and nominal engine performance is utilised only during minimal period of the total time of engine operation (at the level of approx. 1%). The result of this is that most of the operational time the internal combustion engine works in regimes that are far from optimum mode. It means that specific fuel consumption is high. At this type of locomotives operation the frequent and fast changes of engine regimes occur, which results in increased fuel consumption and imperfect fuel combustion with increased quantity of harmful emissions [2].

2.1. Shunting service of locomotive Class 742

The measurements were carried out on the locomotive class 742 (ČKD) on Fig. 1 in shunting service at railway station Trencianska Tepla [3]. This class of locomotives has 883 kW nominal output of engine.

Fig. 1. Shunting locomotive class 742 in service[4]

The distribution of traction generator output is shown in the Fig. 2. The mean output of traction generator was only about 102 kW, which represents about 11.5 % of the nominal output of ICE [2].

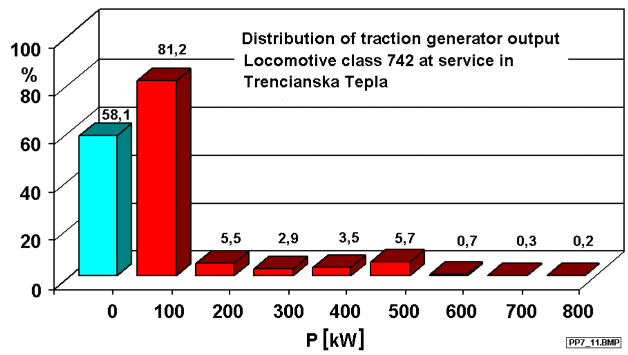


Fig. 2. The distribution of traction generator output of locomotive class 742 in the shunting service at Trencianska Tepla [2]

As we can see at the Fig. 2, the maximum power of locomotive is using only short time period and main engine operation is idling and work with power output up to 100 kW. More efficient is using hybrid locomotives for these types of rail operations. In this case can be used ICE with power about 200 kW and it will cover 86.7% of power needs. The rest 13.3% have to be covered by energy from accumulator which will be charged during idling operation of ICE and recuperation braking.

The accumulator should be able give short-time power about 680 kW, what is ambitious requirement. This high power of accumulators is needed for keeping up maximum traction effort of locomotive. The high power of accumulators is necessary for charging during regeneration of braking power as well.

By this way we can achieve that ICE will be working at optimal conditions and it will cause lower fuel consumption and emission. The next step in designing hybrid locomotive is to choose correct accumulator of energy, which can be fast charging and discharging with high power, which will not damage storage of energy during years of using. For shunting services is suitable use flywheel, ultracapacitors and superconducting magnetic energy storage system and Ni-MH or LiFePo4 batteries as storage of energy, because they can be charged and discharged by high power in short period.

2.2. Shunting service of locomotive Class 770

Another example of output distribution of locomotive class 770 (ČKD) on Fig. 3 during shunting operation on hump in railway station in Zilina is shown in the Fig. 4 [5]. The mean output of the locomotive with nominal rating of 993 kW was only 61 kW in this case, what represents only 6% of nominal output of ICE [2].

Fig. 3. Shunting locomotive class 770 in service[6]

The Fig. 4 shows that ICE shunting locomotives working for a not insignificant duration in the idling mode (approx. 37%) in the area of high specific fuel consumption. This is from reason to power peripheral devices such as compressor.

In the case of a hybrid propulsion would be peripherals driven by an electric motor and, if it is necessary, could be powered by energy from accumulator with turn off ICE. This would achieve the operation of the ICE in area of low specific fuel consumptions.

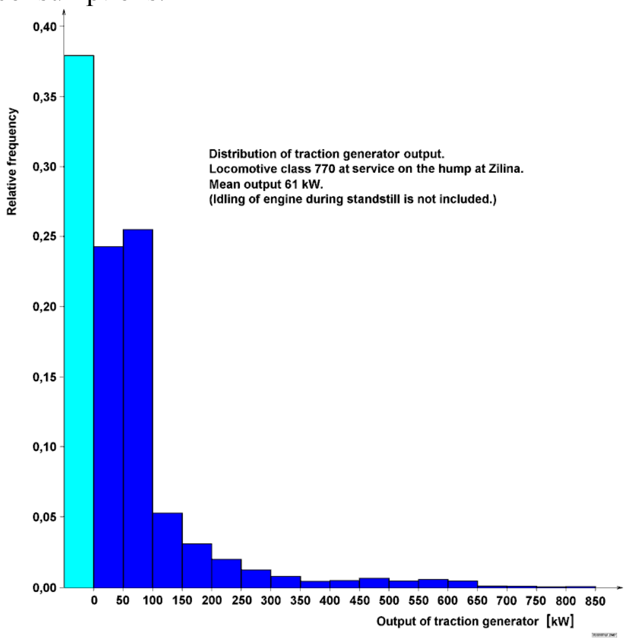


Fig. 4. The distribution of traction generator output of locomotive class 770 shunting at Zilina[5]

2.3. Comparation between shunting hybrid locomotiv Class 718 and non-hybrid locomotive Class 730

In the former Czechoslovakia was in 1986 built the hybrid locomotive Class 718, shown in Fig. 5. There were carried out measurements for comparison this hybrid locomotive and non-hybrid locomotive Class 730. Design and operational properties of locomotive Class 718 was based on locomotive class 730. Basic features of class 718 is shown in Tab. 1. and 730 in Tab. 2.

Fig. 1. Hybrid locomotive Class 718[7]

Tab. 1. Basic features of locomotive class 718 [7]

Locomotive Class 718	
Wheel arrangement	Bo´Bo´
Drivetrain	AC/DC
Engine type	Liaz M 637
Rated engine power	189 kW
Traction batteries	480 NSK 300
Batteries performance	360 kW
Capacity of batteries	300 Ah
Battery voltage	576 V
Auxiliary battery	75 NSK 150
Auxiliary battery voltage	110 V
Max. speed	65 km/h
Continuous tractive effort	104 kN
Max. tractive effort	161 kN
Mass	64 t

Tab. 2. Basic features of locomotive class 730 [8]

Locomotive Class 730	
Wheel arrangement	Bo´Bo´
Drivetrain	AC/DC
Engine type	ČKD K 6 S 230 DR
Rated engine power	600 kW
Max. speed	80 km/h
Continuous tractive effort	104 kN
Max. tractive effort	205 kN
Mass	69,5 t

The results of measurements showed that hybrid locomotive is more effective in all type of shunting except of shunting to hump as it is shown in Tab. 3. It is possible to save approximately 16-22% of fuel compare to non hybrid locomotive.

Increasing fuel consumption of hybrid on shunting to hump is caused by using of hybrid traction drive on maximum. In this operational regime is regenerative braking rare.

To reduction of fuel consumption significantly contributes using of regenerative braking, which save braking blocks or braking pads and achieves higher efficiency of hybrid drive. The measurements at this hybrid locomotive were executed with various loads up to 2500 t.

Tab. 3. Comparation of fuel consumption in shunting service [9]

Type of shunting	Fuel consumption dm^3/h		Ratio of fuel consum-ption
	Class 730	Class 718	
Shunting on hump	14,92	13,09	0,88
Pushing off and allocation of load	13,62	10,33	0,76
Shunting to hump	23,53	25,56	1,09
Pulling of load	12,87	10,86	0,84

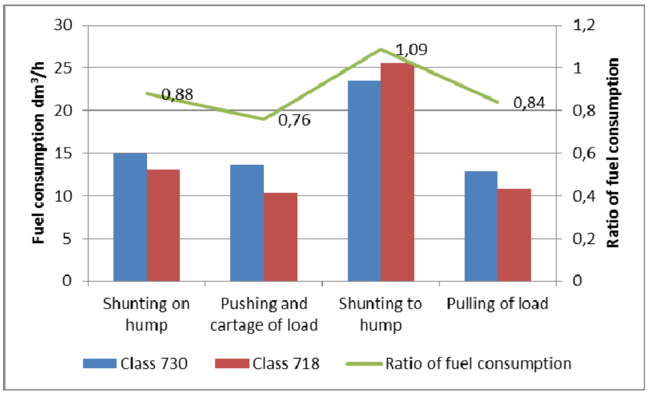


Fig. 2. Graphics processing of data from Tab. 3

Locomotive class 718 has ICE with power only 189 kW and replaced original ICE with power of 600 kW. It is only 31.5% power of original ICE which cause lower fuel consumption and emission compared to original ICE.

3. CONCLUSION

Rising prices of fosil fuels force designers and producers to improve efficiency of diesel locomotives. Better utilization of fuel and decreasing of greenhouse gases emission are required by strict emission limits for rolling stocks. One of the way for better fuel utilization is introducing hybrid propulsion to rolling stocks. With hybrid propulsion it is possible to change kinetic energy of vehicle to electricity through regenerative braking. Kinetic energy is normally changed to heat in non-hybrid locomotives and it is lost during braking process. Another advantage of hybrids are possibility of replacing ICE with high power and fuel consumption with new ICE with lower power and fuel consumption, but with equal traction effort. The hybrid locomotives in shunting operations can reduce the fuel consumption up to approximately 22% and in some case even more.

The most reasonable is using hybrid propulsion in shunting services or at the regional railways where the needs of power are periodically changing and vehicles are still stopping and starting in short period during services. The power peaks are covered from energy stored in accumulators of energy and another power needs are covered by ICE.

Introduction of hybrid locomotives will probably rise in the future, but is necessary to solve problem with high prices of energy accumulators. We can hope that Tesla motors [10] will start massive production of batteries for electric vehicles and it will be possible to use those batteries for hybrid locomotives. Finally hybrid locomotives will cost less than now.

REFERENCES

[1] Chabas, J., Environmentally friendly technologies for railway application, SNCF, Paris, 2001.
[2] Kalinčák, D., Bartík, Ľ., Grenčík, J., Some ways of fuel consumption reduction of diesel railway vehicles, Autobusy – Technika, Eksploatacja, Systemy Transportowe, Nr. 3/2013, Instytut Naukowo-Wydawniczy „SPATIUM" sp. z o.o., Radom, ISSN 1509-5878, 2013.
[3] Palko, P., Hybridné systémy pohonov v koľajových vozidlách. Thesis. University of Žilina, 2008.
[4] Vyskočil, V., Lokomotíva řady 742 (ex T 466.2), online, http://www.vlaky.net/zeleznice/spravy/003232-Lokomotivy-rady-742-T-4662/, 2009.
[5] Müller, J., Kalinčák, D., Pohl, R., Rybičková, D., Truban, M., Šebo, L., Divišová, H.,Herzáň, F., Smolková, A., Balala, L., Spoľahlivosť pojazdu koľajových vozidiel. Report No SET – KKVMZ/2/85. VŠDS Žilina 1985
[6] Foltín, R., Lokomotiva 770412 - 5, online, http://trainweb.cz/foto/lokomotiva-770-412-5-petrovice-u-karvine-11255, 2008.
[7] Kolmačka, R., Řada 718 (ex TA 436.05), online, http://www.prototypy.cz/?rada=718, 2013.
[8] Kolmačka, R., Řada 730 (T457.0) ČD, online, http://www.prototypy.cz/?rada=730, 2007.
[9] Pohl, J., Výsledky výzkumu hybridního diesel-akumulátorového pohonu lokomotiv, Železniční technika 17/1987, pp. 206 - 211, Praha, 1987
[10] Horčík, J., Tesla nestíhá vyrábět, chce postavit největší továrnu na li-ion baterie, online, http://www.hybrid.cz /tesla-nestiha-vyrabet-chce-postavit-nejvetsi-tovarnu-na-li-ion-baterie, 2013.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '14

NEW STADLER “FLIRT³” EMU’S FOR SERBIAN RAILWAYS

Fadi KHAIRALLAH [1]

Abstract *– The FLIRT³ (**F**ast **L**ight **I**nnovative **R**egional **T**rain) meets the highest standards with respect to comfort and safety for the passengers. It represents an evolution in compliance with the latest applicable standards, especially TSI and the crash norm EN 15227. The entire vehicle structure is strictly modular, thus making it possible to fulfil customer needs, such as car body lengths, floor heights and the number of doors or windows, in a simple manner. Furthermore, the interior of the FLIRT³ from the front to the rear end entrance is continuously accessible, in compliance with the TSI PRM. FLIRT³ is available either as an EMU, DMU or HYBRID version. FLIRT³ is equipped with Jacob's trailer bogies. The main advantage of using Jacobs bogies is that the number of axles can be reduced, which leads not only to a reduction in the weight but also reduces maintenance. The vehicle is designed to allow simple maintenance and the use of cost efficient spare parts. Stadler has focused on a light build power traction system which also allows brake energy to be recuperated and fed back into the grid.*

Keywords – Railway vehicle, Crash norm, Jacob's bogie, Maintenance.

1. INTRODUCTION

Worldwide, the demand for EMU's (Electric Multiple Units) is increasing. This type of train is designed for interregional and commuter transportation. Requirements for such trains regarding safety, energy consumption and reliability are thus high.

The Stadler Rail Group is in a position to offer the market complete vehicle concepts. Every aspect of production is carried out under one roof, from body and bogie production, through to the final assembly. State-of-the-art technologies, paired with lightweight and service-friendly designs help to keep energy consumption, and operating and maintenance costs low, while modular concepts cater to the recurring specific requirements of rail companies – one of the reasons for the success of the Stadler Rail Group.

2. CRASH NORMS REQUIREMENTS

The car body must meet the requirements of EN 15227:2008 for crashworthiness, category C-1. The following scenarios have to be considered:

- Scenario 1: Head-on collision at 36 km/h with an identical vehicle
- Scenario 2: Head-on collision at 36 km/h with an 80t freight car
- Scenario 3: Head-on collision at 110 km/h with a side-on deformable barrier (e.g. 15t truck at a railway crossing)
- Scenario 4: Collision with a low object (static load on obstacle deflector)

2.1 Head of vehicle

The head of the vehicle is an aerodynamically optimised fibre reinforced plastic composite element with a modern design.

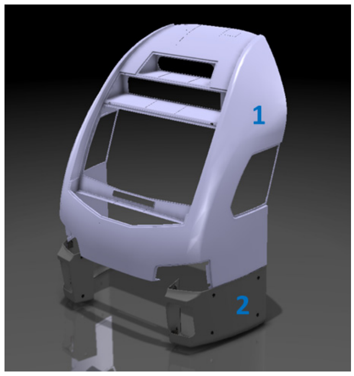


Figure 1: Head of vehicle

No	Explanation
1.	Head of vehicle: aerodynamically optimised fibre reinforced plastic composite element
2.	Cover profile: fibre reinforced plastic composite element for the crash modules

[1] Fadi KHAIRALLAH, Stadler Bussnang AG, Ernst-Stadler-Strasse 4, CH-9565 Bussnang, e-mail: fadi.khairallah@stadlerrail.com

Figure 2: Head of Vehicle FLIRT3

This non-load-bearing cabin is bonded to the aluminium car body as well as to the aluminium crash structure. It provides all necessary mechanical connection points for windows, mirrors, windscreen wiper, etc. for example.

2.2 Crash concept

In the event of a collision, energy absorption takes place in multiple, progressive stages: first within the front coupling, then over the bolted crash modules and finally over the welded crash boxes. Thus, the crash modules can easily be replaced after minor collisions.

The coupling, the crash boxes and the crash modules take effect one after another or with a slight overlap, depending on the collision scenario, and absorb all energy resulting from the collision. With head-on collisions as described in EN 15227, no structural damage occurs up to 10 km/h. In this case, it is not necessary to replace the front coupler.

2.3 Crash front

Normally, a collision initially affects the coupling. The draw and buffing gear are first pushed in by 100 mm, though reversibly, before the irreversible but exchangeable coupling crash element is compressed a further 250 mm. If the impact is more severe, the draft bar of the coupling breaks at a defined location and is pushed backward into the vehicle underbody, compressing the crash modules and then later the crash boxes.

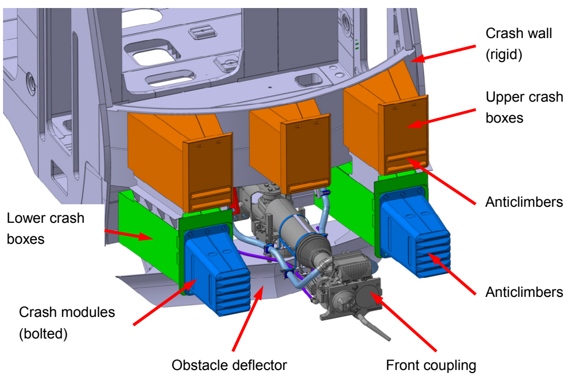


Figure 3: Design of the Crash Front on the End Car

The curved crash wall, as well as the entire underlying front end with the A-pillars, guarantees a rigid, deformation-free structure, which is not part of the crash front that absorbs the energy. The curved crash wall protects the driver's survival space. The crash modules are bolted to the crash boxes, allowing the modules to be easily replaced after minor collisions.

Explicit finite element simulations reveal the behaviour of the vehicle structure for the different collision scenarios described in EN 15227. For the energy absorption modules subject to the largest deformations resulting from collisions, dynamic crash tests were performed. The results of the finite element simulations were then verified by means of the results of the dynamic crash tests.

3. JACOBS TRAILER BOGIE

The Jacobs trailer bogie is placed at the ends of two adjacent car bodies, supporting their weights directly via the four air springs of the secondary suspension stage, two for each car body. This solution cuts down the weight. Moreover, this subsequently reduces the LCC costs, which are due mainly to the maintenance of the bogies.

The traction connection is realised by a Watt's linkage fitted to the car body articulation joint. The brake system consists of four wheel disc brakes.

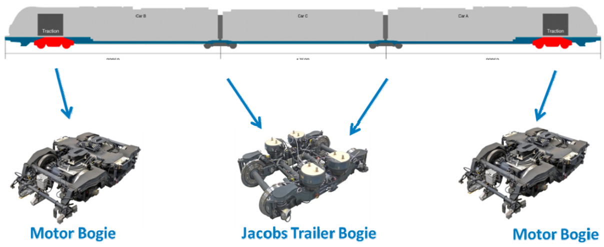


Figure 4: Position of Bogies

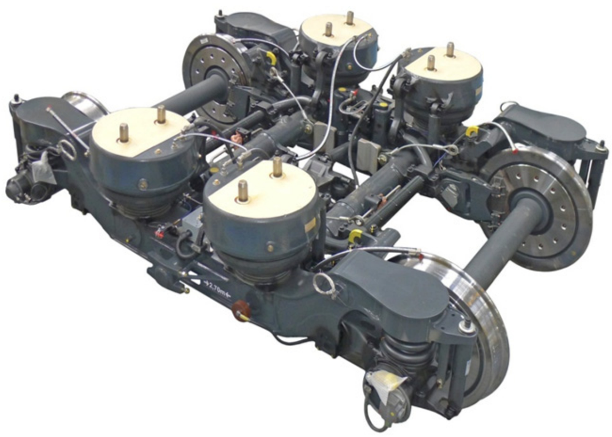


Figure 5: Complete Jacob's Trailer Bogie

Tab. 1. Principal Technical Data of Jacobs Trailer Bogie

No	Item	Explanation
1.	Wheel base	2 700mm
2.	Wheel diameter	New 760 mm – worn 693 mm
3.	Weight	Approx. 6 500 kg
4.	Primary suspension base	2 100 mm
5.	Maximum static axle load	18 tons

3.1 Bogie frame

All connection parts on the bogie frame which are relevant for the following are machined within the required tolerances:

- Parallelism and alignment of the wheel sets
- Safe and reliable operation of the drive units
- Correct function of the brake units

This also ensures that the components installed in the bogie frame can be replaced as required without expensive setting and adjustment work. Furthermore, bogies of the same type are interchangeable within the vehicles. The bogie has been designed for 5g shock.

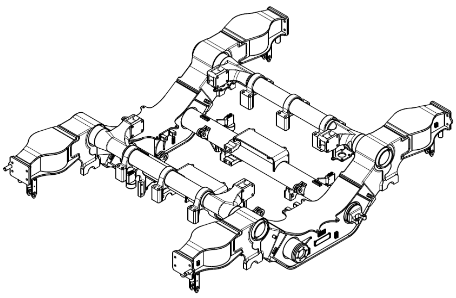


Figure 6: Bogie Frame of Jacobs Trailer Bogie

3.2 Manufacturing

The bogie frames have a welded design. The construction of the bogie frame is carried out according to EN 15085 Parts 1 – 5.

3.3 Material Inventory

The frames consist of components of listed materials:

- Construction sheet metal, grade S355J2+N (EN 10025), DIN material designation 1.0570 (old St 52-3), e.g. sheet metal in longitudinal beam
- Forged parts, grade S355J2G3F (EN 10025), DIN material designation 1.0572 (old PSt 52-3), e.g. axle box supports on motor bogie
- Cast steel, grade GS-20 Mn5 V, DIN material designation 1.1120, e.g. brake supports in bogie frame

3.4 Strength verification and Testing

The bogie frames have been tested for strength and endurance according to current standards, e.g. EN 13749 and EN 15827. Based on standards, a load case document is created for both trailer and motor bogie, which is used for finite element calculation of the bogie frames. The finite element calculation will investigate fatigue load cases and provide static strength proof for the frames. The loads on the bogie frame and adjacent structures are calculated using standard EN 15827. The permissible stresses for welded details are adapted from the listed guidelines of IIW publications and the FKM guideline.

3 MAINTENANCE

EN 50126 defines maintainability as the probability that a given active maintenance action for an item under given conditions of use can be carried out within a stated time interval when the maintenance is performed under stated conditions and using stated procedures and resources.

Maintainability is, according to the definition, a product quality that will be largely determined right from the start of and during the product development process. Initial missed opportunities for creating optimal maintainability can only, if at all possible, be remedied with great effort and increased costs. Should maintainability be hindered or not achieved, the consequence is a significant increase in costs during the product's lifecycle.

In order to prevent this from occurring, Stadler directs the attention to the following topics to enable a constant synchronisation and optimal development of the functional and non-functional goals of the entire system and its components during the development of the vehicle:

Interchangeability, Manageability, Modularity, Assembly / Disassembly, Testability, Cleanability, Robustness, Standardisation, Accessibility.

RAM LCC management is an integral part of Stadler's management system. Reliability, availability and maintainability as far as life cycle costs are in direct dependence and always influencing each other and must be considered as a whole.

Effective RAM LCC management is strongly based on proven vehicle design. All vehicle projects are based on a product family established on the market, which is continuosly improved with each further project.

Stadler Rail has had long term experience in the optimisation of maintenance activities for several customers. At the project start, general requirements for maintainability given by customer documentation and Stadler's experienced pool are defined for the engineers involved.

The RAM LCC process defines activities over the whole life cycle of the vehicles, starting at the design and development phase and ending with the disposal of the vehicles.

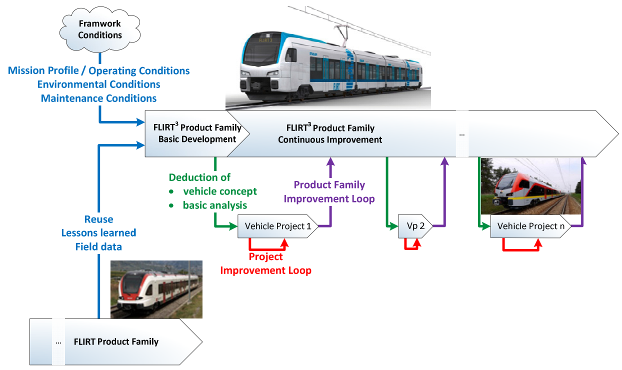


Figure 7: Continuous Improvement of Product Family

The process is applied during all phases of the life cycle of the project. To ensure the best results related to RAM LCC, active participation is required from the beginning in the concept phase by all involved parties:

- Stadler (vehicle integrator)
- Key sub suppliers (traction, HVAC, etc.)

During the design process, Stadler's engineers analyse the actual maintainability performance, following a process based on RCM (Reliability Centred Maintenance) while using the maintainability checklist:

- Accessibility
- List of maintainability critical items
- Time of replacement of the components
- Special tools
- Detectibility of failures
- Modularity
- Maintenance interval
- Availability of spare parts

Based on the customer driven trend to minimise maintenance time to keep to the scheduled timetable, Stadler is accustomed to ensuring service performance in terms of availability instead of reliability. Despite it being accepted that failures on technical systems occur, it is far more important that a component failure does not affect the safety or operability of a vehicle. This results in tough requirement levels regarding availability, which Stadler vehicles achieve with their reliable and redundant vehicle design.

The main condition for maintaining low LCC costs is a high quality product with low energy consumption and high availability, which in turn, depends on the quality of maintenance.

4 CONCLUSION

The FLIRT^3 meets the highest standards of comfort for the passengers. It represents an evolution in compliance with the new TSI standards, especially the crash norm EN 15227. Based on the long experience in building trains and fulfilling the various challenging requirements for customers in many countries all over the world, the entire vehicle structure is strictly modular at all levels, including the bogies. Stadler RAM management rigorously adheres the processes defined in the EN 50126 standard within its own organisation and demands the same of its suppliers. This process starts at the design and development phase and ends with the disposal of the vehicles, thus making it possible to reduce the maintenance costs.

ACKNOWLEDGEMENT

The relevant contract with Serbian Railways was signed in March 2013. According to the schedule, the first EMU Flirt Serbia is to be delivered by Stadler in September 2014.

REFERENCES

[1] B. Schmid, P. Bruderer, H. Welte, G. Wennig, *Tender documents Flirt Serbia*, Bussnang, 2013.

[2] Documents Stadler Rail.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

REQUIREMENTS FOR CUSTOMER FRIENDLY RAILWAY INTERIORS

Bernhard RÜGER [1]

Abstract *– Within the project „FLEXICOACH“, in cooperation with Technische Universität Wien, Fachhochschule St. Pölten, Fachhochschule Joanneum, Siemens, netwiss and ÖBB Personenverkehr AG, passenger opinion surveys regarding their wants and needs were conducted. The aim of those surveys was to obtain information about everything a passenger requires; in order to get all information needed various subjects such as duration and frequency of journeys, activities during journey, well-being, stress factors, age, gender and group dimensions, were interrogated.*

Keywords – Passenger needs, expectations, experiences, comfort.

1. INTRODUCTION

Overall 3.826 questionnaires were analyzed. All questionnaires were conducted in summer 2012 on the Austrian Westbahn-line between Vienna and Linz. Due to the summer holidays a lower participation of students must be considered methodically. Furthermore and also due to summer vacations less rides to or from work are expected.

Approximately 50% of travellers undertake a trip lasting several days, around 10% are free time trips without an overnight-stay. Journeys in connection with education or work (rides from / to work, rides from / to education facilities, business trips either one-day or with a several day’s duration) account for 25% of all journeys. The remaining 10% are to be allotted to private settlements.

Rail travellers mostly are young, approximately 12% are aged between 13 and 18 years, almost half of all interviewees are between 19 and 39 years old. 27% are part of the “40 to 60 years of age” group and around 12% are older than 60 years. The fact that children under the age of 12 are underrepresented is simply because they rarely fill in questionnaires.

54% of travellers are female, 46% are male. With the exception of people older than 60 years, in all age-groups female passengers form the majority.

Approximately one third of the passengers travel alone. Another third travels in a group of two persons. Around 11% travel in a group of three, 7% in a group of four and 12% in a group of five or more people.

The journeys were classified in journeys up to 30 minutes, 30-60 minutes, 60-90 minutes, 90-120 minutes, 2-3 hours, 3-4 hours, 4-5 hours and more than 5 hours. Most journeys (respectively 20-30%) in all age-groups last between two and three hours. With increasing age the duration of journey as well increases slightly, short-term rides mostly are done by younger people. Summing up all general information gained, elderly people take the train less frequently, but if they do, they go for longer free time rides. In opposition, younger people take the train more often, and mostly for short business trips.

The better part of all interviewees quoted “comfort” as the major reason to take the train, around 40 % of all passengers declared “environment”, “no car” and “price” as their major reasons to choose the train (see Fig. 1). “Safety” and “duration of journey” are an inferior aspect.

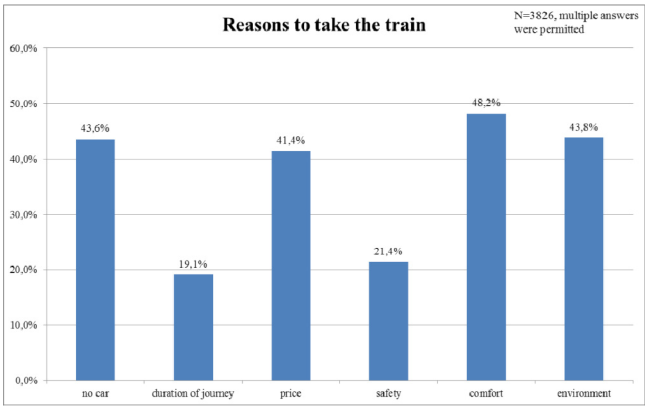


Fig. 1: Reasons to take the train

2. BAGGAGE

Regarding baggage, most information were attained from a diploma thesis [1], which treats issues of baggage transport on an extensive data basis. Amongst other things, various pieces of luggage were

[1] Bernhard RÜGER, Vienna University of Technology, Karlsplatz 13/230-2, 1040 Vienna, Austria, bernhard.rueger@tuwien.ac.at

weight and measured. The accumulated x-, y- and z-dimensions of all luggage measured (not included is carry-on baggage) are demonstrated in Fig. 2.

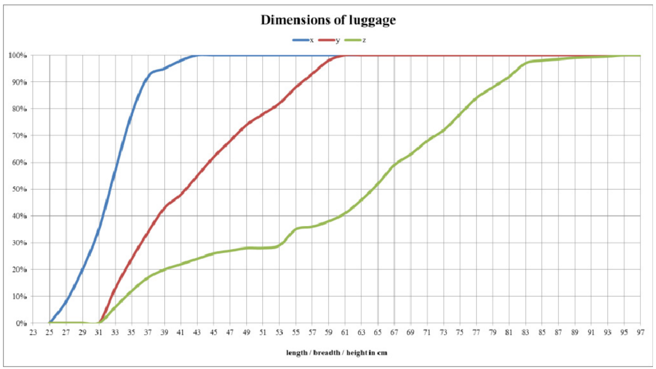


Fig. 2: Dimensions of luggage

Those accumulated measurements can be used in order to design adequate storage between the seat backs or baggage racks.

Analysis show that there are two main issues regarding baggage room. First passengers do not want to lift their luggage, and especially not to the height of overhead storage. This attitude is more common amongst women and increases with age.

Second and due to security reasons, passengers wish to have their luggage in visual range. If these requirements are not met, passengers are very willing to store their luggage in not-intended place, like seats or corridors. This behaviour leads to a lower quality level and to a loss in capacity due to occupied seats.

3. ACTUAL USE OF JOURNEY TIME

A major aspect was the purpose of the journey (business trip or free time ride). Every other business traveller declares to use his laptop, smart phone or tablet while travelling, while only one quarter of travellers on a free time ride uses those devices. Fig. 3 shows the details.

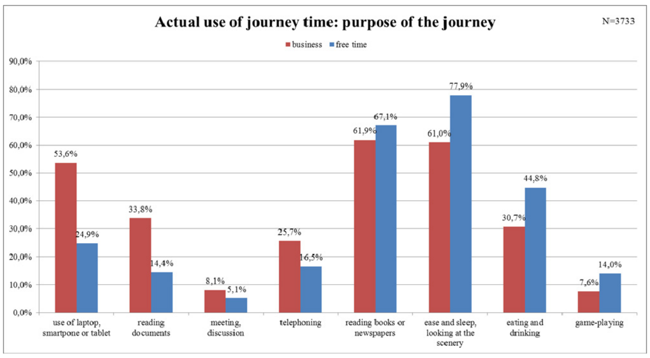


Fig. 3: Actual use of journey time - influence of the purpose of the journey

Another major aspect regarding the use of the journey time is the age of the traveller. Generally speaking there is a slight decrease regarding actually performed activities with rising age. However activities need to be considers separately, while using electronic devices decreases with increasing age, activities like "looking at the scenery" or "reading a book / the newspaper" increase with increasing age.

4. EXERCISES ON THE TRAIN

The longer the journey, the higher need to move. Around 20% of passengers travelling up to an hour wish to exercise during their journey. The percentage rises to 40% when the duration of the journey rises up to five hours or more.

5. DESIRED USE OF JOURNEY TIME

Analysis (Fig. 4) shows that there is a connection between the use of journey time and the purpose of the journey.

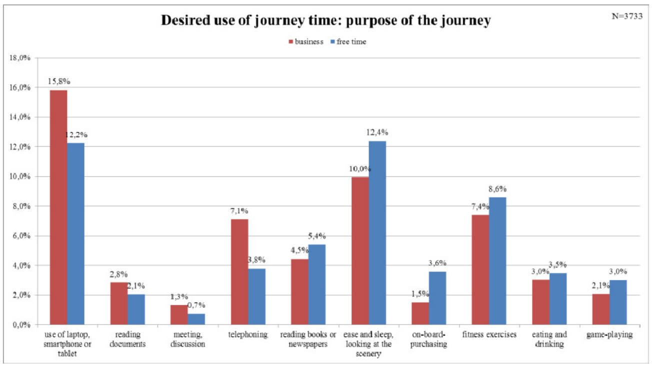


Fig. 4: Desired use of journey time: influence of the purpose of the journey

All too often (around 20% of all interviewees) passengers criticize missing mobile services. Because of several comments it is obvious that a missing WLAN-connection is intended. Together with the absences of tables (respond 12% of all interviewees), this is the biggest obstacle when it comes to using tablet, smartphones and laptops. Around 17% of all interviewees criticize uncomfortable and fixed seats as well as absent silence, which holds them from their desired activity "ease and sleep". The need to move reflects in the desire for a possibility to exercise.

The age has significant influence regarding the desired use of travel time. The younger the interviewee, the more non accomplishable activities are quoted. Anterior passengers are significantly more satisfied with the possibilities offered, respectively less frequently express a wish to use the time in another way.

In Fig. 5, every desired activity is marked in a different colour (the lowest layer indicates "using the laptop", the second lowest "using tablet or smartphone" and so on).

Similar images with heavy age-related variation often occurred in the course of the examination, for instance regarding questions about well-being, stress factors, activities, etc.

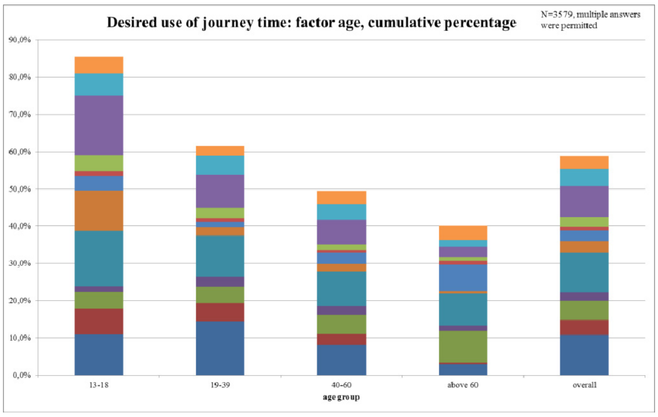


Fig. 5: Desired use of journey time: factor age, cumulative percentage

The journey time is a major aspect when it comes to desirable use of time. The longer the journey time, the more requirements were quoted, in particular if the duration excesses two hours.

6. TIME WELL-BEING

Around 33% of the interviewees feel "very well" when travelling by train, about 52% feel "rather good", 14 % feel "rather bad" and only 1 % of the passengers do not feel well during train journeys.

The assumption that those outcomes correspond with the fact that younger passengers mostly are on business trips, while anterior passengers use the train prevailing for free time trips, is unfounded. Around 50% of all train journeys are leisure time trips, lasting several days. Interviewees between 13-18 years, the group that feels most uncomfortable during train journeys, mostly goes on free time rides without an overnight stay. Thus there is no obvious connection between the purpose of the journey and the well-being.

Passengers travelling first class are feeling better than passengers travelling second class. Furthermore there is a strong connection between the well-being of the passengers and the degree of capacity. Therefore on weekdays from Monday to Thursday passengers mostly feel "rather well" or "very well", while travellers on Fridays and weekend feel "rather bad" or "not well". The higher degree of capacity during weekends leads to an oftener nomination of stress factors like "high degree of capacity", "search for seat", "noise" and "fellow passengers".

7. STRESS FACTORS

The stress factor most frequently nominated was "search for a seat", around 20% of the passengers feel stressed (see Fig. 6). Also sensed as stress factors were "high degree of capacity", "noise" and "fellow passengers". The factors most frequently mentioned are those which appear at a high degree of capacity and obviously lead to a deterioration of the well-being.

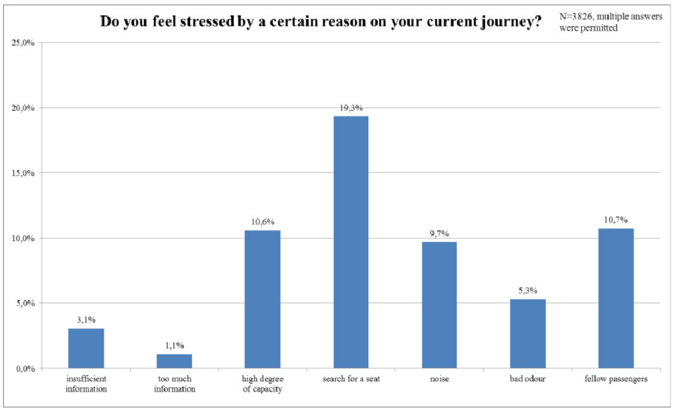


Fig. 6: Stress factors during the current journey

Analogue to the well-being, the age of the passengers is crucial when it comes to cognition of stress. Younger passenger are more stressed than anterior passengers, at least they quote it more often. With increasing age (groups from 13-18 years, till 60 years) the nomination of arising stress factors during an actual train journey decreases under 50%. Considering the most frequently quoted stress factor "search for seat", the nominations in the age group "over 60 years" decrease even to a third of those from passengers between 13-18 years. This is a very notable fact, because precisely this stress factor was assumed to arise with increasing age, also in terms of luggage.

Generally speaking, anterior passengers are more satisfied with the frame conditions than younger ones.

8. SERVICE FEATURES

Most frequently nominated when it comes to service features were „reasonable priced meals" (31%), "purchase of newspapers" (24%), "transmission of knowledge" (23%), "entertainment" (20%), "possibilities to exercise " (18%), "relaxation practises" (17%). With increasing age the interest in service features heavily decreases.

With increasing journey duration, the interest in service features increases as well. Passengers on a free time ride show more interest in service features than travellers on a business trip. Around two-thirds of all respondents show interest in healthy nutrition during their train journey. This desire is more common under female passengers than under male ones.

9. ATMOSPHERIC ENVIRONMENT

The outcomes of this particular subject won't be discussed any further. Generally speaking, the nominations made by the passengers are very subjective and do not always refer to any comprehensible objective criteria. For instance, in every sort of train the temperature was between 25 and 26 °C, nevertheless there are different sensations and evaluations regarding the temperature, which can be connected to the sort of train. The highest percentage of satisfied passengers is to be found in trains of the private operator Westbahn (over 80% satisfaction). The average registered temperature is exactly identical to the temperature registered in the Railjet-trains of ÖBB. However, Railjet was evaluated ten percentage points less than Westbahn. It is obvious that not only the temperature, but rather the general well-being or the consciousness of a deliberately taken decision to travel with a new operator (Westbahn war operating only eight months at the moment of the opinion survey) contributed to this outcome.

The opposite way around also Railjet was not only evaluated regarding temperature, but rather general well-being (for that matter Railjet scores rather low).

There is a similar effect notable when it comes to train categories (first or second class). Passengers travelling first class rated the atmospheric environment higher than passengers travelling second class, there was no objective difference however.

It has to be considered that subjective sensations had a great influence also on questions regarding well-being, illumination and stress factors. Advanced studies would be very helpful in order to interpret the outcomes in the right way.

10. CONCLUSION

Compared to other modes of transportation the railway system has got the big advantage that passengers are able to use the travel time efficiently. This is one of the biggest advantages of competition. Unfortunately today's vehicles hardly offer the requested equipment which allows the best possible time use. Train passengers are very interested in using the travel time for working, mostly on technical devices like one note books or tablets, for reading or for relaxing. For efficient time use the investigations have shown that the individualisation of the space in the train is essential. It is important that all passengers can follow their requested activities without affecting other passengers. For example people who are working may produce noise but on the other hand need calm for concentration. Additionally they need light whereas people who want to sleep need it dark and calm. So further investigation must focus on how the space in the vehicle can be individualized in a best possible way.

ACKNOWLEDGEMENT

The outcome is part of the project FLEXICOACH, fundet by the Austrian Ministry of Transportation. More info is available under: http://FLEXICOACH.netwiss.at

REFERENCES

[1] Viktor Plank: Dimensionierung von Gepäckanlagen in Reisezügen, Wien 2008

[2] Viktor Plank, Bernhard Rüger, "Grundlagen für eine optimierte Gepäckunterbringung in Reisezügen"; ETR - Eisenbahntechnische Rundschau (eingeladen), 07+08 2009 (2009), 07+08; S. 417 - 421

[3] Flexicoach, Endbericht AP2, Nutzerbedürfnisse, Wien 2013

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

EXPERIMENTAL MEASUREMENTS AND NUMERICAL SIMULATIONS OF THE WHEEL-RAIL ANGLE OF ATTACK

Dragan MILKOVIĆ [1]
Goran SIMIĆ [2]
Jovan TANASKOVIĆ [3]
Živana JAKOVLJEVIĆ [4]

Abstract *– Angle of attack is important wheel-rail contact parameter and serves for estimation of the rolling stock curving performance. Together with wheel-rail contact forces, angle of attack influences the wear index. This paper presents experimental on-track measurements of the angle of attack using specially designed laser device installed on track. Experiments were performed on three type of rail vehicles: shunting locomotive series 631-301, motor unit 412-077 and trailing unit 416-077 of the electromotor train 412/416. Experimental measurements were compared with multibody system (MBS) simulations using specialized computer package VAMPIRE Pro. We found good agreement between the results obtained experimentally and by simulations.*

Keywords – Angle of attack, Measurements, Multibody simulations, Wear index.

1. INTRODUCTION

Criteria for estimation of the railway vehicle dynamics during curve negotiation including derailment safety, depend on ratio between lateral Y and vertical Q forces in the wheel-rail contact (Y/Q), as well as on the wheel-rail angle of attack α [1]. These parameters, together, influence wear intensity expressed using wear indices. Considering the importance of these parameters for experimental research and prototype testing of the railway vehicles in this paper we present the developed device for angle of attack (AOA) measurements and experimental results obtained by its use. The device for measurement of the wheel-rail contact forces and appropriate wayside system for measurement is more detailed presented in [2].

2. DEVICE FOR AOA MEASUREMENTS

Developed device for angle of attack measurements identifies position of the wheel relative to some surface or axis using Micro-Epsilon optoNCDT 1700 laser device (Fig. 1). Angle between the wheel and defined reference, which represents longitudinal rail axis, defines wheel-rail angle of attack α. Considering lasers's accuracy and measurement principle, this device should be positioned normaly to rail longitudinal direction.

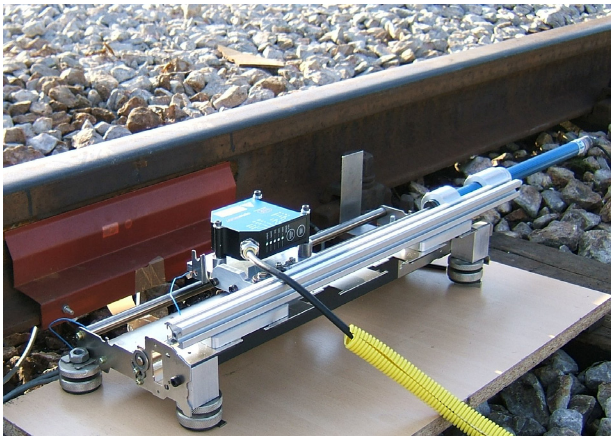


Fig. 1. Laser device positioning relative to rail

3. IN-SITU MEASUREMENTS OF THE AOA

Characteristic results recorded for shunting

[1] Dragan MILKOVIĆ, Assistant Professor, Ph.D, University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, dmilkovic@mas.bg.ac.rs
[2] Goran SIMIĆ, Full Professor, Ph.D, University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, gsimic@mas.bg.ac.rs
[3] Jovan TANASKOVIĆ, Assistant Professor, Ph.D, University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, jtanaskovic@mas.bg.ac.rs
[4] Živana JAKOVLJEVIĆ, Assistant Professor, Ph.D, University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, zjakovljevic@mas.bg.ac.rs

locomotive 621-301 and electromotor unit 412/416 are presented in the paper.

Immediately before measurements, direction of the laser beam was checked relative to rail (Fig. 2). It appeared that deviation from the 90° was 12,4 mrad (0,71°). According to analysis performed in [3], such a small deviation has negligible influence on measurement accuracy (less than ± 1%), so it was not necessary to correct laser position.

In the following paragraphs, we will use example of the measurements on electromotor train's trailing unit 416-077 to present the method for data processing, as an example are presented complete results of measurements on electromotor train's trailing unit 416-077.

Fig. 2. Trailing unit EMU 416-077– angle of attack measurement device without protective cover

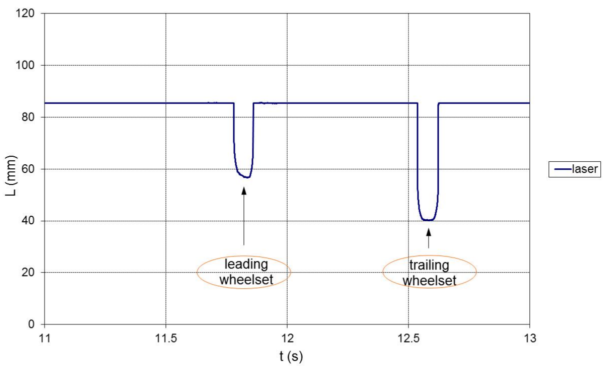


Fig.3. Trailing unit EMU 416-077 outer wheels – recorded data

In Fig. 3 is presented outer wheel position of the leading and the trailing wheelsets relative to rail in time domain recorded using laser device.

For obtaining of the wheel-rail angle of attack recorded data were transformed from time domain to spatial domain using measured speed of the train. Passing of the outer wheels in spatial domain after transformation is presented in Fig. 4 and Fig. 5. From these diagrams could be derived angle of attack and the wheel position relative to rail. Angle of attack α was estimated based on the linear regresion slope of the central segment of the recorded line with 100 mm length, which is far enough from rounded zones caused by flange passing by the laser.

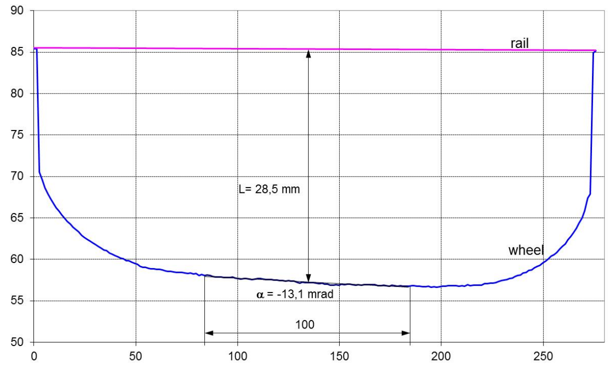


Fig. 4. Trailing unit EMU 416-077 – relative position and angle of attack of the outer wheel of the leading wheelset

Measured angle of attack was α=-13,1 mrad for outer wheel of the leading wheelset and α=1,0 mrad for the outer wheel of the second wheelset. Relative position between the back surface of the outer wheel and the side of the outer rail in the mid position of the wheel, defined as distance between wheel and the rail measured 10 mm below TOR (top of rail), was 28,5 mm for the leading wheelset and 45,0 mm for the second wheelset of the leading bogie.

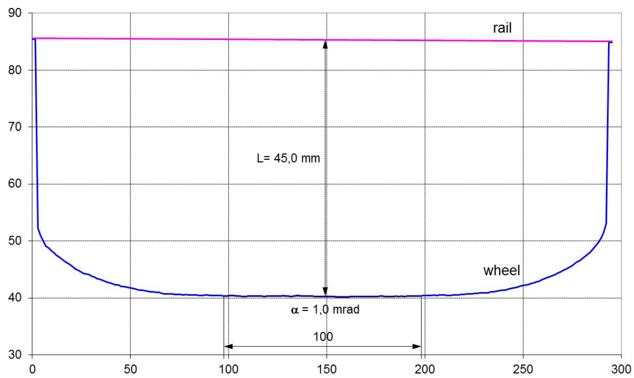


Fig. 5. Trailing unit EMU 416-077 – relative position and angle of attack of the outer wheel of the second wheelset

3.1. Wheel-rail wear indices

All three vehicles were tested under the similar or even the same conditions (same location) and all the vehicles while passing over the measurement section were pushed or hauled or with turned off traction. In this subsection we present relative comparison of the wear characteristics of the outer wheels of the leading wheelset for each of the tested vehicles. For comparison diferent authors have defined diferent wear characteristics, which are called wear indices. Starting from expressions for wear index given in [4], which includes work of tangential forces in the wheel-rail contact, for comparison of the wear characteristics of the diferent vehicles with diferent wheel profiles, with some approximations we used product of lateral force and angle of attack according to following expression:

$$I_h = k \cdot Y \cdot \xi_y = k \cdot Y \cdot \frac{V_y}{V} = k \cdot Y \cdot \alpha \quad (1)$$

where: k – constant, Y – measured lateral force, ξ_y – creepage in lateral direction, V_y – speed component in lateral direction of the wheelset, V – speed of the wheel forward movement, α - angle of attack.

Relation between the creepage ξ_y and angle of attack α was established based on kinematics and geometric relation shown in Fig. 6. Approximation and asumption based on which expression (1) was derived are:

- Creepage in genereal represents ratio between speed component in the creep direction and speed of the wheel forward movement,
- During curve negotiation with turned off traction, wear is influenced dominantly by work of tangential force in lateral direction.

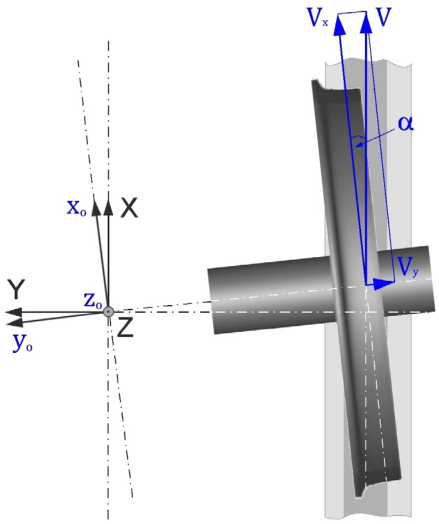


Fig. 6. Creepage in lateral direction

Obtained results of the relative wear index for the three tested vehicles are presented in Tab. 1.

From the table it can be seen that the lowest value of the angle of attack and the best wear performance and lowest wear index has trailing unit 416-077.

Tab. 1. Relative wear index I_h of the tested vehicles

	V (km/h)	Y (kN)	α (rad)	$Y{\cdot}\alpha$ (N rad)	Relative wear index I_h
Shunting locomotive 631-301	13	26900	16.6	446.54	1.00
Motor unit 412-077	14	23300	14.7	342.51	0.77
Trailing unit 416-077	13	15400	13.1	201.74	0.45

4. NUMERICAL ANALYSIS

Simulation of the railway vehicle dynamics using some of the specialized computer simulation packages may also serve as a good design tool. Depending on the scope of an analysis, simulation can have very detailed vehicle models and at the same time use some simplifications of the track model, such as considering it either as rigid or as installed on uniform elastic foundation. The others focus on the track analysis using 2D models, while the excitation influence of the vehicle is approximated using some simplified vehicle models [5, 6]. There are also simulations that consider vehicles and tracks as a multibody system (MBS), while considering only vertical vehicle/track interaction [7–9]. Within our research, we used the computer programme Vampire Pro [10] for the curving analysis during passing through the sharp curve with a 214 m radius, on the track without superelevation, excluding the influence of any other geometric imperfections. Below we present an overview of the performed simulations and obtained results. Fig. 7 shows non-linear model of the EMU series 412/416 indicating detail of one bogie with suspension elements. Bogie frame and wheelsets are presented transparently in order to provide better overview of the suspension system and link elements.

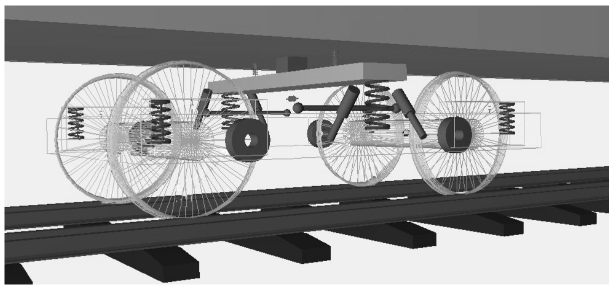


Fig. 7. Model of EMU– detail of the bogie [2]

Vampire Pro allows linear stiffness and damping terms to be specified between the rail and sleeper and sleeper to ground as shown in Fig. 8. Damping terms are not important for quasi-static curving analysis. They just support convergence of the simulation results. The most significant stiffness terms used in simulations for lateral rail to sleeper stiffness were experimentaly obtained, while lateral sleeper to ground stiffness, as less important for this analysis, was adopted from literature [10]. The rails and sleepers are considered to be massless degrees of freedom, which is appropriate for the steady-state curving analysis.

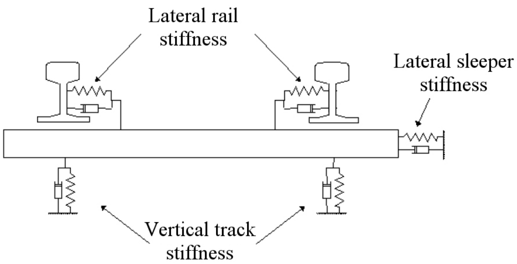


Fig. 8. Track model [10]

The majority of the vehicle and track parameters used in the simulation are selected based either on performed measurements, or the available technical documentation and only several parameters of the track, due to the lack of experimental results, are selected on the basis of the literature review.

For the modelling of the wheel-rail contact, Non-Linear Creep law was used. This creep law uses a pre-calculated contact data table which describes the contact data parameters with respect to wheelset lateral shift across the track at rail level. For that purpose real wheel and rail profile data measured using profilometer were used as input for the computation of the actual creep forces.

The results of steady-state curving analysis have shown fairly good agreement having in mind strong dependence of the simulation results on various input parameters of the simulation model. Although this programme was benchmarked during several internationally recognized benchmarking exercises and the results have shown fairly good agreement, the simulation results should be interpreted with caution.

From the research performed on the traling unit of the electromotor train 412/416 it can be seen that angle of attack of the leading wheelset obtained by simulation was equal to -12,0 mrad while the experimental result was -13,1 mrad. Angle of attack of the second wheelset of the trailing unit obtained using simulation was -0,5 mrad, and the appropriate measured value was 1,0 mrad.

5. CONCLUSION

Based on the obtained results it can be concluded that for curving analysis of the railway vehicles and for control of the wheel-rail wear, it is necessary to know vertical Q and lateral Y forces, as well as angle of attack α. The most reliable method for the determination of these parameters is to perform experimental measurements. However, it also appeared that by using quality dynamic model and reliable simulation software, with as accurate as possible values of the simulation parameters of the railway vehicle and the track, it is possible to predict vehicle's dynamic behaviour in the phase of design and to apply changes in order to obtain favourable dynamic behaviour.

ACKNOWLEDGEMENT

The authors express the gratitude to the Ministry of Education, Science and Technological Development, Republic of Serbia research grant TR 35045, TR 35006 and TR 35007.

REFERENCES

[1] EN 14363 Railway applications - Testing for the acceptance of running characteristics of railway vehicles - Testing of running behavior and stationary tests, June 2005.

[2] Milković, D., Simić, G., Jakovljević, Ž., Tanasković, J., Lučanin, V., Wayside systems for wheel-rail contact forces measurements, Measurement 46, pp. 3308-3318, 2013.

[3] Milković, D., The influence of wheel-rail contact parameters on railway vehicle dynamic behaviour (in Serbian), Doctoral Dissertation, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2012.

[4] Kumar, S., Prasana Rao, D. L., Wheel-Rail Contact Wear, Work, and Lateral Force for Zero Angle of Attack—A Laboratory Study, Journal of Dynamic Systems, Measurement, and Control, Vol. 106, pp. 319-326, 1984.

[5] Grassie, S. L., A contribution to dynamic design of railway track, In: G. Sauvage (Ed.): The Dynamics of Vehicles on Roads and Tracks, Proc. 12th IAVSD Symposium, Lyon, France, August 1991, Supplement to Vehicle System Dynamics Vol. 20, Swets and Zeitlinger Publishers, Lisse, pp. 195-209, 1992.

[6] Kerr, A. D., On the determination of the rail support modulus k, International Journal of Solids and Structures 37 pp. 4335-4351, 2000.

[7] Ripke, B., Knothe, K., Simulation of high frequency vehicle–track interactions, Journal of Vehicle System Dynamics, Supplement 24, pp. 72–85, 1995.

[8] Sun, Y. Q., Dhanasekar, M. A., A dynamic model for the vertical interaction of the rail track and wagon system, International Journal of Solids and Structures 39 (2002) 1337-1359.

[9] Zhai, W., Sun, X., A Detailed Model for Investigating Vertical Interaction between Railway Vehicle and Track, Vehicle System Dynamics 23 (1994) 603- 615.

[10] VAMPIRE® Pro Version 5.50 Programme, DeltaRail Group Ltd., Derby 2011..

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

DETERMINATION OF FRICTION HEAT GENERATION IN CONTACT OF WHEEL-RAIL SET USING FEM

Aleksandar MILTENOVIĆ [1]
Milan BANIĆ [2]
Dušan STAMENKOVIĆ [3]
Miloš MILOŠEVIĆ [4]
Miša TOMIĆ [5]

Abstract – *The modeling of the friction heat generation has become increasingly important in product design process including areas such as electronics, automotive, aerospace, railway (e. g. wheel and rail rolling contact, braking systems, and so on), medical industries, etc. Determintation of generated friction heat in the contact of wheel and rail is important for understanding the damage mechanisms on this two bodies such as wear. This paper presents a method to determine the friction generated heat in contact of wheel and rail during normal operaton using transiental structural-thermal analisys in Ansys software.*

Keywords– wheel-rail system, contact temperature, friction heat, FEM.

1. INTRODUCTION

Today, computer simulation has allowed engineers and researchers to optimize product design process efficiency and explore new designs, while at the same time reduce costly experimental trials. Generatied friction heat is some physical process like contact of rail and wheel during operation is important factor for damage forms and other processes.

There is a great number of studies and research papers that deal with this problem of rail and wheel contact.

Knote [1], in his study, analysed contact temperatures and temperature fields of components in relative sliding motion by Laplace transforms and the method of Green's functions. He investigate the case of loadings with fluctuations due to surface roughness and indents.

Ertz [2] has concuded that the contact of wheel and rail can be investigated very efficiently with Hertzian contact with polynomial approximation. He also presented methods for the calculation of contact temperatures using Blok's flash temperature formula. The bulk temperature of the wheel increases with time by continious friction heat. He presented that the wheel temperature during normal operating condition cannot be more than double the average temperature of the cold wheel.

Sundh [3] analyse wear of wheel and rail focusing on *contact temperature, elemental and morphological analysis of the airborne particles, and surface-layer microstructure of test specimens by using several analytical techniques*.

Tombergera [4] presented in his paper wheel-rail contact model. His model computes *local mechanical and thermal stress distributions and resulting traction–creep curves under consideration of interfacial fluids, surface roughness and contact temperatures*. His model shows that contact temperatures become significant above the saturation point, where the complete contact zone slips with an average slip velocity equal to the creepage between wheel and rail.

Wu [5] analysed wheel rail contact using thermal-elastic-plastic deformation and residual stress after

[1] Aleksandar MILTENOVIĆ, Faculty of Mechanical Engineering, University of Niš, Aleksandra Medvedeva 14, Niš, aleksandar.miltenovic@masfak.ni.ac.rs
[2] Milan BANIĆ, Faculty of Mechanical Engineering, University of Niš, Aleksandra Medvedeva 14, Niš, milan.banic@outlook.com
[3] Dušan STAMENKOVIĆ, Faculty of Mechanical Engineering, University of Niš, Aleksandra Medvedeva 14, Niš, dusans@ masfak.ni.ac.rs
[4] Miloš MILOŠEVIĆ, Faculty of Mechanical Engineering, University of Niš, Aleksandra Medvedeva 14, Niš, mmilos@masfak.ni.ac.rs
[5] Miša TOMIĆ, Faculty of Mechanical Engineering, University of Niš, Aleksandra Medvedeva 14, Niš, misa.tomic@masfak.ni.ac.rs

wheel sliding on a rail. He simulated sliding contact process by translating the normal contact pressure and the tangential traction across the rail surface. His results indicated that the friction thermal load of contact between wheel and rail has a significant influence on the residual deformation, plastic strain and residual stress at the rail surface.

2. GEOMETRY

2.1. Rail profile

Standard EN 13674-1:2011 specified 23 rail profiles. This European Standard specifies Vignole railway rails of 46 kg/m and greater linear mass, for conventional and high speed railway track usage.

Two classes of rail straightness are specified, differing in requirements for straightness, surface flatness and crown profile. Two classes of profile tolerances are specified. Figure 1. represent rail profile 50E2 which is used in further analisys.

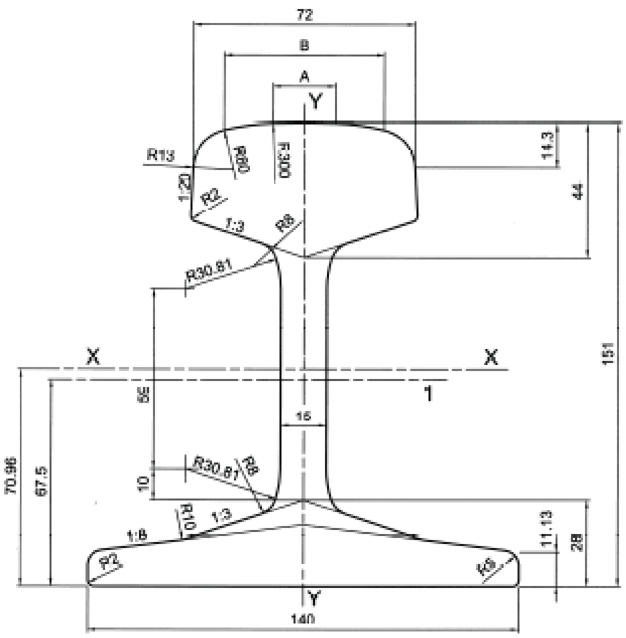


Figure 1. Rail profile 50E2 [6]

2.2. Wheel profile

UIC CODE 510-2 [7] contains the conditions relating to the design and maintenance of wheels and wheelsets for coaches and wagons used on international services. It covers wheel diameters from 330 to 1000 mm, and indicates the permissible axle loads from the standpoint of stresses of the metal used for the wheel and the rail.

UIC CODE 510-2 contains detail coordinates of wheel rim line. It is valid for a nominal track gauge of 1435 mm and cannot be readily transposed to apply to other track gauges. Figure 2. represent wheel profile which is used in further analisys.

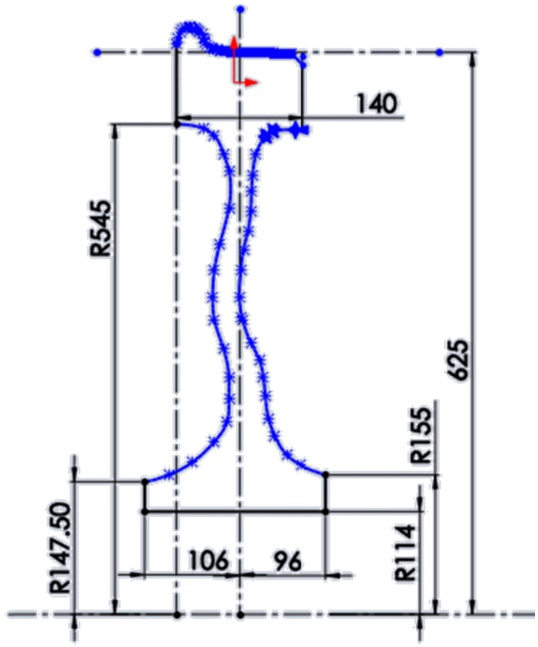


Figure 2. Wheel profile

3. ANALISYS SETUP

Basic model of wheel-rail set was made in Solidworks and than it is exported in Ansys. As higher order element was used due to computational limitations only a fraction of wheel model was considered in analysis. For the FEM analysis was used only upper part of rail long 10 meters and outer ring of wheel.

In analise were used Ansys elements SOLID226 (Figure 3) and SOLID227 that supports the thermoplastic effect, “which manifests itself as an increase in temperature during plastic deformation due to the conversion of some of the plastic work into heat”. Thermoplastic analysis exists in the following Ansys elements:

- SOLID226 - 3-D 20-Node Coupled-Field Solid
- SOLID227 - 3-D 10-Node Coupled-Field Solid

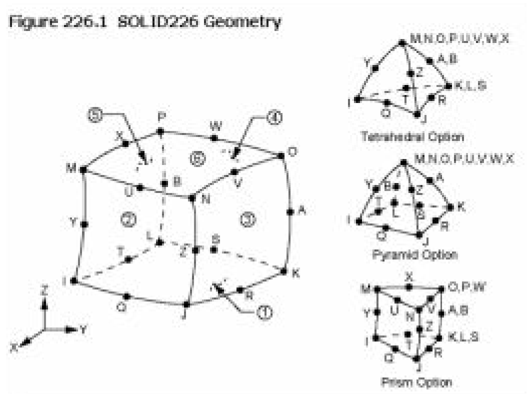


Figure 3. Elements SOLID 226 used in analysis

For mesh of rail body was used SOLID 226. Complicate geometry of wheel body forced use of SOLID 227 instead od 226 (Figure 4). In the Table 1. was given numbers of elements and nodes.

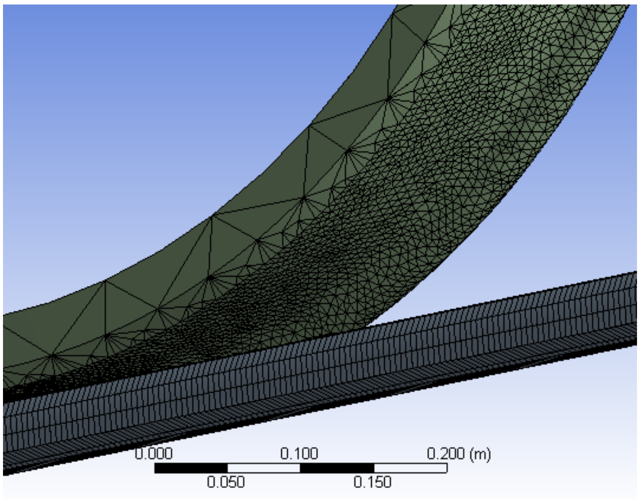


Figure 4. Mesh of wheel and rail

Table 1. Number of elements and nodes

	wheel	rail	Sum
elements	76502	62400	138902
nodes	114735	94820	209555

$$q = FGHT \cdot \tau \cdot v \quad (1)$$

where τ is the equivalent frictional stress, v the sliding rate and *FGTH* the fraction of frictional dissipated energy converted into heat (the default value of 1 was used).

Due to limited resources analises were limited on 0.6 sec which is enough for wheel to make more than one whole rotation. During normal operation there is sliding between wheel and rail. In the same time rail is moving in the same direction 1%, 2% or 3% which represent some of slip ratios used in paper [10]. This moving of rail represents sliding that is expected during normal train operation. Wheel has speed of 30 km/h. But with slip ratio wheel has speed of 29.7 km/h in case when sliding is 1% respectivly 29.4 km/h for 2% sliding and 29.1 km/h for 3% sliding. In the same time pressure load on wheel is 49050 N which represent the weight of the wagon. Friction between wheel and rail is 0.1.

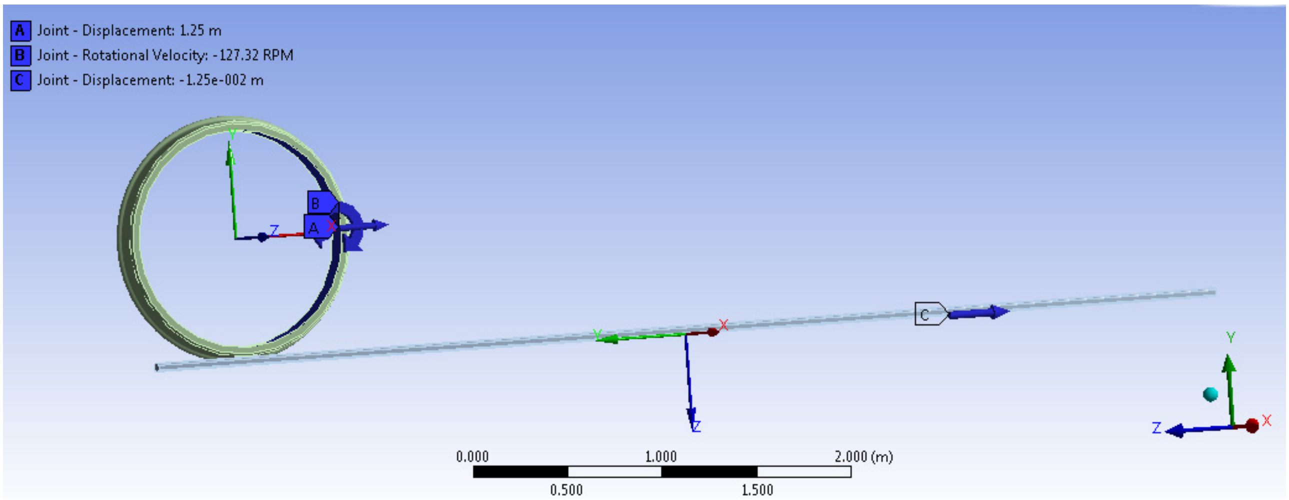


Figure 5. Analisys setup of wheel and rail set for case with sliding 1%

The properties of the materials used in the analysis are listed in Table 2.

Table 2. The mechanical properties used in this study

Density [kg/m^3]	7850
Coefficient of thermal expansion [C^{-1}]	$1.2*10^{-5}$
Young's modulus [Pa]	$2*10^{11}$
Poisson's Ratio	0.3
Tensile Yield Strenght [Pa]	$2.5*10^{8}$
Tensile Ultimate Strenght [Pa]	$4.6*10^{8}$
Isotopic Thermal Conductivity [W/mC]	60.5
Specific Heat [J/kgC]	434

Analysis was defined as direct coupled transient structural-thermal analysis. The rate of frictional dissipation in contact elements in Ansys is evaluated using the frictional heating factor and is given by:

4. RESULTS

In Tables 3. and 4. are given results of generated temperature on wheel and rail. In Table 4. are relative increase of temperature since the normal temperature is 22 ^{o}C. Temperatures on wheel are greater than temperatures on rail. Compared with temperatures on rail, temperatures on wheel are for circa 66 – 68 % higher.

Comparation of generated temperature show that the increase of sliding leads to increase of generated temperature on wheel and rail. Temperature on wheel is circa 3 times for 3% sliding, respectivly circa 2 times for 2% sliding higher compared with generated temperature in case when sliding is 1%.

Figure 6. shows relative temperature increase in function of sliding.

Table 3. Temperature on wheel and rail [°C]

sliding	wheel	rail
1%	28.4	26.3
2%	35.1	30.7
3%	41.5	35.2

Table 4. Relative temperature on wheel and rail [K]

sliding	wheel	rail
1%	6.4	4.3
2%	13.1	8.7
3%	19.6	13.2

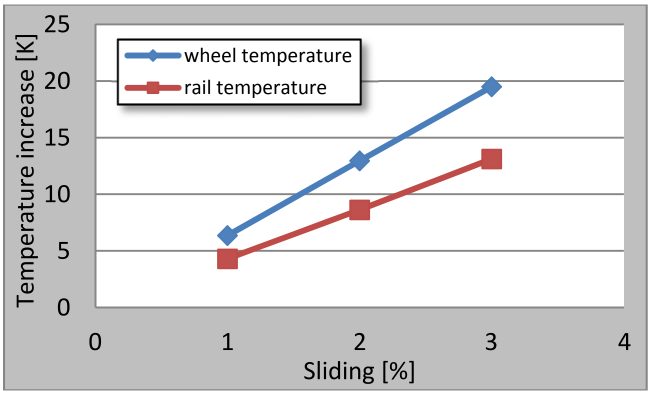


Figure 6. Relative temperature increase

In Table 5. are given Maximal equivalent stress on wheel and rail in Pa. Maximal equivalent stress on wheel is 2.8% and on rail is 4.2% higher when sliding is 1%, respectivly for 3% sliding on wheel 3.5% and on rail 5.8% compared with Maximal equivalent stress in case when sliding is 2%. Maximal equivalent stress on wheel are greater than maximal equivalent stress on rail. When sliding is 1% Maximal equivalent stress on wheel are 3.9% resprectivly 5.3% for sliding 2%, and for sliding 3% Maximal equivalent stress are 3.7% higher comparing with Maximal equivalent stress on wheel.

Table 5. Maximal equivalent stress [10^8 Pa]

sliding	wheel	rail
1%	4.04	3.89
2%	3.93	3.73
3%	4.07	3.95

In Table 6. are given Contact pressure on wheel and rail in Pa. Contact pressure is higher for 3 % when sliding is 3% and 1.7% when sliding is 2% compared with contact pressure in case when sliding is 1%.

Table 6. Contact pressure [10^8 Pa]

sliding	wheel - rail
1%	6.47
2%	6.58
3%	6.65

5. CONCLUSION

The paper present approach to determine the friction generated heat in wheel rail contact by using of FEM.

Analysis shows that temperatures on wheel are greater than temperatures on rail in all cases of slip ratio. Increase of sliding leads to increase of generated temperature on wheel and rail.

Maximal equivalent stress on wheel is slightly higher when sliding is 1% and 3% compared with Maximal equivalent stress in case when sliding is 2%. Maximal equivalent stress on wheel is greater than maximal equivalent stress on rail.

Contact pressure is slightly highest when sliding is 3%, and the lowest contact pressure is in case when sliding is 1%.

Further research should compare temperatures of simulation with real temperatures. Also, it would be very interesting to calculate generated heat in case of acceleration and braking of train.

REFERENCES

[1] Knothe, K., Liebelt, S.: Determination of temperatures for sliding contact with applications for wheel-rail systems, Wear, Volume 189, Issues 1–2, October 1995, pp 91–99

[2] Ertz, M., Knothe, K.: A comparison of analytical and numerical methods for the calculation of temperatures in wheel/rail contact, Wear 253 (2002) pp 498–508

[3] Sundh, J., Olofsson, U.: Relating contact temperature and wear transitions in a wheel–rail contact, Wear, online (2010): www.elsevier.com/locate/wear

[4] Tombergera, C., Dietmaierb, P., Sextroc, W., Sixd, K.: Friction in wheel–rail contact: A model comprising interfacial fluids, surface roughness and temperature, Wear, online (2010): www.elsevier.com/locate/wear

[5] Wu, L., Wen, Z., Li, W., Jin, X.: Thermo-elastic–plastic finite element analysis of wheel/rail sliding contact, Wear, online (2010) www.elsevier.com/locate/wear

[6] EN 13674-1:2011: Railway applications - Track - Rail - Part 1: Vignole railway rails 46 kg/m and above, approved 10. December 2010.

[7] UIC CODE 510-2: Trailing stock: wheels and wheelsets. Conditions concerning the use of wheels of various diameters, May 2004

[8] Milošević, M., Stamenković, D., Milojević A., Tomić, M.: Modeling Thermal Effects In Braking Systems Of Railway Vehicles, Thermal Science, Year 2012, Vol. 16, Suppl. 2, pp. 515-S526

[9] Miltenović, V., Banić, M., Miltenović, A.: Prediction of Heat Generation in Meshing of Crossed Helical Gears, International Conference Gears. VDI-Society for Product and Process Design. October 7th to 9th, 2013, Munich, Germany pp.586-597

[10] O. Arias-Cuevas, Z. Li, R. Lewis, E.A. Gallardo-Hernandez, Rolling–sliding laboratory tests of friction modifiers in leaf contaminated wheel–rail contacts, in: 2008 International Joint Tribology Conference, October 20–22, Miami, Florida, USA, 2008.

ANALYSIS OF THE RESULTS OF THEORETICAL AND EXPERIMENTAL STUDIES OF FREIGHT WAGON FALS

Svetoslav SLAVCHEV [1]
Kalina GEORGIEVA [2]
Valeri STOILOV [3]
Sanel PURGIĆ [4]

***Abstract** – Comparative analysis based on the results from strength-deformation analysis of wagon body, series Fals, and on the results from the real wagon test was made. Calculations were carried out in the Department of Railway Engineering at Technical University of Sofia and are based on the finite elements method. Two computational models of wagon design were developed. One of them consists of shell elements (triangular), and the second one of solid elements (tetrahedral). Experimental studies on real wagon were conducted at the National Transport Research Institute. It was found that the results obtained for the stresses are similar, which proves that the models are appropriate and they can help to solve a wide range of issues, for example those related to lightweight design of railway vehicles.*

Keywords – Railway wagon, strength analysis, FEM, tests.

1. INTRODUCTION

The paper is a comparative analysis [1,2] of the static strength analysis of the supporting steel structure of Wagon series Fals and actual tests carried out.

This comparison is to determine which of the theoretical models that emerged in recent years in the calculation of railroad structures, describes more accurately the actual test article. The first model was built with the type of finite elements "Solid" and the second with "Shell" finite elements. Stress-strain analysis was performed by the method of finite elements [3,4,5,6] in the Department of Railway Engineering of Technical University of Sofia. Theoretical and experimental studies have been done in full compliance with international requirements described in the European standard DIN EN 12663[7], TSI (Rolling stock)[8] and code 577 of the International Union of Railways (UIC)[9]. According to these regulations, 13 static load cases and 8 fatigue load cases were carried out on the wagon.

Due to the limited volume, the report presents the results of only two of the obligatory load cases: Compressive force at buffer height 2000 kN (provisionally marked LC-1) and Tensile force in coupler area 1500 kN (provisionally marked LC-2) [7,8,9,10]. In the present research, the comparison of the two models was done in a limited number of zones. In the real prototype, the same areas where the strain gauges were located were then tested with our two theoretical models and relatively high stress values were measured.

2. ANALYSIS OF THE RESULTS

For the purpose of this study, two complicated calculation models for strength analysis were developed.

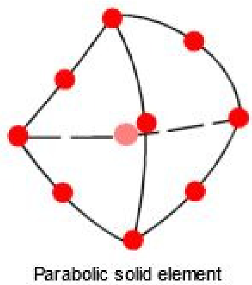


Fig.1.

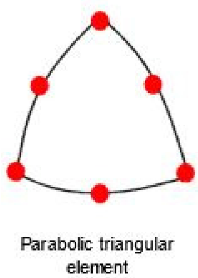


Fig.2.

The first model (fig. 3) was built up from a type of finite element 3D solids (fig. 1) and consists of 697 047 nodes and 349 371 elements. The maximum size of the finite elements is 42,6 mm. All theoretically required ratios between the parameters of

[1] Svetoslav SLAVCHEV, TU-Sofia, Kliment Ohridski Blvd. 8, Sofia, Bulgaria, slavchev_s_s@tu-sofia.bg
[2] Kalina GEORGIEVA, s_nasic@abv.bg
[3] Valeri STOILOV, TU-Sofia, Kliment Ohridski Blvd. 8, Sofia, Bulgaria, vms123@tu-sofia.bg
[4] Sanel PURGIĆ, TU-Sofia, Kliment Ohridski Blvd. 8, Sofia, Bulgaria, s_purgic@tu-sofia.bg

finite elements that allow modeling of the structure of the body with 3D solids were observed.

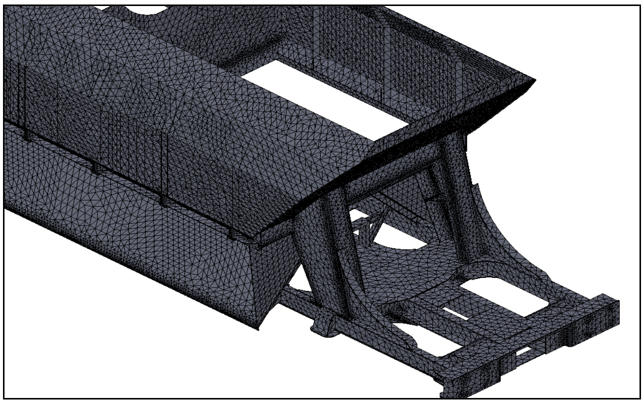


Fig.3. FEA model with solid elements

In the second model the generated mesh parameters were: maximum size – 31,8mm; minimum size – 10,6mm; Rate of increase -1,5; number of finite elements - 401 874; number of nodes - 801 408. Fig. 4 shows the finite element mesh (shell FIG. 2) in the computing model.

The models were optimized by studying the convergence of the solution [11,12,13,14].

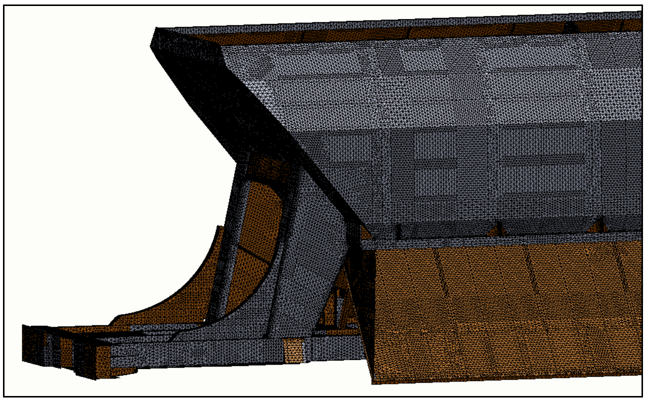


Fig.4. FEA model with shell elements

The third major component of this research is the real test of the structure [15]. Fig. 5 shows the plan and the locations of the strain gauges through which the values of stress were measured in experimental wagon used in this report for comparative analysis.

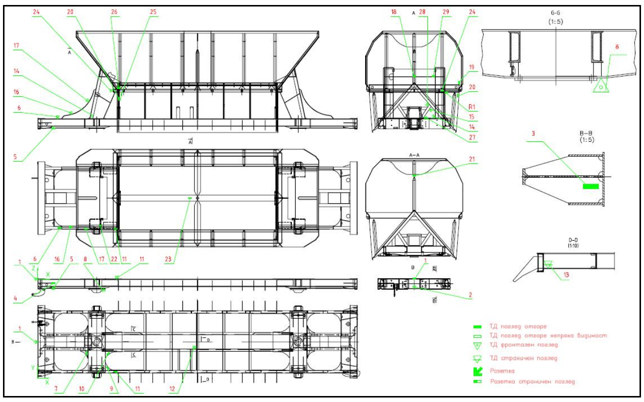


Fig.5. Measuring points

The horizontal loads were applied by means of hydraulic cylinders in the buffer and draw gear.

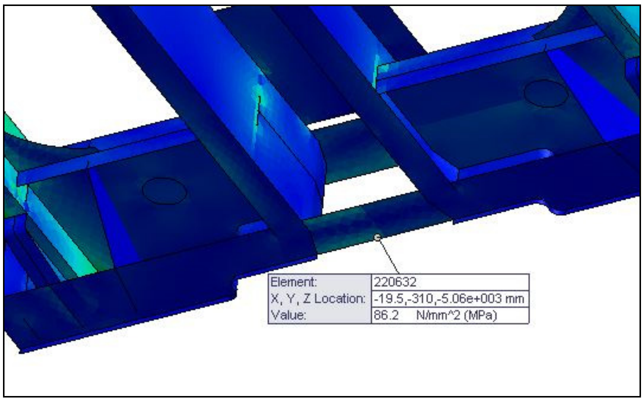


Fig.6. Stress value in shell model

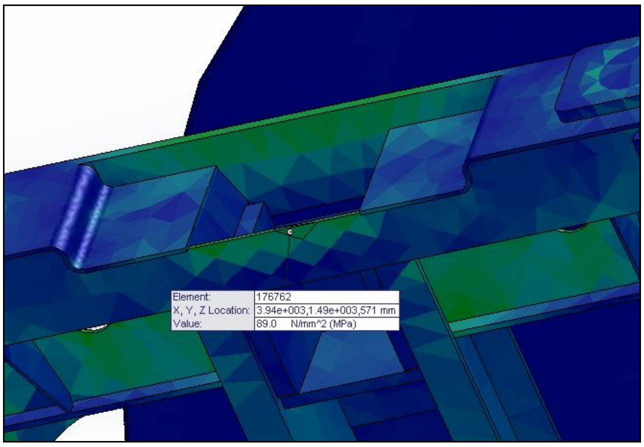


Fig.7. Stress value in solid model

Fig.8. Strain gauge No2

To achieve more precise comparative analysis, so-called "clear load cases" were selected, i.e. those in which the forces are applied only in one of the coordinate axes. This allows us to avoid some subjective factors arising from the improper positioning of the force producing elements.

In the analysis of the two theoretical models the forces and restrictions [16,17,18] on transfer were not compared in the boundary areas, as the stress values obtained might be unrealistically high due to modeling. These stress values do not have to be taken into account in the analysis of the results [13].

It is advisable that the comparison of the results from the two computing models is to be performed by elements not by nodes. The elements cover the area where the strain gauges are located and stress value contains the information of the value of its constituent nodes. This in turn leads to a slight problem with the shell model when deploying strain gauges on the thin side of the profile. The analysis shows that it is practically impossible to make a comparison because of the way the shell model was built - with shell elements defined by the mid surface of the profile. Analysis of other problems related to modeling and FEM analysis with shell elements the authors have published in [19].

Tab.1. Stress values

No	LC- 1			LC- 2		
	FEM Shell	FEM Solid	Test	FEM Shell	FEM Solid	Test
1	118,6	105,7	91,4	129,8	132,1	105,3
2	86,2	89,0	80,0	98,3	160,8	149,7
4	48.6	148,4	67,9	52,5	12,4	103,5
6	127,1	139,8	283,1	70.5	51.9	67,9
8	52.1	72.6	67,5	101,9	93.8	55,9
9	64.7	53,6	77,8	133	108,7	107,5
11	138,7	249,2	205,2	107,3	126,5	151,3
12	50.2	58.3	55,1	107.1	89.5	107,3
16	***32.3***	***29.8***	***69,1***	***8.3***	***4.7***	***25,9***
19	29.9	16.5	17,1	15.1	13.8	13,5

The analysis of the results obtained shows relatively high correlation of the stress values obtained in the two models. In most cases, the stress values in the shells model are lower than those constructed with 3D solid. Table 1 represents the data of the stress values from FEM analysis calculated in those areas with the highest stress values, obtained from the test of the wagon in both horizontal load cases.

Fig. 6 and 7 show the stress values measured in the zone of gauge No. 2 for the shell and 3D solid models respectively. Fig. 8 shows the arrangement of strain gauges on the wagon structure.

All three types of results (theoretical of the two types of finite elements and physical measurements) show significant similarities. The analysis for all load cases shows a significant difference between the FEM values (Fig. 9 and 10) and the values obtained by strain gauge No. 16 (Fig. 11).

Possible reasons for the differences, according to the authors, are defects in the welding located underneath the strain gauges, structural changes in the material because of bending and welding during the manufacturing of the wagon and possible inaccurate reporting caused by strain gauges installed in the bent part of the piece.

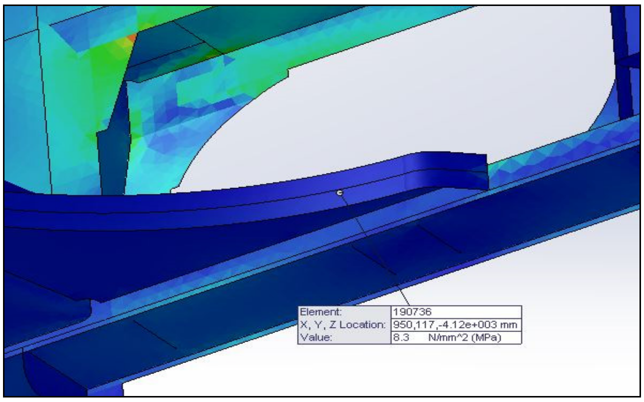


Fig.9. Stress value in shell model

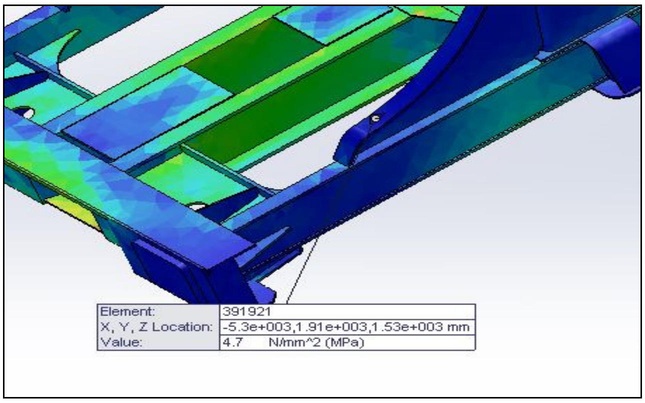


Fig.10. Stress value in solid model

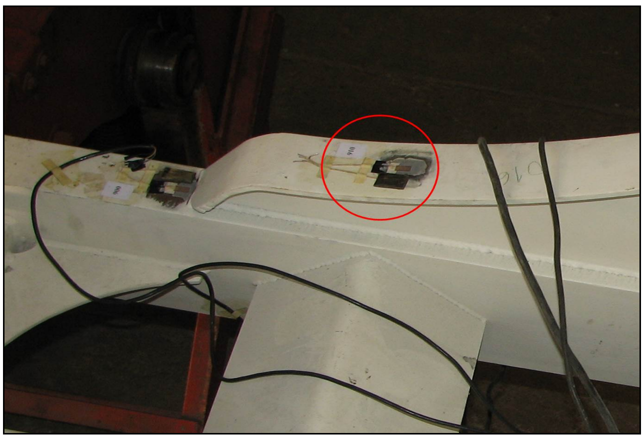


Fig.11. Strain gauge No.16

However, the results of FEM analysis correctly reflect the general nature and distribution of stresses in the wagon structure.

3. CONCLUSION

3.1. Computational models for strength analysis of the construction of a specialized wagon series Fals were developed. Strength calculations were computed and the results were analyzed. A comparative analysis of the results obtained by calculations and those obtained in actual tests of the wagon. The stress values were compared for a limited number of zones.

3.2. A high correlation between the results from the theoretical models and the actual tests were found. In both theoretical models identical distribution stress values in the wagon structures were observed. This allows the developed computational models to find application in the design of new constructions of the wagons of the same series as well as more effectively to optimize the parameters of the supporting construction of this type of wagon.

3.3. Certain shell model problems were identified in the strength analysis due to modeling, correct mesh generation, stress values etc. Detailed information about these and other issues can be found in [18].

3.4. Based on the analysis and conclusions, a simple answer cannot be given as to which model – Shell or 3D solid – should be used for FEM analysis of the wagon. It is a matter of experience and personal preference as to what finite elements – shell or 3D solid – should be used to build a computational model. The authors recommend the use of 3D solid finite elements, which show greater similarity with test data for large values of stresses. They have a number of advantages: a more precise and easy construction of the geometry; a clear visualization of the elements of the structure; fewer restrictions in modeling.

Construction of the hybrid model (if possible), composed of 2D and 3D finite elements for strength-deformation analysis of the wagon structure is appropriate and will reduce the modeling errors.

REFERENCES

[1] Slavchev S., V. Stoilov. *Comparative analysis of the results of the static strength calculations and strength tests of a wagon series Lagrs*. Sozopol, TRANS&MOTAUTO'08, 2008.

[2] Slavchev S., V. Stoilov. *Comparative analysis of the results of the static strength calculations and strength tests of a wagon series Zans*. Sozopol, BULTRANS-2012

[3] Stoilov V., A. Mayster. *Strength analysis of the body of wagon series Falns*, S., MOTAUTO'03, 2003.

[4] Stoilov V., A. Mayster. *Strength calculation of the body of freight wagon series Falns by Finite Element Method*. Plovdiv, MOTAUTO'04, 2004.

[5] Slavchev S., V. Stoilov. *Strength analysis of the body of wagon series Lagrs with finite elements method*. Sozopol, TRANS&MOTAUTO'08, 2008.

[6] Slavchev S., V. Stoilov., S. Purgic. *Static strength analysis of the body of a wagon, series Zans*. Sozopol, BULTRANS-2012, 2012.

[7] DIN EN 12663-2:2010, *Railway applications - Structural requirements of railway vehicle bodies - Part 2: Freight wagons*.2010

[8] TSI *Rolling stock- freight wagons*.Brussels, 2007.

[9] UIC leaflet 577 – *Wagon stresses*. 2005.

[10] ERRI B12/ RP17 8th Edition of April 1997

[11] Zenkiewicz O.C. *The Finite Element Method in Engineering Science*. McGraw-Hill, London, 1971.

[12] Segerlind, L. *Applied Finite Element Analysis*. New York, 1976.

[13] Tenchev R., *Operation manual for COSMOS/M*, Sofia, 1998.

[14] Stoychev G. *The Finite Element Method the strength and strain analysis*, Sofia, 2000.

[15] Report on Contract for testing the freight wagon *Fals*. Sofia. NRIT, 2010.

[16] COSMOS/M User's Guide, Revision 1.65, Santa Monica, California, USA, 1991

[17] Software COSMOSWorks – User manual. 2012

[18] Kurowski P., *Engineering Analysis With COSMOSWorks 2005*. Schroff Development Corporation, 2005

[19] Slavchev S., K. Georgieva, V. Stoilov.*Issues of wagon modeling with shell elements*. Niš, RAILCON'14, 2014

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '14

ABOUT THE PROCESS OF BRAKED WEIGHT LOSS IN THE FREIGHT TRAINS

Kiril VELKOV [1]
Oleg KRASTEV [2]
Sanel PURGIĆ [3]

Abstract *– This study is dedicated to the process of braked weight loss in freight trains, a phenomenon observed on freight trains with increased length. Our research is based on results received from test bench for train braking systems stationed in Laboratory of Department of railway engineering. Using these results the braking efforts were calculated for different track gradients and different initial braking velocities. The analysis of the calculated braking forces allows identifying the points at which the braked weight is getting lost.*

Keywords – Railway, braking systems, braked weight, long train.

1. INTRODUCTION

Many studies conducted by UIC have shown that with increasing length of freight trains braked in "P"(passenger) position a phenomenon of braked weight loss occurs. This process results in reduced braked weight percentage λ, increased braking distances s and lack of control over the braking system. In certain cases, this phenomenon can conduct deteriorations of safety operation of the trains.

UIC has conducted a lot of researches on this issue and in their leaflet UIC 544-1[1], chapter 9.2.2, the calculations of variations in braked weight according to the legth of the train are given. In the case of freight trains more than 500 m in length the actual braked weight required for operating purposes is calculated by multiplying braked weight of the train by a correction factor κ, which is a function of the actual length of the train:

$$B_{corrtr} = \kappa . B_Z \tag{1}$$

where:
B_Z - braked weight of the train [t],
B_{corrtr} - corrected braked weight of the train [t],
κ(Kappa) - correction factor in respect of train length.

The correction factor κ as specified in the length of the train is shown in figure 1 und shall be valid only up to the train length indicated in the figure.

The equivalent brake response time and resulting average deceleration of the train at a given brake equipment is dependent by the transmission time of signal along brake pipe and the brake pipe length.

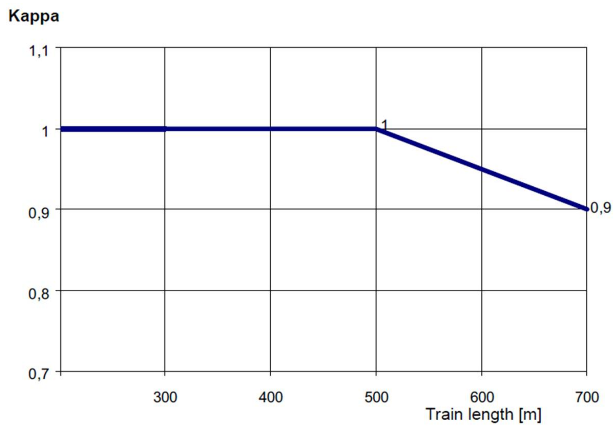


Fig.1. Correction factor κ *(Kappa)*

In order to specify the relationship between the length of the train and braked weight of long freight trains, experiments were conducted in Department of "Railway Engineering" of Technical University Sofia.

2. EMPIRICAL STUDY

2.1. Test bench for train braking systems

Test bench for train pneumatic braking systems [2] is built in the Laboratory of Department of Railway Engineering. At this test bench is possible to simulate processes in pneumatic braking systems for different train compositions. The general structure of test bench is shown in figure 2.

[1] Kiril VELKOV, Technical University Sofia, Kliment Ohridski blvd. 8, Sofia, Bulgaria, khvel@tu-sofia.bg
[2] Oleg KRASTEV, Technical University Sofia, Kliment Ohridski blvd. 8, Sofia, Bulgaria, okrastev@tu-sofia.bg
[3] Sanel PURGIĆ, Technical University Sofia, Kliment Ohridski blvd. 8, Sofia, Bulgaria, s_purgic@tu-sofia.bg

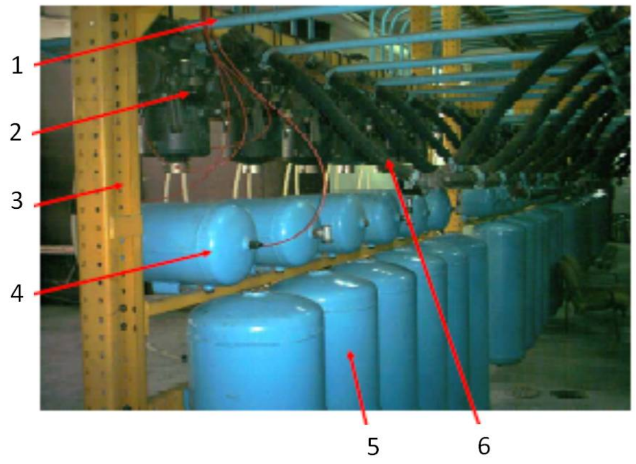


Fig.2. Test bench for train pneumatic braking systems

Test bench is built up of following main components as illustrated on figure 2: 1 is brake pipe, 2 is distributor valve, 3 is supporting structure, 4 is brake cylinder, 5 is auxiliary reservoir and 6 are couplers (brake hoses).

On this test bench is possible to simulate different train lengths by varying the number of wagons from one to 45. All wagons are fitted with distributor valves of type Knorr KE1cSL. Brake cylinders are replaced with reservoirs with air volumes equivalent to real ones. In order to conduct reliable tests, the brake pipe is made of steel pipe with prescribed parameters, while keeping the actual length of 15,5 m (average length of the four-axle freight wagon). All other components of the system used, are same as actually mounted on freight wagons. This is the so-called principle of nature reproduction of brake systems.

Driver's brake valve mounted on test bench is one of the most used driver's brake valves in European railway administrations and it is a type Knorr D2.

Test bench for train pneumatic braking systems meets all conditions according to UIC Code 540 [3].

For capturing experimental data received from test bench, specialized multichannel measurement system was developed [2]. It is built based on pressure transmitters (sensors) installed in different control points of the braking system. The signal produced by the transmitters enters the virtual instrument based on the programming environment *LabView 7.1*.

Virtual instrument [2] for measurement of pressure received from test bench has 8 analog channels, each including a transmitter for pressure measurement. It is based on a standard computer system with functional measurement module *PCI NI6221* and software *LabView 7.1*. The latter has 16 analog voltage inputs, of which eight are used for the eight channels.

Virtual instrument has a scanning frequency of 0,1 seconds, so that is possible to receive big amount of measured values in relatively short time, which also allows a big accuracy of later calculations.

The measured voltage values are being saved in a *Excel* file and then calculated in pressure unit *bar* or other unit suitable for different calculations.

2.2. Experiment methodology

The tests were conducted for both full (emergency) and ordinary (graduated) brake applications for "P"-(passenger) position. First experiment was conducted for only one wagon, and for each next experiment the number of wagons was gradualy increased. So we were able to variate the length of train composition from 1 wagon (15,5 m) up to 45 wagons (697,5 m). The pressure transmitters were placed first along brake pipe in first, eighth, fourteenth, twentysecond, thirtysecond and fourtyfifth wagon and the pressure in this points of brake pipe was measured. Then the transmitters were placed in brake cylinders of same wagons and pressure in brake cylinders was measured.

2.3. Experiment results

Due to limited volume of this paper only results for full brake application are shown and discused in this chapter. The experiment results for graduated brake application are analogue to results for full application.

Obtained values for pressure in brake pipe are shown in figure 3.

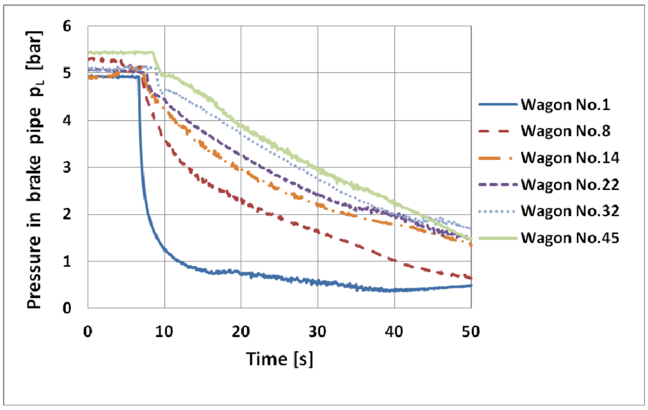


Fig.3. Pressure in brake pipe $p_L=f(t)$

From the figure can clearly be seen, that as expected, the pressure in brake pipe of first wagon drops much faster then in following wagons. Also the signal strength decreases with increasing length of the train. The drop of pressure in last wagon is significantly smoother than the drop in first wagon, i.e. it does not have the same run typical for full brake application. As a consequence, the pressure in brake cylinders rises respectively to pressure drop in brake pipe as shown in figure 4. Both pressure distributions depend directly on transmission speed of braking signal.

This transmission speed is determined when we divide length of brake pipe circuit that runs from driver's brake valve on locomotive upto air shut-off cock at the end of the train, with time that ticks from the moment when driver has put the handle of a driver's brake valve in braking position till the moment when air begins to enter into brake cylinder of the last vehicle circuit [4]. The required transmission speed is 250 m/s [3].

Time elapsed from entering of air in the first cylinder of the first vehicle circuit till entering of air in the last train cylinder is 2,6 s (figure 4) which represents transmission speed of 697,5 m/2,6 s = 268,2 m/s. Achieved transmission speed is more than minimal expected and required in [3] - 250 m/s.

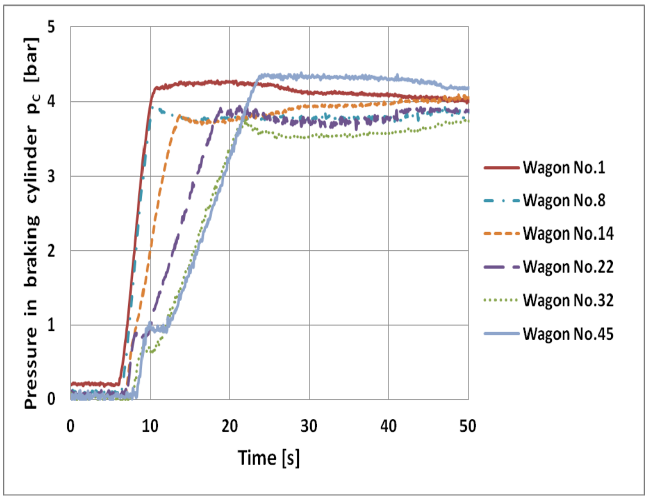


Fig.4. Pressure in braking cylinder $p_C=f(t)$

The moment when driver has put the handle of a driver's brake valve in braking position is also the moment when pressure in braking cylinder of first wagon begins to rise. This happens at time 5,8 seconds. The maximum pressure value in braking cylinder of first wagon is reached at time 10,6 seconds. Pressure in braking cylinder of last (45th) wagon begins to rise at time 8,4 seconds and maximum pressure value is reached at time 24 seconds.

In this way obtained values for pressure in brake cylinders were used to calculate brake weight according to [1]:

$$B = \frac{k.\Sigma F_{dyn}}{g} \tag{2}$$

where:

B – braked weight [t],

k – assessment factor for determining the braked weight [-],

ΣF_{dyn} – sum of all the brake block forces during the run [kN],

g – acceleration due to gravity [9,81 m/s^2].

The assessment factor for determining the braked weight k is given by a mathematical formula [1]:

$$k = a_0 + a_1.F_{dyn} + a_2.F_{dyn}^2 + a_3.F_{dyn}^3 \tag{3}$$

The constants a_0, a_1, a_2 and a_3 depend on type of brake blocks and their values are given in table in chapter 2.2.2.1 of [1].

Sum of all the brake block forces during the run ΣF_{dyn} is calculated as given in [1] using the formula:

$$\Sigma F_{dyn} = (F_t.i_G - i^*.F_R).\eta_{dyn} \tag{4}$$

where:

F_t – effective force at the brake cylinder [kN], calculated using measured values for pressure in brake cylinders and cylinder geometry,

i_G – total multiplication ratio for the brake rigging (in our case 11,2 for loaded wagon),

i^* – multiplication ratio after the central rigging (normally 8 for bogie wagons),

F_R – counteracting force of the brake rigging regulator (generally 2 kN),

η_{dyn} – mean efficiency of the rigging while the wagon is moving. With standard rigging the value is 0,83.

In the calculation, following requirements were met:

- maximum speed ≤ 120 km/h,
- maximum axle load 22,5 t,
- wheels are braked on both sides and have a minimal diameter of 920 to 1000 mm,
- brake blocks are made of P10 cast iron,
- rolling stock is 100 % braked, i.e. all brake blocks are active.

In this way is possible to receive values of brake weight for each wagon, in which the pressure was measured, dependent on time, as shown in figure 5. The distribution of braked weight is similar to distribution of pressure in brake cylinders.

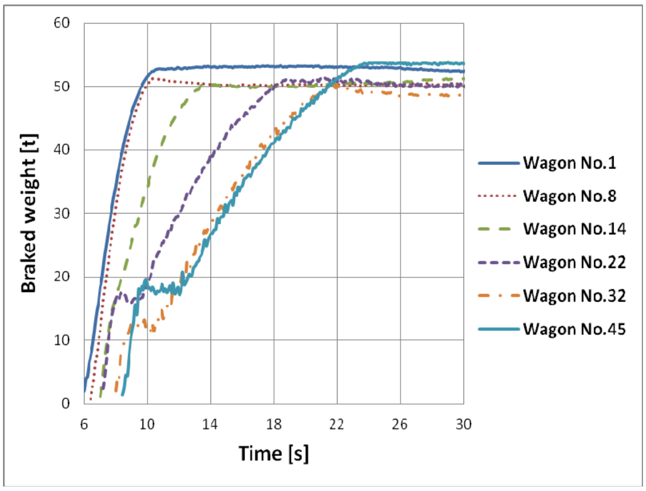


Fig.5. Calculated braked weight

The average value of braked weight is 51 t. By assuming the homogenity of train composition, for 45 wagons total braked weight will be 45 x 51 t = 2295 t.

Otherwise, by grouping the wagons and approximating the calculated values for braked weight of single wagons is possible to obtain the dependence of braked weight from the time for whole train composition built of 45 wagons as shown in figure 6.

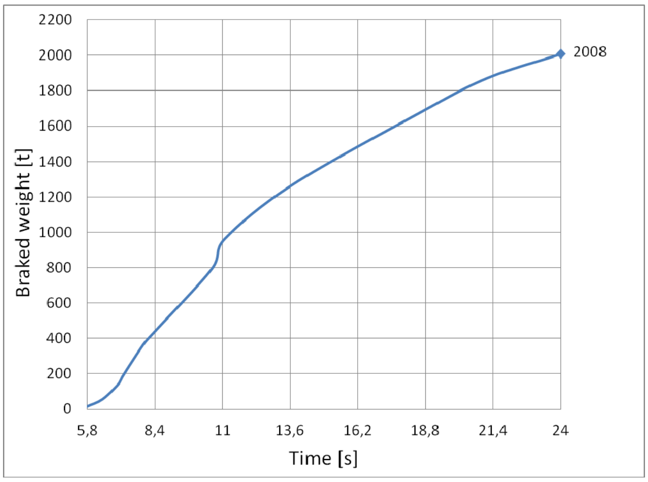


Fig.6. Total braked weight f(t)

As it can be seen from the figure 6, the total braked weight develops in total time of 18,2 seconds and has a value of 2008 t. This value is smaller than value for total braked weight of 2295 t as calculated above and this is the exactly how the braked weight is getting lost. For different moments of the braked weight development, is possible to determine number of wagons with fully developed braked weight and from there to determine the length of train at which this braked weight is fully developed. Finally, this value is divided with nominal average value of braked weight for each wagon (51 t) multiplied with number of wagons (train length respectively). In this way, the correction factor kappa can be calculated as shown in figure 7.

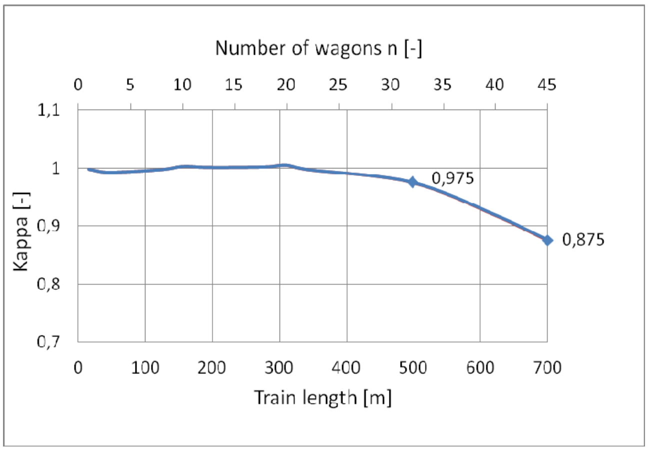


Fig.7. Calculated kappa

The run of the curve of correction factor κ in figure 7 is similar to those in figure 1, as given in [1].

The loss of braked weight according to our calculations begins at point 350 m, earlier than 500 m as shown in figure 1. The value of κ in points 500 m (0,975) and 700 m (0,875) is by 2,5% smaller than given in [1].

3. CONCLUSION

Dissipation of the brake signal leads to deceleration of the braking wave. The conducted bench tests confirmed that with increasing train length the development time of the brake weight delays, and therefore the braking distance also increases. The results obtained for correction factor κ are similar to those given in the UIC Code 544-1, but there are small differences in begin point of decrease and in final values.

REFERENCES

[1] UIC Code 544-1, *Brakes - Braking power*, 4th edition, 2004.

[2] Velkov, K. *Study of the braking processes in long freight trains in order to improve their braking efficiency*. PhD Thesis, Technical University of Sofia, Sofia, 2007 (in Bulgarian).

[3] UIC Code 540, *Brakes- Air Brakes for freight trains and passenger trains*, 4th edition, 2002.

[4] Vukšić, M. *Effect of Response Time on Stopping Distance*. FME Transactions, Vol. 32, No. 1, Belgrade, 2004.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

ISSUES OF WAGON MODELING WITH SHELL ELEMENTS

Svetoslav SLAVCHEV [1]
Kalina GEORGIEVA [2]
Valeri STOILOV [3]

Abstract *– The report contains an analysis of the issues occurred using shell elements in the modeling of wagon series Falns. All load cases specified in the TSI, DIN EN 12663-2 and ERRI B 12/17 were analyzed. Sophisticated three-dimensional calculation models have been developed describing precisely the body geometry. The software products SolidWorks and CosmosWorks were used. This allows the development of the most suitable models with regard to visualization of the object geometry, input of the applied pressures and reactions and obtaining precise enough results concerning the distribution of deformations, displacements and stresses.*

Keywords – Railway wagon, strength analysis, FEM, shell elements.

1. INTRODUCTION

Commissioning of any new wagon design is a complex and lengthy process, spanning a number of stages required. One of them is the strength analysis of the supporting structure. Theoretically, it can be done using any internationally approved methods, but in practice the authorizing bodies are approving the results carried out only by the finite element method. Moreover - most of them have preferences, which software, type of finite element, their minimum and maximum size, their number, etc., has to be used. In case of deviations from the accepted stereotypes, serious justification for chosen solution has to be undertaken and a big amount of theoretical and practical evidence has to be presented.

One of these stereotypes refers to the type of finite element used. Traditionally, in the construction of computational models for strength-deformation analysis, most teams uses elements of type Shell. Taking into account: the current state of software for FEM-analysis [1,2,3] and hardware, load cases of wagon structure; structural features of the vehicles; way of distribution of internal forces and stresses; experience in FEM-analysis of a big number of ordinary and specialized wagons - we consider and prove [4,5,6,7,8,9] that the use of both Shell and Solid 3D elements is equivalent. Crucial for the accuracy of the results for the studied variables are the theoretical training of researchers, good understanding of the structure, analysis of boundary conditions and experience in developing computational models.

In light of the above, this paper provides an analysis of some of the issues in modeling wagons with Shell elements and gives concrete solutions to overcome them.

2. ESSENCE OF MODELING WITH SHELL ELEMENTS

The shell has a body delimited by two surfaces, the distance between which (thickness t) is less than the other two dimensions. Geometrically, the shape of its middle surface and thickness describes it [1,10,11,12]. The modeling was performed by the separation of the shell into small flat elements. It is well known that the accuracy of solution increases with increase in the number of components or the number of nodes. When establishing the models built up of Shell elements with arbitrary spatial configuration, most commonly finite elements with a triangular or quadrangular shape are used.

Wagon structure is built up of many hot-rolled, cold formed and welded profiles and plating - from sheet steel. Consequently, much of the details correspond to the requirements of the shell and can be modeled as such.

3. ISSUES OF MODELING

In the preliminary analysis of the design documentation and during work on an analytical model a number of problems were found, the most important of which are summarized below:

[1] Svetoslav SLAVCHEV, TU-Sofia, Kliment Ohridski Blvd. 8, Sofia, Bulgaria, slavchev_s_s@tu-sofia.bg
[2] Kalina GEORGIEVA, s_nasic@abv.bg
[3] Valeri STOILOV, TU-Sofia, Kliment Ohridski Blvd. 8, Sofia, Bulgaria, vms123@tu-sofia.bg

3.1. Connecting parts with different thickness

In accordance with the theory, the geometric positioning of the shells is in the coordinates of the middle surface. For complete definitions, also parameter thickness is set. The issue is indicated (appears) at butt joint of two or more parts with different thickness and difference in the mid level of the surfaces (Fig. 1) - a common design solution in the manufacturing of wagon structures.

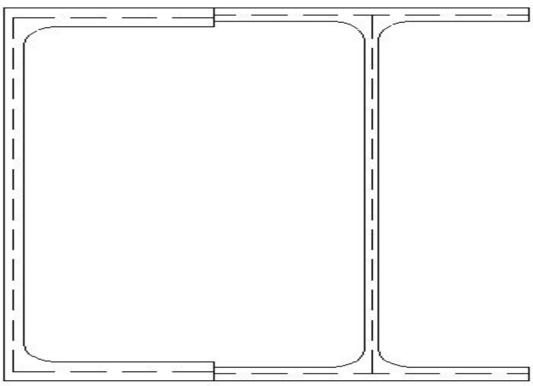


Fig.1. Connection between profiles

Therefore, in the modeling of the shells on their mid surfaces, the two pieces will not have contact with each other, wherein the continuity of the supporting structure getting lost (Fig. 2).

Option to solve this problem is introducing of additional connections (Fig. 2) with elements that do not exist. The main disadvantages of this solution are: imaginary additional elements, i.e. non-existent; they are usually small, making it difficult to build a finite element mesh and a prerequisite for registration of areas with large stress concentrators in the calculation.

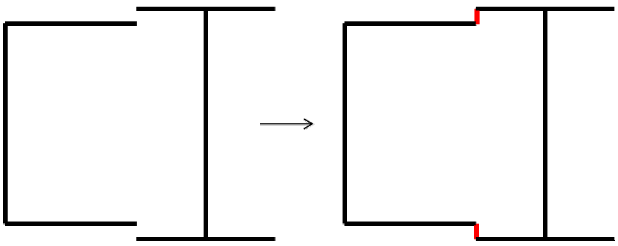


Fig.2. Connection between mid surfaces

This can lead to unrealistic calculated values for displacements and stresses in this zone and in the model as whole.

Based on theoretical and extensive practical experience, the authors recommend two parts to be joined in the middle surface of the more massive and longer component. In the case that none of them meet the two conditions, the priority is given to the length, and i.e. connection is along the mean surface of the longer part.

3.2. Geometric modeling of overlapping profiles or sheet steel

Cases of overlapping sections or steel plates are visualized in fig.3.

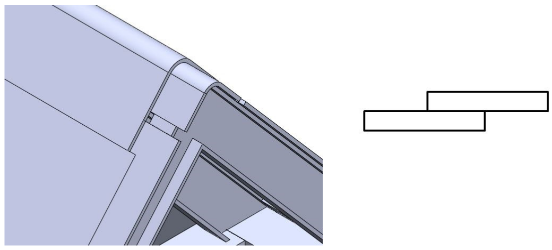


Fig.3. Overlapping profiles

The essence of the issue is analogous to that of 3.1, i.e. the details will not be connected with each other, wherein the continuity of the supporting structure is getting lost.

Introduction of additional connections (Fig. 4) is not only impractical (for the reasons mentioned in 3.1), but it is impossible because you have to use the entire area of overlap.

In this case, it is recommended in modeling to use the mean surface of the more massive and longer component and the thickness of the overlap should be equal to the sum of the thicknesses of the two profiles or sheets (Fig. 5).

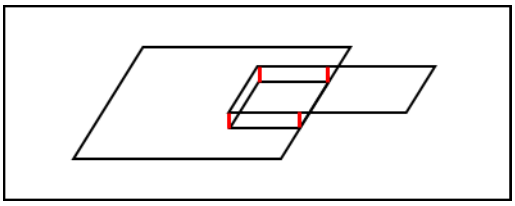


Fig.4. Connection between surfaces

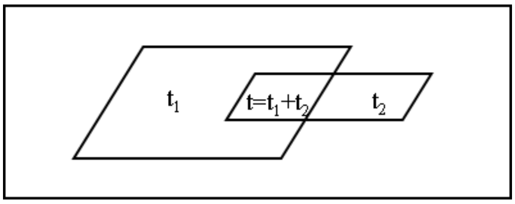


Fig.5. Connection between surfaces

3.3. Modeling of hot-rolled profiles

Hot rolled profiles (Fig. 6) are characterized by variable thicknesses of the layers and the presence of various curvatures. In this respect, the precise modeling with shell finite elements is practically impossible.

This issue can be solved if standard profile is replaced with an equivalent one, built of rectangular zones (Fig. 6), which cross section has the same geometric characteristics (height, width, area, static and moments of inertia, etc..) as the original.

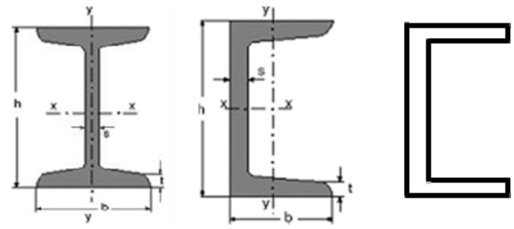


Fig.6. Profile and equivalent profile

3.4. Modeling of parts and details of great thickness

Typical in this respect for each wagon structure are absorbing sets of buffers (Fig. 7), the supports of the draw gear and automatic couplings and other units involved in loading.

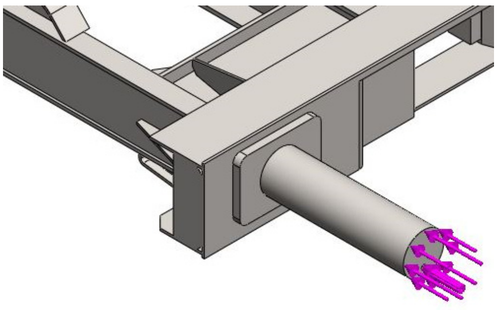


*Fig.7. Model of f*orce *applied* to the buffer

Similar parts do not meet the theoretical formulation for finite element type Shell.

Solutions to this issue are two:

- Construction of a hybrid model composed of 2D and 3D finite elements;

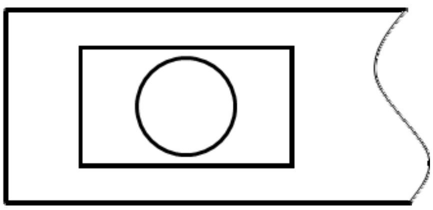


Fig.8. Regions with different thicknesses

- Presentation of the part with its contact patches to the corresponding structural element and load application in so defined area (Fig. 8).

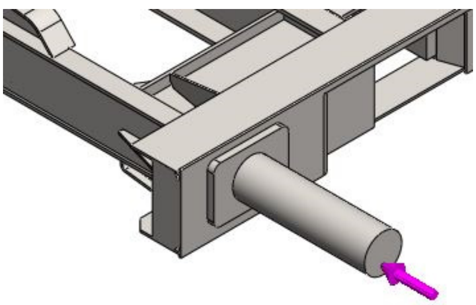


Fig.9. Force applied 50 mm below the buffer axis

The first solution gives results that are more accurate. Additionally it should be noted that it is possible to assess the structure also for obligatory load case, known in the special literature [13,14,15,16] under the name "eccentric compression force of 750 kN applied 50 mm below the buffer axis" (fig. 9) .

The main disadvantage is that some software products do not allow the use of hybrid models or do not give satisfactory results when applied.

The second solution is simpler to use and gives satisfactory results in the calculations. The "eccentric pressure" is modeled by reducing and shifting the area of force application. The disadvantages are: it is necessary to properly define the area of application of force in load case "eccentric pressure" and in the same area local unrealistic stress values are received that should not be considered in the assessment of the wagon structure.

3.5. Defining the thickness of the shell in the areas of overlap of the parts

When creating a spatial calculating wagon model using finite element of type Shell was found that during overlapping of areas of the parts (see Fig. 3), the thicknesses of the shells are not accumulated automatically by the software. Two independent areas are being defined, which causes the continuity loss of the supporting structure. This fact was established when visualizing the mesh. It turned out, that for each of the overlapping parts independently from each other two meshes, built up from different elements, are being formed, superimposed one over another and without connection between them (fig. 10).

The existence of this problem requires that each overlapping area of two parts has to be detached as a separate surface and later to set its thickness corresponding to the sum of the thicknesses of the overlapping parts (fig. 11).

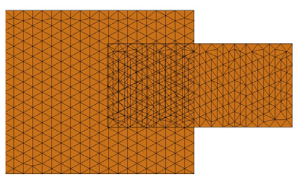


Fig.10. Failure of mesh

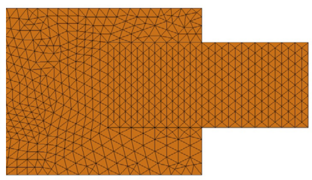


Fig.11.Correct mesh

3.6. Issue in surfaces intersection

At the intersection of two surfaces calculation module does not perceive them as connected and similar to the problem of 3.5., sees them as separate structural parts, and i.e. in the intersection is no connection between the individual elements of the two surfaces (Figure 12).

To solve this problem it is appropriate to define manually line penetration between two parts. In this way, connections between intersecting surfaces are being forcibly made (Fig. 13). This operation should be performed for all such areas, which increases the model built-up time and may result in lot of subjective errors.

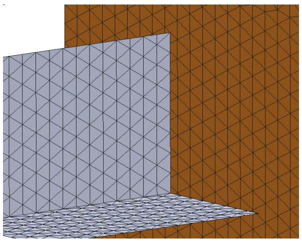


Fig.12. Failure of mesh

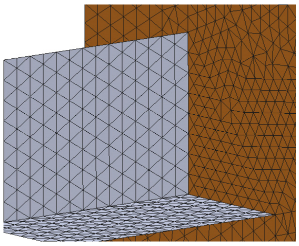


Fig.13. Correct mesh

3.7. Issue of model lines length limitation

This problem is a specific for some software products for strength-deformation analysis including *CosmosWorks*. The reason for this stems from the need to build an optimal mesh of finite elements with approximately same and small as possible size. It was found that in the software the limit is set, that the smallest element dimension model must be equal to or greater than 1/100 of the largest dimension. The modeling of objects with large dimensions (such as wagon structure) this limitation cannot be met. There is need to identify the minimum dimension and based on this to comply all the other dimensions. The identification process is done periodically during modeling and, if necessary, the dimensions of long lines can be adjusted (represented as composition of several shorter lines).

Fig. 14 shows the final version of the calculating model of wagon series Fals.

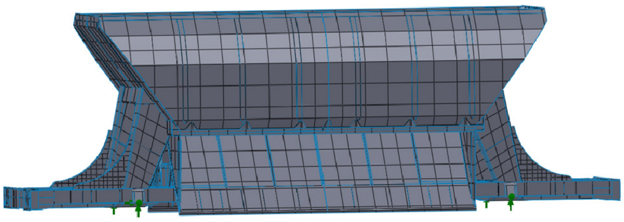


Fig.14. CAD geometry

3.8. Orientation of the shell surfaces

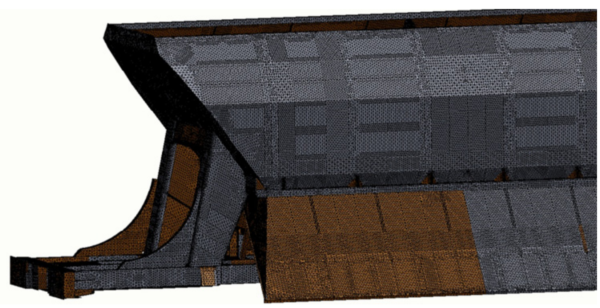


Fig.15. FEM geometry

In spatial structures, built-up by inclined structural parts and by the use of options for symmetry the geometry and automatically form a mesh of finite elements, phenomenon of "variation of the orientation of the surface" is commonly observed. It is well known that the shell is characterized by an upper, lower and middle surface. When changing the orientation, some of the finite elements have properly oriented upper surfaces, and others - wrongly, in the opposite direction.

The phenomenon is illustrated in fig. 15, where improperly oriented elements are colored brown. This disadvantage should be controlled, because it can lead to serious errors, as in applying of load cases as on the results obtained.

The adjustment of the model is carried out manually, which leads to a further loss of time.

4. CONCLUSION

In this paper, eight serious issues in the development of computational models using the finite element type Shell were analyzed. Disregarding those issues leads to serious errors in the strength-deformation analysis of wagon structures and other objects.

REFERENCES

[1] Tenchev R., *Operation manual for COSMOS/M*, Sofia, 1998.

[2] COSMOS/M User's Guide, Revision 1.65, Santa Monica, California, USA, 1991

[3] Kurowski P., *Engineering Analysis With COSMOSWorks 2005*. Schroff Development Corporation, 2005

[4] Stoilov V., A. Mayster. *Strength analysis of the body of wagon series Falns*, S., MOTAUTO'03, 2003.

[5] Stoilov V., A. Mayster. *Strength calculation of the body of freight wagon series Falns by Finite Element Method*. Plovdiv, MOTAUTO'04, 2004.

[6] Stoilov V., Sv. Slavchev. *Strength analysis of the body of special flat wagon series Lagrs*. Sozopol, TRANS&MOTAUTO'08, 2008.

[7] Slavchev S., V. Stoilov. *Strength analysis of the body of wagon series Lagrs with finite elements method*. Sozopol, TRANS&MOTAUTO'08, 2008.

[8] Slavchev S., V. Stoilov, Valcheva Ts. *Application of the methodology for assessment of stress using numerical method*. Sozopol,BULTRANS-2011.

[9] Slavchev S., V. Stoilov., S. Purgic. *Static strength analysis of the body of a wagon, series Zans*. Sozopol, BULTRANS-2012, 2012.

[10] Zenkiewicz O.C. *The Finite Element Method in Engineering Science*. McGraw-Hill, London, 1971.

[11] Segerlind, L. *Applied Finite Element Analysis*. New York, 1976.

[12] Stoychev G. *The Finite Element Method the strength and strain analysis*, Sofia, 2000.

[13] DIN EN 12663-2:2010, *Railway applications - Structural requirements of railway vehicle bodies - Part 2: Freight wagons*.2010

[14] ERRI B12/ RP17 8th Edition of April 1997

[15] TSI *Rolling stock- freight wagons*. Brussels, 2007.

[16] UIC leaflet 577 – *Wagon stresses*. 2005.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

FRICTION CHARACTERISTICS OF THE FRICTION PAIRS IN DISC BRAKES

Vasko NIKOLOV [1]

Abstract: *The results of tests of the friction characteristics of the friction pairs of the disc brake systems in railway rolling stock are presented. A method for performing the tests is described. The change of the friction coefficient in friction pairs is studied. An evaluation of the impact of the material of pads and thermal condition of the discs is performed. The brake pads wear is analyzed.*

Keywords: disc brake system, brake pads, friction, friction pairs.

1. INTRODUCTION

Disc brake systems of coaches refer to high-performance brakes. They have several advantages over the widely used rail brakes and are particularly suitable for high-speed movement of railway vehicles. The article studied the friction characteristics of the friction pairs in disc brake systems and the factors on which they depend.

2. METHODS AND TEST MODES

Friction characteristics of the friction pair in disc brakes are tested on an inertia bench having a moment of inertia of the swing mass 142 Nm/s, which corresponds to the load on the wheel at 60 kN and wheel diameter of 950 mm. On the bench were tested discs and pads used in the operation with area of friction of the discs 0,2 m^2, nominal area of the brake pad 0,0425 m^2, i.e. by a factor of 0,213 to mutually overlap.

Tests of disc brakes have been performed in both of braking to stop and prolonged braking modes. When is performed braking to stop traction motors on the bench is off when reaching a certain speed and by pressing the brake pad to the disc shaft is braked to stop. Braking to stop are performed by speeds of 30, 70, 100, 120, 140, 160 and 180 km/h (in three attempts for each speed).

In continuous braking (steady friction), imitating the operation of the brake on long downhill, traction engine is switched off, but the set speed (60 km/h) and brake power (26 kW) are regulated by the compressive force of the pad on the brake disc and power consumed by the traction motor. In this mode, the time for performing the test is 20 minutes. After mode of steady friction speed has been increased to 140 km/h, then emergency braking has been performed.

In the process of braking to stop and prolonged braking modes measurements of torque, braking distance, surface temperature of the disc and the pads are performed. The temperature of the friction surface of the disc before any braking is 35-40°C.

During the operation on the surface of the friction discs and brake pads, moisture falls which reduces braking efficiency. Therefore, experiments were performed to evaluate the influence of humidity on the coefficient of friction of the pads. On the surface of the friction discs moisture is fed in an amount of about 4-6 ml/s through four nozzles. For the bench test are used brake discs made of cast iron, labeled A, high strength iron labeled B and alloy gray cast iron, labeled C. Coupled with these discs are tested and treated pads. The pads are made of a different material, provisionally designated with the numbers 1 to 9.

3. INVESTIGATION OF THE COEFFICIENT OF FRICTION

The friction coefficient of friction pairs with disc brakes is:

$$\varphi = \frac{M_T}{2KR_T} \tag{1}$$

where:
M_T – braking moment, Nm;
K – compressive force, N;
R_T – radius of load application to the pad.

Tests have shown that when the sliding speed increases, the friction coefficient of the friction materials decreases, as a rule, and the temperature in the contact point increases too (Table 1). It is typical of the friction material in contact with a friction disc of high strength cast iron and an alloy cast iron.

[1] Vasko NIKOLOV, Todor Kableshkov University of transport, Bulgaria, Sofia, 158 Geo Milev str., e-mail: va_r_nikolov@abv.bg

Table 1

Material of the pads	Coeffitient of fricion at pressure of 0,38 MPa and initial speed of braking, km/h					Maximal temperatures in °C on the surface of friction of the disc at initial speed of braking, km/h			Maximal temperatures in °C on the body of the disc at initial speed of braking, km/h			Wear of the pads, mm³/kWh
	30	**70**	**100**	**120**	**160**	**70**	**120**	**160**	**70**	**120**	**160**	
1	0,39	0,34	0,34	0,35	0,33	300	400	450	70	150	270	1500
2	0,32	0,31	0,29	0,28	0,31	340	500	600	50	120	180	3825
3	0,37	0,32	0,29	0,29	0,34	350	600	750	50,	110	210	4275
4	0,32	0,32	0,31	0,29	0,31	300	600	700	60	110	220	3375
5	0,24	0,23	0,35	0,33	0,32	400	480	560	40	120	180	4575
6	0,34	0,38	0,37	0,38	0,35	200	300	520	50	180	280	1125
7	0,55	0,52	0,44	0,37	0,35	250	400	450	80	120	220	1050
8	0,49	0,47	0,46	0,39	0,37	250	350	470	70	110	250	900
9	0,43	0,40	0,40	0,37	0,34	320	450	520	70	120	250	2775

Comparing the friction characteristics of the various friction pairs indicates that pads of material 7 have the greatest frictional heat resistance. This determines the most stable coefficients of friction and does not damage the friction surface of the disc. Therefore, further development of tests of the discs are performed with and pads of material 7 compared with those ones of material 1.

Coefficient of friction pairs brake disc – pads 7 is amended in the process of initial braking speed from 100 km/h from 0,4 to 0,47, speed from 160 km/h from 0,38 to 0,44. In pair with disc B the friction coefficients vary respectively from 0,41 to 0,48 and from 0,35 to 0,42. The coefficients of friction of the disc B with pads 1 during the first braking from 100 and 160 km/h are respectively in the range from 0,34 to 0,4 and from 0,32 to 0,36. By increasing the speed to 180 km/h the friction coefficients reduced to 0,28.

Major impact on the value of the coefficient of friction has the temperature of the friction surface at the beginning of the braking. In experiments on friction pairs disc C – pad 7 depending on the temperature in the contact friction coefficient varies from 0,18 to 0,4 (Table 2).

Table 2

Temperature in the contact point °C		Coefficient of friction
In the beginning of braking	**In the end of braking**	
20	65	0,33-0,36
45	115	0,30-0,40
175	260	0,24-0,34
310	380	0,18-0,19

In continuous braking at a constant speed of 60 km/h and braking power 26 kW temperature within the body of the disc rises exponentially up to 360°C depending on the time of braking. With increasing temperature, the friction coefficient decreased from 0,51 to 0,28. The most rapid reduction in the coefficient of friction of 0,51 to 0,32 was observed in the temperature range 260-320°C. Upon further temperature increase, the friction coefficient decreased to 0,28.

The examination of the frictional characteristics of the materials 1 and 2 in a friction disc made of cast iron A shows that the material 2 has a stable coefficient of friction. The coefficient of friction of the brake pads 2 is changed from 0,28 to 0,34 with an increase of the speed of 120 to 160 km/h and remained practically constant during the entire process of braking. The friction coefficient of material 1 in similar conditions varied from 0,35 to 0,32 and increases during braking respectively 0,43 and 0,35.

Assessing the impact of humidity on the friction coefficient is performed in pairs friction disc A – pads 6 and 2. Pads 6 are solid, and 2 – sectional. Attempts at dry friction were performed at speed 120 km/h and in the presence of moisture in the frictional contact of 90 km/h and a pressure of 0,3, 0,4, 0,6 MPa.

The analysis of the test results shows that, the friction under dry disc with an increase in pressure on the brake pad, friction coefficients reduced and in the presence of moisture at the contact point these ones increased. It should be noted that a substantial reduction of the friction coefficient with presence of moisture at the contact point was observed in the pads of molded material, and in a pair of sectional pads friction coefficients are modified slightly.

4. ASSESSMENT OF THE INFLUENCE OF THE MATERIAL OF THE PADS ON THERMAL CONDITION OF THE DISCS

These experiments were performed with two discs.

Pads are made from materials 1, 2 and 7, characterized by polymeric joints.

The temperatures occurring in the friction surface and the volume of the disc at friction with the pads 7 are of a material several times lower than in the pads 1. The temperature of the friction surface is increased to 600°C during braking with pads 2, as the body temperature did not exceed 200°C. This proves that the braking with pads 2 the temperature gradient is higher than in the pairs of materials 1 and 7. Explanation is that the material 2 with combined joints is harder than materials 1 and 7 with rubber joints and is unable to deform evenly under load. This leads to a reduction of the area of real contact, and the number of spots in the contact area, and hence the increase in the specific pressure and temperature in the contact point. Heat accumulated in the process of friction is transmitted to the disc mainly by the contact areas, thereby increasing the difference in temperature on the surface of the friction disc and in the its volume. On the friction surface of the disc after braking with pads 2 are observed dark spots, where as a rule they develop thermal cracks.

Studies of temperature modes of the brake discs C and B in braking to stop with pads 7 from different initial speeds indicate that the temperatures of the friction surface of disc C are several times lower than those of discs B. The heating in the body of the brake disc B proceeds more slowly than in disc C in the same brake mode (pressure 0,4 MPa, initial speed of 160 km/h), and the final temperature in a depth of 8 and 16 mm is 15% greater than disc C. The difference between the heating temperature of disc B at a depth of 8 and 16 mm is 50°C, and at disc B – 30°C. More rapid and uniform heating of brake disc C shows its better thermal conductivity, which improves the cooling of the friction unit in the braking process, and reduces the temperature gradient and thermal stress. The maximum temperature on the friction surface of both discs, C and B is the same, but the time for action by the friction surface of the disc B is 40% greater than in disks C.

5. BRAKE PADS WEAR

Comparative evaluation of the durability of the brake pads is performed on the size of the wear for ten braking cycles from initial speed of 160 km/h at a pressure of 0,4 MPa. Pad thickness was measured before and after braking at ten fixed points. Wear (in mm^3) is calculated as the average of ten measurements per unit braking power.

Analysis of wear of the pads (Table 1) in friction on disc C shows that the best wear resistance have the pads with rubber joints. Tests to wear a pair of drive C show that the wear resistance of the pads working with these discs is increased 8 – 8,5 times. Wear of pads 7 working with discs B is 1800 mm^3/kWh, and disc C – 220 mm^3/kWh. Wear of pads 1 is 1,5 times faster both in discs B and C. Wear of these pads are 2600 and 1800 mm^3/kWh.

Analysis of those data shows that the wear of brake pads 7 and 1 is 8 times lower in interface with discs C than with B ones. The wear resistance of the material of brake pad 7 is 1,5 times higher than that in pads 1.

6. CONCLUSION

The frictional characteristics of the friction pairs at the disc brakes depend on the temperature at the surface of friction during braking, and since the heat transfer characteristics of the friction materials. The greatest stability of the friction characteristics in both dry friction and friction in humid environments have sectional brake pads. The best friction properties and high wear resistance holds material 7.

Perspective friction pair for disc brakes in Railway rolling stock is brake disc C and brake pad 7.

REFERENCES

[1] Тонев, С., Основи на теорията, изчисленията и експлоатацията на подвижния железопътен състав, ВВТУ „Тодор Каблешков“, С., 1985.

[2] Гнездилов, Г. В., В. Ф. Титаренко, Исследование фрикцонных характеристик пар трения дисковых тормозов, ЦНИИ МПС, М. 1974.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

ENERGY ANALYSIS OF FRACTIONAL ORDER OSCILLATIONS OF A COMPOSITION OF THE TRAIN BY A CHAIN MODEL OF FRACTIONAL ORDER PROPERTIES

Katica R. (Stevanović) HEDRIH [1]

Abstract – *A fractional order model of train composition oscillations is presented. A chain fractional order model as an abstraction of the real railway train composition oscillations in longitudinal direction is taken. By standard light fractional order, elements coupling structures between wagons of train, are presented. Fractional order differential operators express constitutive relation for force-elongation of each standard light fractional order element. New function of fractional order energy dissipation of the standard light fractional order element is introduced. Coupled ordinary fractional order differential equations of a fractional order model of the train composition oscillations, are defined. These fractional order differential equations for both cases, for the case of a train composition moving by constant or changeable velocities are considered. New method for determination of characteristic numbers as well as of eigen main fractional order modes of a chain fractional order system oscillation with finite number of degrees of freedom is presented. Analytical expressions of fractional order vibrations – real oscillatory displacements of wagons and locomotive of train composition model with fractional order properties are determined. Energy analysis of fractional order dynamics of train composition, is presented. On an example of train composition fractional order model with 11 wagons and a locomotive, an important task for next numerical experiment as well as next engineering applications, is defined.*

Keywords – Fractional order oscillations, fractional order energy dissipation, train composition fractional order model.

1. INTRODUCTION

In numerous scientific and professional literatures, simple and complex light rheological elements with elastic, visco-elatic, elasto-viscosic and plastic properties are known [1-4]. All these light simple elements with only one property are component elements in a complex, hybrid element with complex material properties. A hybrid element is built by parallel, or series or by different hybrid combinations of these simple, mass neglected elements [1-11]. Then, it is known, the numerous rheological elements named by some scientists [1]. A new property of material, no neglecting mass and mass inertia properties are introduced by new schematic presented element in Figure 1.a by a rolling element taking into account translator and rotator inertia properties [8,11]. In parallel coupling of four simple elements, presented in Figure 1: (a) rolling inertia element, (b) linear elastic element, (c) linear dissipative (damping) element and (d) fractional order dissipative element and (e) new hybrid fractional order element is obtained.

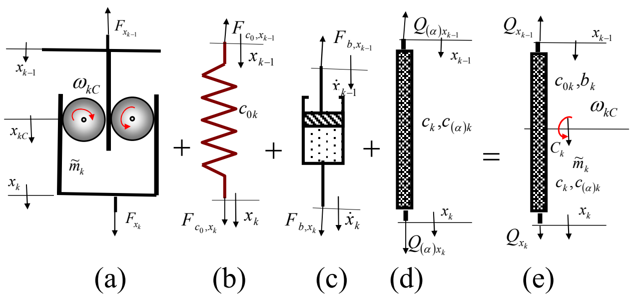


Figure 1. (e) *Hybrid fractional order viscoelastic element with translator and rotation inertia properties consisting of parallel coupled standard:* (a) *rolling inertia element*, (b) *linear elastic element*, (c) *linear dissipative element (damper) and* (d*) fractional order dissipative element*

In the basic of these elements, there are fictive models of the rods with corresponding material

[1] Katica R. (Stevanović) HEDRIH, Mathematical Institute SANU Belgrade, Department for Mechanics and Faculty of Mechanical Engineering, University of Niš, Serbia, Priv. address: 18000-Niš, ul Vojvode Tankosića 3/22, Serbia, e-mail: khedrih@eunet.rs, katicahedrih@gmail.com, khedrih@sbb.rs

properties and axially stressed by pair of the opposite direction forces, with equal intensity for light, and different if mass inertia properties is taken into account. In addition, relations between intensity of the external active loading forces and deformation (extension or compressing) of the rods, we called constitutive stress strain relations.

Kinetic energy for a rolling element, presented in Figure 1.(a), with mass $\tilde{m}_k$ with rotator and translator inertia properties is [11]:

$$\mathbf{E}_{K,k}^{rolling-element} = \frac{1}{8}\tilde{m}_k \left\langle \left(\dot{x}_k + \dot{x}_{k-1}\right)^2 + \frac{i_{C_k}^2}{R^2}\left(\dot{x}_k - \dot{x}_{k-1}\right)^2 \right\rangle \qquad (1)$$

where $\mathbf{J}_{\mathbf{C}_k}$, $i_{C_k}^2 = \frac{\mathbf{J}_{\mathbf{C}_k}}{\tilde{m}_k}$ and $\kappa_k = \frac{i_{C_k}^2}{R^2}$, respectively are axial mass inertia moment of the rolling elements, square of radius of a axial mass inertia moment and radius of disk or sphere. Coefficient for disk and sphere is not dependent of radius and is no changeable when radius increase or decrease.

Standard light fractional order element (See Figure 1. (d)) of negligible mass is in the form of axially stressed rod without bending, for which the constitutive stress-strain relation for the restitution force as the function of element elongation is given by expression containing a term in the form of fractional order derivative. This constitutive relation is in the form (see References [2-11]):

$$P_k(t) = -\left\{c_{0k}\left(x_k - x_{k-1}\right) + c_{(\alpha)k}\mathsf{D}_t^{\alpha}\left[x_k - x_{k-1}\right]\right\} \qquad (2)$$

where $\mathsf{D}_t^{\alpha}[\bullet]$ is fractional order operator of the α^{th} derivative with respect to time in the following form (see References [2-12]):

$$\mathsf{D}_t^{\alpha}[x(t)] = \frac{d^{\alpha}x(t)}{dt^{\alpha}} = x^{(\alpha)}(t) = \frac{1}{\Gamma(1-\alpha)}\frac{d}{dt}\int_0^t \frac{x(\tau)}{(t-\tau)^{\alpha}}d\tau \qquad (3)$$

where $c_{0k}, c_{(\alpha)k}$ are rigidity coefficients – momentary and prolonged one, is a rational number between 0 and 1, $0 < \alpha < 1$, determined experimentally.

In this paper we present a new element fractional order visco-elastic with translator and rotational inertia properties for describing a model of coupling hybrid elements between wagons (coaches) in a railway train composition, presented in Figure 2, fractional order chain with $n+1$ degrees of mobility and n degrees of fractional order oscillations).

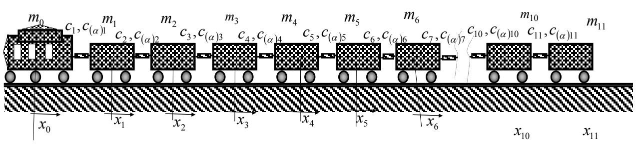


Figure 2. Abstraction of a railway composition of train with eleventh wagons and locomotive: A fractional order system in the form of fractional order chain with twelve degrees of freedom motion and eleventh degrees of freedom oscillations

Model of this hybrid element consists by a elastic spring, a damper, a fractional order dissipation element and a rolling element coupled in parallel order, and presented in Figure 1.(a-d).

Generalized forces of interactions between this hybrid fractional order element and two wagons, see Figure 2, are:

$$Q_{x_k}^{hybrid\ elem} = -\left\langle \frac{d}{dt}\frac{\partial \mathbf{E}_{K,k}^{hybrid\ elem}}{\partial\left(\dot{x}_k(t)\right)} - \frac{\partial \mathbf{E}_{K,k}^{hybrid\ elem}}{\partial x_k(t)} \right\rangle - \qquad (4)$$
$$-\frac{\partial \mathbf{E}_{p,k}^{hybrid\ elem}}{\partial x_k(t)} - \frac{\partial \Phi_{linear,k}^{hybrid\ elem}}{\partial \dot{x}_k(t)} - \frac{\partial \Phi_{0\le\alpha\le1,k}^{hybrid\ elem}}{\partial\left(\mathsf{D}_t^{\alpha}\left[x_k(t)\right]\right)} = Q_{x_k(t)}^{hybrid\ elem}$$

$$Q_{x_{k-1}}^{hybrid\ elem} = -\left\langle \frac{d}{dt}\frac{\partial \mathbf{E}_{K,k}^{hybrid\ elem}}{\partial\left(\dot{x}_{k-1}\right)} - \frac{\partial \mathbf{E}_{K,k}^{hybrid\ elem}}{\partial x_{k-1}(t)} \right\rangle - \qquad (5)$$
$$-\frac{\partial \mathbf{E}_{p,k}^{hybrid\ elem}}{\partial x_{k-1}(t)} - \frac{\partial \Phi_{linear,k}^{hybrid\ elem}}{\partial \dot{x}_{k-1}(t)} - \frac{\partial \Phi_{0\le\alpha\le1,k}^{hybrid\ elem}}{\partial\left(\mathsf{D}_t^{\alpha}\left[x_{k-1}(t)\right]\right)} = Q_{x_{k-1}(t)}^{hybrid\ elem}$$

$$k = 1,2,3,,....,n$$

expressed by kinetic energy $\mathbf{E}_{K;k}^{hybrid\ elem}$ of component rolling element, porential energu $\mathbf{E}_{p,k}^{hybrid\ elem}$ of component linear spring element, Railigh function $\Phi_{linear,k}^{hybrid\ elem}$ of linear dissipation of energy in damper and generalized function of component fractional order energy dissipation $\Phi_{0\le\alpha\le1,k}^{hybrid\ elem}$.

Component fractional order energy dissipation is expressed by generalized function $\Phi_{0\le\alpha\le1,k}^{hybrid\ elem}$ is defined in the form [5]:

$$\Phi_{0\le\alpha\le1,k}^{hybrid\ elem} = \frac{1}{2}c_{(\alpha)k}\left\langle \mathsf{D}_t^{\alpha}\left[x_k(t) - x_{k-1}(t)\right]\right\rangle^2 \qquad (6)$$

2. ENERGY EXPRESSIONS OF A RAILWAY TRAIN COMPOSITION AS A DISCRETE FRACTIONAL ORDER CHAIN SYSTEM

Taking into account generalized coordinates in a matrix column $\{x\}$ with $n+1$ elements – a known rheonomic coordinate $x_0 = f(t)$, correspond to the locomotive programmed motion, and n unknown generalized coordinates x_k, $k = 1,2,3,....,n$, correspond to the wagons relative motion in relation to the locomotive stationary motion as reference. This system is determined by corresponding mass inertia coefficients $a_{kj}, k, j = 0,1,2,3,....,n$, $a_{kj} = a_{jk} = 0$, $j \ne k$, $a_{kk} = m_k$, coefficients of linear elastic properties of springs $c_{kj}, k, j = 0,1,2,3,....,n$, and coefficients of fractional order system properties $c_{\alpha,kj}$, $k, j = 0,1,2,3,....,n$, and $0 < \alpha \le 1$, and damping coefficients $b_{kj}, k, j = 0,1,2,3,....,n$. Taking into account that for $\alpha = 1$ generalized function (6) is in the form Rayleigh's functions and that is possible to take $c_{\alpha=1,kj} = b_{kj}$ for next consideration, no loosing generality we omitted these damping coefficients b_{kj}.

Expression for kinetic energy is in the form of two parts:

$$2\mathbf{E}_{K,wago+loc} = \sum_{k=0}^{k=n} m_k \langle \dot{x}_0 \rangle^2 + 2\dot{x}_0 \sum_{k=1}^{k=n} m_k \dot{x}_k + \sum_{k=1}^{k=n} m_k \langle \dot{x}_k \rangle^2 \quad (7)$$

$$\mathbf{E}_K^{rolling-element} = \frac{1}{8}\sum_{k=1}^{k=n} \tilde{m}_k \left\langle (\dot{x}_k + \dot{x}_{k-1})^2 + \frac{i_{C_k}^2}{R^2}(\dot{x}_k - \dot{x}_{k-1})^2 \right\rangle \quad (8)$$

Expression for potential energy is in the form:

$$2\mathbf{E}_{p,linearelements} = c_1 \langle x_0 \rangle^2 - 2c_1 x_0 x_1 + \sum_{k=2}^{k=n} c_k \langle x_k - x_{k-1} \rangle^2 \quad (9)$$

Expression for generalized function of fractional order energy is in the form [5[:

$$2\Phi_{0\le\alpha\le1, all\ elements} = \quad (10)$$
$$= c_{(\alpha)1}\left\langle \mathsf{D}_t^\alpha[x_0]\right\rangle^2 - 2c_{(\alpha)1}\mathsf{D}_t^\alpha[x_0]\mathsf{D}_t^\alpha[x_1] + \sum_{k=2}^{k=n} c_{(\alpha)k}\left\langle \mathsf{D}_t^\alpha[x_k - x_{k-1}]\right\rangle^2$$

3. FRACTIONAL ORDER DIFFERENTIAL EQUATIONS OF A RAILWAY TRAIN COMPOSITION AS A DISCRETE FRACTIONAL ORDER CHAIN SYSTEM

Fractional order differential equations of dynamical equilibrium of the railway train composition as a discrete fractional order chain system, presented in Figure 2. are [12]:

*for locomotive

$$m_0\ddot{x}_0 + c_1x_0 - c_1x_1 + c_{(\alpha)1}\mathsf{D}_t^\alpha[x_0] - c_{(\alpha)1}\mathsf{D}_t^\alpha[x_1] = \sum_{k=1}^{k=n} m_k\ddot{x}_k + F_0(t)$$

* for wagons from first to ($n-1$)-th:

$$m_k(\ddot{x}_k + \ddot{x}_0) + c_k(x_k - x_{k-1}) - c_{k+1}(x_{k+1} - x_k) +$$
$$+ c_{(\alpha)k}\left\langle \mathsf{D}_t^\alpha[x_k] - \mathsf{D}_t^\alpha[x_{k=1}]\right\rangle - c_{(\alpha)k+1}\left\langle \mathsf{D}_t^\alpha[x_{K+1}] - \mathsf{D}_t^\alpha[x_k]\right\rangle = 0$$
$$k = 1,2,3,....,n-1 \quad (11)$$

* last wagon in composition:

$$m_n(\ddot{x}_n + \ddot{x}_0) + c_m(x_n - x_{n-1}) + c_{(\alpha)n}\left\langle \mathsf{D}_t^\alpha[x_n] - \mathsf{D}_t^\alpha[x_{n=1}]\right\rangle = 0$$

After summarizing all fractional order differential equations in the system (11) an result is obtained:

$$\ddot{x}_o\left(\sum_{k=1}^{k=n} m_k + m_0\right) = F_0(t) \quad (12)$$

which present expression for the rheonomic force $F_0(t)$ which correspond to the programed known rheonomic coordinate $x_0(t)$ corresponding displacement of locomotive. Rheonomic generalized force $F_0(t)$ for rheonomic coordinate $x_0(t)$ depending of programed acceleration of the railway train composition and total mass of all wagons including mass of locomotive. For the case that motion of the railway train composition is stationary, when velocity $\dot{x}_0(t) = v_0 = const$, is constant, them all system is moving by inertia without external excitation to the locomotive, but wagons oscillate in relation to the locomotive with corresponding number of fractional order modes, and mechanical energy of the oscillations decrease with time, followed by fractional order mechanical energy dissipations.

For precise analysis of the energy is necessary to take into acount friction forces between Railway traks and wheels of the wagons and Locomotive.

For the stationary motion $\dot{x}_0(t) = v_0 = const$ of the railway train composition, system of the fractional order differential equations, describing relative oscillations of the wagons in relation to locomotive, by n unknown generalized coordinates x_k, $k = 1,2,3,....,n$, correspond to the wagons relative motion in relation to the locomotive stationary motion as reference, is:

$$m_1\ddot{x}_1 - \sum_{k=1}^{k=n} m_k\ddot{x}_k - c_2(x_2 - x_1) - c_{(\alpha)2}\left\langle \mathsf{D}_t^\alpha[x_2] - \mathsf{D}_t^\alpha[x_1]\right\rangle = 0$$

$$m_k(\ddot{x}_k + \ddot{x}_0) + c_k(x_k - x_{k-1}) - c_{k+1}(x_{k+1} - x_k) +$$
$$+ c_{(\alpha)k}\left\langle \mathsf{D}_t^\alpha[x_k] - \mathsf{D}_t^\alpha[x_{k=1}]\right\rangle - c_{(\alpha)k+1}\left\langle \mathsf{D}_t^\alpha[x_{K+1}] - \mathsf{D}_t^\alpha[x_k]\right\rangle = 0$$
$$k = 2,3,....,n-1 \quad (13)$$
$$m_n(\ddot{x}_n + \ddot{x}_0) + c_m(x_n - x_{n-1}) + c_{(\alpha)n}\left\langle \mathsf{D}_t^\alpha[x_n] - \mathsf{D}_t^\alpha[x_{n=1}]\right\rangle = 0$$

4. CONCLUDING REMARKS

Then we have an autonomous fractional order differential equations along n unknown generalized coordinates, x_k, $k = 1,2,3,....,n$, correspond to the wagons relative motion in relation to the locomotive stationary motion as reference. For this system is possible to find eigen normal coordinates using formula transformation between generalized and eigen main coordinates of corresponding linear system to the fractional order using modal matrix. Previous system of fractional order differential equations (13) is possible to present in the matrix form:

$$\mathbf{A}\{\ddot{x}\} + C\{x\} + C_\alpha\left\{\mathsf{D}_t^\alpha\{x\}\right\} = \{0\} \quad (14)$$

with corresponding linear matrix form

$$\mathbf{A}\{\ddot{x}\} + C\{x\} = \{0\} \quad (15)$$

Then, we take into account that system (13) or in the form (14) have properties of special family of the fractional order system free vibrations for which matrix $\mathsf{C}_{\alpha,s\rightarrow\ s=1,2,3,...,n}^{\downarrow\ k=1,2,3,...,n}$ is diagonal and in the form:

$$\mathsf{C}_{\alpha,s} = \mathbf{R}'\mathbf{C}_\alpha\mathbf{R} = \left(c_{(\alpha)sS}\right) \quad (16)$$

where $\mathbf{R}$ is modal matrix of linear system (15) , and that by formula transformation of the generalized coordinates $\{x\} = \mathbf{R}\{\xi\}$ [12] previous system (14) can be transformed along new eigen main fractional order system coordinates ξ_s, $s = 1,2,3,...,n$, in the form of system of containing, only independent, fractional order differential equations each along one of these coordinates:

$$\ddot{\xi}_s + \omega^2_{(\alpha)s} \mathsf{D}^{\alpha}_{\mathsf{t}} \{\xi_s\} + \omega^2_s \xi_s = 0 \,, s = 1,2,3,...,n \tag{17}$$

where:

$$\omega^2_s = \frac{c_{ss}}{a_{ss}} \quad \omega^2_{(\alpha)s} = \frac{c_{(\alpha)ss}}{a_{ss}} \,,\ s = 1,2,3,...,n \tag{18}$$

characteristic number of railway train composition fractional order oscillations and eigen main fractional order independent modes are (see Refs, [2,3,13]):

$$\xi_s(t) = \xi_s(0) \sum_{k=0}^{\infty} (-1)^k \omega^{2k}_{(\alpha)s} t^{2k} \sum_{j=0}^{k} \binom{k}{j} \frac{(\mp 1)^j \omega^{-2j}_{(\alpha)s} t^{-\alpha j}}{\omega^{2j}_s \Gamma(2k+1-\alpha j)} + \tag{19}$$

$$+ \dot{\xi}_s(0) \sum_{k=0}^{\infty} (-1)^k \omega^{2k}_{(\alpha)s} t^{2k+1} \sum_{j=0}^{k} \binom{k}{j} \frac{(\mp 1)^j \omega^{-2j}_{(\alpha)s} t^{-\alpha j}}{\omega^{2j}_s \Gamma(2k+2-\alpha j)}$$

$$s = 1,2,3,...,n$$

For each eigen main fractional order vibrations mode is possible to define a theorem of the energy rate in the form [5]:

$$\frac{d}{dt} \left\langle \mathbf{E}_{kin,s} + \mathbf{E}_{pot,s} \right\rangle = -2\Phi_s - \dot{\xi}_{ss} \frac{\partial \Phi_{\alpha,s}}{\partial \left(\mathsf{D}^{\alpha}_{\mathsf{t}} [\xi_s] \right)}, \tag{20}$$

On the basic author's References, we can conclude that in the system exists independent eigen main fractional order modes (19), and that between these modes no transfer energy from one mode to other (20). Also two theorems is possible to formulate of rate of mechanical energy decease with fractional order energy dissipation defined in this model of railway train composition with fractional order energy dissipation in oscillatory regimes of wagons in relation to locomotive stationary motion with constant velocity. For the case, that system of railway train composition is not in stationary motion and that locomotive motion is with periodic changes of velocity and acceleration, it is possible to identified forced fractional order vibrations of all wagons and eigen fractional forced modes appear as coupled, and complex investigation in present fractional order model. If we take into account some of simple nonlinearity is possible to wait some stochastic like and chaotic like oscillations of the wagons and no stability of composition.

ACKNOWLEDGEMENT

Parts of this research were supported by Ministry of Sciences of Republic Serbia trough Mathematical Institute SANU Belgrade Grant ON174001:"Dynamics of hybrid systems with complex structures; Mechanics of materials.", and Faculty of Mechanical Engineering, University of Niš.

REFERENCES

[1] Goroško O.A. and K.R. Hedrih (Stevanović), (2001), *Analitička dinamika (mehanika) diskretnih naslednih sistema, (*Analytical Dynamics (Mechanics) of Discrete Hereditary Systems), University of Niš, 2001, Monograph, p. 426, YU ISBN 86-7181-054-2.

[2] Hedrih (Stevanović) K., (2008), The fractional order hybrid system vibrations, Chap in Monograph. Advances in Nonlinear Sciences, ANN, 2008, Vol. 2, pp. 226-326.

[3] Hedrih (Stevanović) K., (2011), Analytical mechanics of fractional order discrete system vibrations. Chap in Monograph. Advances in nonlinear sciences, Voл. 3, ANN, pp. 101-148.

[4] Hedrih (Stevanović) K., (213), Fractional order differential equations of dynamics of two mass particles, constrained by a fractional order element, Plenary Lecture, 8th INTERNATIONAL SYMPOSIUM ON CLASSICAL AND CELESTIAL MECHANICS (CCMECH'8), Siedlce, Poland, (The Russian Academy of Sciences, A. A. Dorodnicyn Computing Centre of RAS, Moscow State University, Moscow State Aviation Institute, Warsaw University of Life Sciences, and Collegium Mazovia in Siedlce (Poland).Book of Abstracts, **pp. 27-28. ISBN 078-83-63169-4,** @Copyright by Collegium Mazovia.

[5] Hedrih (Stevanović) K., (2013), Generalized function of fractional order dissipation of system energy and extended Lagrange differential equation in matrix form, *Dedicated to 86th Anniversary of Radu MIRON'S Birth. 30 minutes* Plenary Lecture, Abstracts of THE 13TH INTERNATIONAL CONFERENCE OF TENSOR SOCIETY ON DIFFERENTIAL GEOMETRY AND ITS APPLICATIONS, AND INFORMATICS BESIDES., ***The 86th Anniversary of Radu MIRON'S Birth.*** September 3rd (Tuesday) to September 7th (Saturday) in 2013. Faculty of Mathematics, Alexandru Ioan Cuza University and Mathematical Institute "O.Mayer" in Iaşi Romania And Tensor Society, Japan, 2013, p.3. (Full paper paper submitted for publishing in the journal Tensor of Tensor Society, Japan.).

[6] Katica R. (Stevanović) Hedrih, J. Tenreiro Machado, (2013), Discrete fractional order system vibrations, (*Preprint submitted for review-January 6, 2014).*

[7] Hedrih (Stevanović) K., (2013), Two mass particle fractional order plane system dynamics, **Dynamical Systems – Theory**, Edited by J. AWREJCEWICZ and all. 2013, **pp. 403-4012.** ISBN 978-83-7283-588-8, Printed by: Wydawnictwo Politechniki Łódzkiej,.

[8] Hedrih (Stevanović) K., (2006), Modes of the Homogeneous Chain Dynamics, Signal Processing, Elsevier, 86(2006), 2678-2702.. ISSN: 0165-1684 .

[9] Hedrih (Stevanović) K., (2005), Partial Fractional Order Differential Equations of Transversal Vibrations of Creep-connected Double Plate Systems, Chap in in Monograph - Fractional Differentiation and its Applications, Edited by Alain Le Mahaute, J. A. Tenreiro Machado, Jean Claude Trigeassou and Jocelyn Sabatier, p. 780, U-Book, Printed in Germany, pp. 289-302.

[10] Hedrih (Stevanović) K., (201`3), Fractional order hybrid system dynamics, PAMM, Proc. Appl. Math. Mech. 13, 25 – 26 (2013) / DOI 10.1002/pamm.201310008.

[11] Hedrih (Stevanović) K R. (2012), Energy and Nonlinear Dynamics of Hybrid Systems, Book Chapter, in *Dynamical Systems and Methods, Edited by Albert Luo, Tenreiro Machado and D Baleanu, , 2012, Part 1, Pages 29-83,* 2012, DOI: 10.1007/978-1-4614-0454-5_2 , ISBN 978-1-4614

[12] Rašković, D., (1965), Teorija oscilacija, (Theory of Oscillations), Nau~na knjiga, 1965, 503.(in Serbian).

[13] Bačlić, B.S., Atanacković, T., (2000), M., *Stability and creep of a fractional derivative order viscoelastic Rod*, Bulletin T, CXXI de L'Academie Serbe des Sciences st de Arts - 2000, Class des Sciences mathematques et naturelles Sciences mathematiques, No. 25, 115-131.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '14

BAGGAGE TRANSPORT SYSTEM – NEW SOLUTION

Bernhard RÜGER [1]

Abstract *– Baggage features the highest value regarding traffic flexibility. This fact is one of the main reasons for people to choose their car instead of public transport, either regarding their daily routine or journeys. Due to the complexity of an intermodal „public luggage transport system" which ideally works simultaneously to passenger transport, as a first step an exploratory project will be launched. The project aims to survey all customer requirements as well as technical and logistical challenges and as a consequence generate a list of requirements for prospective research and development projects.*

Keywords – baggage transport, passenger needs, expectations, comfort.

1. INTRODUCTION

The carriage of baggage shows the highest flexibility value in the railroad and is one of the main reasons why the automobile is chosen instead of the train for travel. However, studies show that through the implementation of a suitable baggage logistics system, very good modal shift effects can be achieved and the train can expect up to a 20% increase in passenger numbers.

2. PROJECT IDEA

The project "BaggageLess" sponsored by the Austrian Research Promotion Agency (FFG) and the Austrian Federal Ministry of Transport (bmvit) aims to develop a suitable system for baggage transport that can be implemented for everyday traffic as well as for longer travel. This means a decisive simplification for the customer and can also change the modal-split in favor of public transport.

The demands and challenges, which will be defined in the project, orient themselves on the following scenario:

Relevant first and foremost for customers is the interface with the system, i.e. the baggage transfer and return procedure. First and foremost from the point of view of the operator are all of the phases in between, i.e. from the time the operator receives the baggage, through baggage handling and transport, up to the return to the customer.

The basic structure of what the most flexible baggage logistics system can look like is depicted in figure 1.

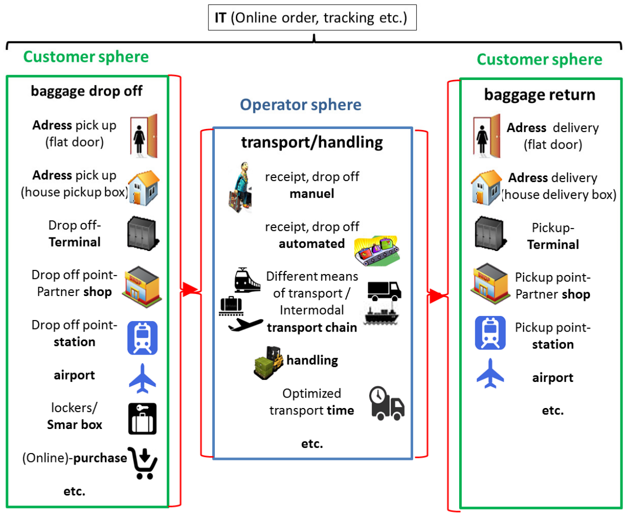


Fig. 1: Schematic depiction of a baggage logistics system

The baggage logistics system is modularly structured. For example, in the area of baggage transfer there must be different transfer possibilities from which the customer can choose. There are many conceivable scenarios which are described below:

- **Pickup/Delivery at the house door:** This service is already offered in the area of package delivery (at this time only for delivery) as well as in railroad transport house-house-baggage service. However, it must be optimized as it is at this time expensive and inflexible.
- **Pickup/Delivery at a house delivery enclosure (house-pickup/delivery box):** Analogous to house delivery enclosures (post boxes), large boxes make possible the delivery as well as

[1] Bernhard RÜGER, Vienna University of Technology, Karlsplatz 13/230-2, 1040 Vienna, Austria, bernhard.rueger@tuwien.ac.at

pickup of bulk freight such as baggage; but also packages in cases where the personal presence of the customer is not possible. Due to the necessary size of the boxes, it is hardly possible to provide every housing unit with its own box.

A system must be designed which is flexibly utilisable. For example, several small boxes can be combined to achieve the required larger size. At the same time it must be ensured that only the currently authorized persons (staff of the delivery/pick up services in combination with the respective piece of baggage or the owner) have access to the contents. A house box would have the advantage that both baggage and other packages which do not fit into a conventional house delivery enclosure could be transferred even if no one is personally present to meet the delivery/pickup service. At the same time, this box can also be used for the pickup of any pieces of baggage or packages. On one hand, because recipients do not need to go at fixed opening times to the nearest post office or the nearest partner shop to pick up deposited packages; this system would be, in the area of normal package delivery, a great convenience for the customer. On the other hand, it offers the implementation of a completely new service. The house box makes it possible to send packages without having to go to a post office.

The desired pickup of pieces of baggage or packages can be ordered over the internet; whereby, the box automatically informs the delivery service as soon as it is filled.

- **Central Drop Off Terminals:** At central points (hot spots) analogous to baggage lockers, innovative baggage deposit systems can be set up as short-term interim storage of baggage (e.g. while shopping) but the same time, as reception or retrieval points for baggage transport. These central drop off terminals can for example, include smart-boxes (see below) for the storage of diverse pieces of baggage.
- **Smart Boxes:** A key research question describes the necessary standardization of packaging and transport units. In particular it must be examined whether by baggage transport, transport containers such as for example the above mentioned SmartBox can be used system-wide or what additional requirements for style and (re) design of the pieces of baggage are needed. Baggage can be stored in the SmartBox. The SmartBox contains a chip and a small display. It is at any time possible to configure the SmartBox (e.g. using a smart phone or terminal) so that at a desired time it can be set to a defined goal. This system can then handle many small pieces of baggage (e.g. while shopping) as well as travel baggage.
- **Special challenges in the logistics chain:** People travel independently using available systems of public transport and make travel breaks. Along the way they do things which are not directly connected to their travel purposes, make detours and are not time bound to the transportation offered.

  The baggage being transported parallel to the traveler must be taken over by the transport service provider, collected, stored, transported, sorted and once again separated for the individual traveler. This requires not only appropriate systems but also minimization of processing time. Therefore, in general the baggage arrives at its destination at a different time than the traveler; and that implies the need for storage at the destination and the design of a pickup system by delivery service or individual.

3. OPERATOR MODEL

The innovation with respect to a future baggage logistics system is: that similar to multimodal personal mobility, a corresponding and accompanying freight mobility will be created. Thus there will be a complete decoupling of personal mobility from freight transport.

Similarly, as currently flexible systems are used in the framework of direct personal mobility, be it classical public transport or multi-purpose rental systems such as Car2Go or City Bike, in which at almost any time a vehicle can used and then parked; it should also be possible in the future to drop off baggage at an adequately available transfer point and have it transported to the desired destination. This system will allow in the future a significant increase in the flexibility of personal mobility; since the choice of transport as to whether or how much baggage is conveyed must not be considered, but limiting baggage can be dropped off at any time.

In the field of energy supply as well as telecommunication and public transport it is increasingly common for infrastructure and operations to act separately. This means for example, that a telecommunications provider does not have its own infrastructure but makes use of alternative infrastructure and only offers service "telephony". An operator model specializing in baggage services can look similar.

There are a variety of companies that specialize in the field of freight mobility. These are both shippers who transport freight using various means of transport, as well as traditional mail and package delivery. Also, other service facilities such as baggage deposit systems at train stations etc. should be considered. Because the requirements for baggage transport are very diverse, it is not useful to create a completely new system. On the contrary, existing service providers including their infrastructure must be integrated into the system and their systems optimized to ensure the best possible efficiency. For example, it can be a separate operator who is responsible for all matters relating to the transportation of baggage. The booking of service takes place through this operator; the operator takes care of the smooth flow of transport and is also the sole point of contact in all matters. The operator itself has no available infrastructure in the true sense but accepts the intermediary and coordinator role and depending on the specific requirements uses various service providers and service facilities (see Fig. 2).

This system also gives rise to a better utilization of existing systems; as free capacity can be used in a more targeted way.

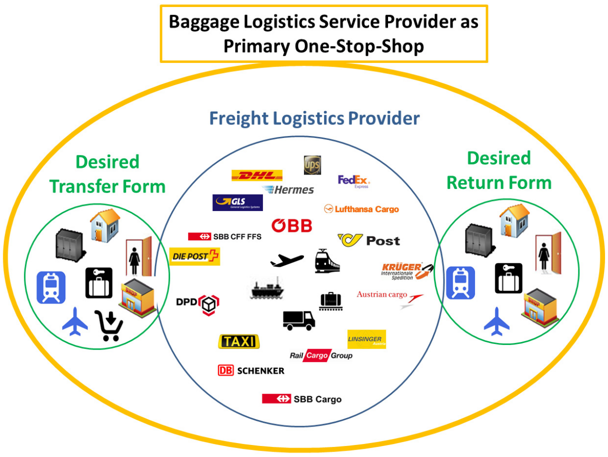


Fig. 2: Possible Operator Model

Those accumulated measurements can be used in order to design adequate storage between the seat backs or baggage racks.

Analysis show that there are two main issues regarding baggage room. First passengers do not want to lift their luggage, and especially not to the height of overhead storage. This attitude is more common amongst women and increases with age.

Second and due to security reasons, passengers wish to have their luggage in visual range. If these requirements are not met, passengers are very willing to store their luggage in not-intended place, like seats or corridors. This behaviour leads to a lower quality level and to a loss in capacity due to occupied seats.

4. CONCLUSION

The actual innovation, which is discernible from the outside, is that a fully adequate replacement for the trunk of the private automobile will be created. Only when the same flexibility can be created that one's own automobile trunk provides, is it possible to leverage sustainable mobility forms such as public transport to make the required breakthrough!

REFERENCES

[1] Rüger Bernhard, Reisegepäck im Eisenbahnverkehr, Dissertation TU Wien, 2004

[2] Chiambaretto, Paul; Baudelaire, Claude; Lavril, Thibault: Measuring the willingness-to-pay of air-rail intermodal passengers, in: Journal of Air Transport Management, Volume 26, 2013, S. 50-54.

[3] Plank Viktor, Dimensionierung von Gepäckablagen in Reisezügen, Diplomarbeit TU-Wien, 2009

[4] Rüger Bernhard, "Bereitschaftselastizität - Empirische Ermittlung zum Verkehrsmittel-wahlverhalten"; 20. Verkehrswissenschaftliche Tage in Dresden, Dresden; 19.09.2005 - 20.09.2005; in: "Grenzenloser Verkehr in einem grenzenlosen Europa", (2005), 31 S.

[5] KOWARCZ, Sascha; VOSPERNIK, Stefan: GBÖ Kurzreisen Winter 2000/01, (Gästebefragung Österreich Winter 2000/01) Info Research International, Wien

PESA 122NASF SWING - THE NEW TRAMS IN SOFIA

Zornitsa EVLOGIEVA [1]
Emil M. MIHAYLOV [2]

Abstract *– At the end of 2013 began the delivery of 20 trams for the city of Sofia - type PESA 122NaSF Swing, production of Pojazdy Szynove PESA Bydgoszcz SA. The trams are with 6-axes and 1009 mm wheel gauge. With low-floor along the entire vehicle, designed for one-way traffic. They use a entirely new composition for the city of Sofia – three bogies supporting five sections, connected by four floating joints. The new trams have systems for management, monitoring, passenger information. They are suitable for transporting elderly, disabled and people in wheelchairs. This paper will give a description of trams PESA 122NaSF Swing, indicate the differences with the currently operated trams in Sofia and analyse the problems arising in the beggining of their service.*

Keywords – trams, Sofia, PESA, chassis, traction equipment.

1. INTRODUCTION

The *PESA 122NaSF Swing* trams were delivered to „Sofia Public Electrical Transport Company" JSC[1] in the period from December 2013 – May 2014. They were manufactured in Poland by the Polish company Pojazdy Szynove PESA Bydgoszcz SA[2].

These trams have a composition that is used for the first time in the city of Sofia - five complete low-floor sections, interconnected via four floating joints, which allows better negotiation of tight railroad curves.

The delivery of the new trams is part of an integrated city transport project, financed by Operational Programme "Environment". The total value of the delivery contract for the 20 trams, diagnostic equipment, spare parts and personnel training is 33 784 726,65 euro. The price of a single vehicle is 1 660 000 euro.

These trams are the first non second-hand ones introduced into the transport network of Sofia since year 2000.

2. BRIEF DESCRIPTION OF THE *PESA 122NASF* TRAM

2.1. General overview

The *PESA 122NaSF Swing* tram (fig. 1) is a continuation of the *120Na Swing* model and is a specially modified version to suit the specific usage requirements of Sofia city. The trams has six axles, matching the wheel gauge of 1009 mm that is used in the city. It is designed for one-way traffic, and is not a Multiple Unit (MU) type.

The tram has the following dimensions: length– 30,120 m, width – 2,3 m, body height – 3,4 m, height with a current collector in operational position – 5,8m. The designed speed of *PESA 122NaSF Swing* is 70km/h, but is limited by the onboard computer to 55km/h to comply with city traffic regulations. When this speed is exceeded, the traction units are turned off. The maximum slope grade that can be climbed is 60 ‰. The minimum curve radius is 18 m. The tram has capacity to transport 201 passengers, from which 41 sitting, and the rest 160 are standing, at a density of 5 passengers per m^2.

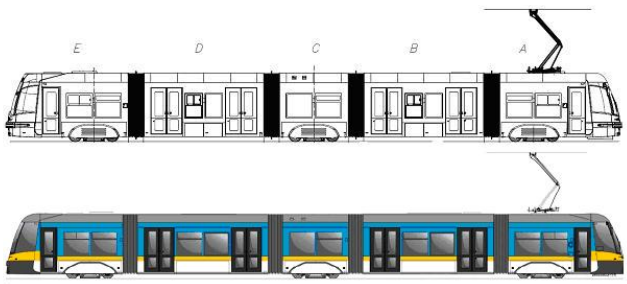


Fig.1. PESA 122NaSF Swing tram

[1] Zornitsa EVLOGIEVA, M.Sc., PhD Student, University of Transport, 158 Geo Milev Street, Sofia 1574, Bulgaria, zrukova@abv.bg
[2] Emil MIHAYLOV, M.Sc., PhD Student, University of Transport, 158 Geo Milev Street, Sofia 1574, Bulgaria, Sofia Public Electrical Transport Company JSC, Head of Dep. "Emergency service", emm_1968@abv.bg

2.2. Technical specifications

Tab. 1. Technical specifications

Wheelset formula	$B_0' \, 2' \, B_0'$
Wheel gauge	1 009 mm
Kinematic gauge	PN-K-92008
Length of tramcar	30 120 mm
Width of tramcar	2 300 mm
Body height	3 400 mm
Height of tramcar with retracted current collector	3 850 mm
Height of tramcar with maximum extended current collector (in operational mode)	5 800 mm 6 380 mm
Floor height from top of rail	330 mm
Weight Empty (Tare) Loaded – 5 passengers/m^2	 40 858 kg 54 756 kg
Wheelbase between bogies	10 750 mm
Wheelbase of bogies	1 800 mm
Design speed	70 km/h
Maximum slope grade	60 ‰
Minimum curve radius in operational conditions	18 m
Passenger capacity at 5 passengers/m^2	201 passengers
Sitting places	41
Operation ambient tempeature	- 30 ÷ + 40
Traction motors	4

2.3. Chassis

The chassis is comprised of three bogies – two traction (type 03PND) and one support (type 03PTD), fixed to sections A, C e E.

The bogies have two axles, with two-stage suspension. The bushing suspension stage has two cylindrical metal-rubber bushes, and the central stage has two pairs of two cylindrical coil springs on each side. In the two suspension stages of each bogie there are altogether eight hydraulic shock absorbers with vertical and horizontal action.

The wheels are elastic, and the elastic elements are arranged in rings between the hubs and the wheel bandage.

2.4. Traction equipment

The traction equipment of the trams comprises 4 traction electrical motors of type *DKCBZ 0211-4SA*. The motor is 3-phase asynchronous, the rotor is a squirrel-cage design, the stator is connected in a star (WYE) arrangement. The motor provides both traction and dynamic braking. The motors are mounted on both sides outside the frame of the bogie and transfer torque to the axles via two-stage cylindrical-conical reduction gearboxes and elastic clutches. The housings of the traction motor and gearbox are rigidly connected in one single block.

Each traction motor is powered individually by a power inverter converting the DC from the overhead power line into 3-phase 400V / 50Hz AC. The power (throttle) control is performed via Pulse Width Modulation (PWM), by IGBT power transistors.

2.5. Body

The body of the tram has a complete low floor and is composed of five sections, connected by four floating joints. The body has a fully supporting structure, and complies to the requirements of the standards EN 15227:2008 cat. IV and A1:2010.

The passenger compartment (fig. 2) is equipped with 41 seats, and the area for 201 standing passengers is 32,21 m^2.

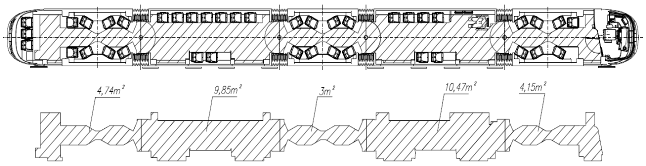


Fig.2. Arrangement of the seats and the standing passenger area

The doors are situated on the right. The second door is equipped with a ramp for wheelchair and baby stroller roll-on/roll-off access. Opposite to the door there is a place for securing a wheelchair or baby stroller.

2.6. Brakes

Braking of the *PESA 122NaSF* tram is performed by three independent braking systems: electrodynamic brake, hydromechanic brake; electromagnetic track brake. The collective work of the different brake systems is controlled by the onboard computer, which optimizes braking efficiency in the different braking regimes.

Main braking is performed by the electrodynamic brake. After the speed reaches 3 km/h, until complete stop of the tramcar, braking is performed by the hydromechanical brake. The energy recovered by regenerative electrodynamic braking is recuperated to the overhead power line.

In case of extreme brake action, the hydromechanic and electromagnetic track brake are collectively applied.

3. MAIN DIFFERENCES FROM ALL OTHER TRAMCARS IN SOFIA

The *PESA 122NaSF Swing* tram is different from the currently operational articulated railcars, produced in the Sofia Tramcar Factory, in the following aspects:

- Fully low body floor;

- Fully computerized control by an onboard computer;
- Different arrangement of the seats in the passenger compartment;
- Bogies are fixed to the sections, and the joints are floating type;
- Fully air conditioned passenger compartment;
- Excellent noise insulation of the passenger compartment.

PESA 122NaSF Swing trams offer more passenger conveniences and superior ride comfort.

The higher safety level of the machines leads to more safety shutdowns than the older tram types. The procedure to reset the system back in operational mode takes more time than with the currently used trams. There are two emergency modes that minimize the necessity of using another vehicle for towing.

There are considerable structural differences between the new and the currently used trams. These differences require changes both in the tram depot repair shop and in Emergency Service procedures.

Due to the lower floor of these trams, all equipment containers are mounted on the roof. This required building of new service and repair equipment (Fig. 3). Changes were made to the operation of the underfloor grinding machine. A procedure is in progress for purchasing an underfloor wheel lathe.

Fig 3. The new roof access service equipment

Considerable changes are required in equipment and workflow in case of emergencies, especially when partial hoisting of the tram is necessary - in cases or derailment of chassis malfunction. The manufacturer-provided technology is complex and requires more preparation time.

Fig.4 compares *PESA 122NaSF Swing* trams (top) and similar in length and passenger capacity *T8M 700 M* trams (bottom). The main differences in the composition are the floating joints and the fixed bogies of the Polish trams.

While the bogies of the currently used trams can rotate up to 11 degrees related to the body, around a central pivot, the *PESA 122NaSF Swing* bogies are fixed to the body sections. The Bulgarian trams have the support bogies under the joints, unlike the Polish ones, which have two floating joints between each two bogies. This leads to twisting of the body in case of derailment. Because of this, before partial hoisting of the tram in case of emergency and repair, one or two joints have to be blocked.

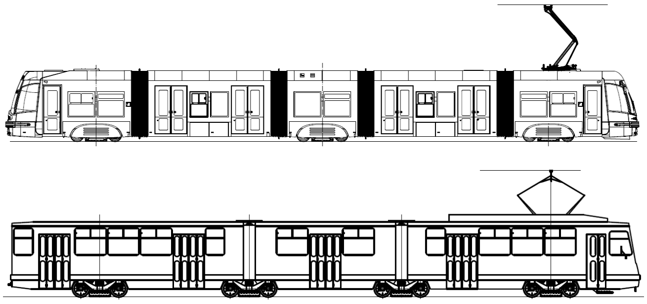


Fig.4. Comparison between the composition of PESA and TM, manufactured in the tram factory in Sofia.

These specifics of the new trams do not allow the use of the currently employed techniques for rerailment.

4. IMPROVEMENT OF THE ACOUSTIC ENVIRONMENT

The noise levels measured in the city of Sofia during the last years are constantly increasing. According to a report from the Regional Health Inspection Service[4], the noise levels measured in 2013 reach 77 dB. This is above the 65 dB level allowed by the current regulations № 6 / 2006 for ambient noise levels [5]. The high noise levels have negative psychological and physiological impact on the quality of life. The main noise pollution source is transportation. For this reason, various measures are taken to lower noise emissions. One of these measures is the purchase of the new *PESA 122NaSF Swing* trams and the start of a new public procurement procedure for commissioning more new trams for the city.

The new trams completely meet the current European noise level regulations. These trams are considerably quieter than the rest in the fleet of „Sofia Public Electrical Transport Company" JSC. Their introduction will contribute to the improvement of the acoustic environment of the Bulgarian capital.

5. EXPLOITATION-RELATED PROBLEMS

In the first months after the introduction of *PESA 122NaSF Swing* in Sofia, the usual new equipment adoption problems appeared.

The drivers had to adapt to the different way of operation of the new tramcars. In the cases of failures and emergencies, the drivers are frustrated with the procedures for restarting the machine in emergency mode.

The technical problems that occurred are related to the fact that the prescribed functional tests were not carried out in the manufacturing factory, because it lacks a track with a 1009 mm wheel gauge. The test runs were carried out in Sofia, before their acceptance according to the commission contract.

Together with the tramcars, in accordance with the warranty clauses in the contract, a team of Polish experts was sent to Bulgaria. Together with their Bulgaria colleagues, in the period of 3 years, they will be in charge of the technical condition of the tramcars.

Meanwhile, lecturers from the manufacturing company are training Bulgarian personnel in the depot's workshop and at the Emergency Service.

Consulting with colleagues from the city of Warsaw, where a significant number of tramcars of the base model are in service, shows that the problems observed in Bulgaria are identical to the ones observed in Warsaw. Experience was exchanged.

6. CONCLUSIONS

After about one year of service of the *PESA 122NaSF Swing* tramcars, it can be concluded that they show excellent operational characteristic and are well accepted both by the personnel working in them and by the passengers.

REFERENCES

[1] http://www.elektrotransportsf.com/ - Sofia Public Electrical Transport Company JSC
[2] www.pesa.pl/en/ - PESA Bydgoszcz SA
[3] Pojazdy Szynove PESA Bydgoszcz SA, Dokumentacja techniczna, 2013.
[4] www.srzi.bg – Regional Health Inspection Service – „Report of noise levels observed in the city of Sofia in 2013", Sofia 2013.
[5] Regulation № 6 / 2006 for ambient noise characteristics, describing the level of discomfort at different time of the day, ambient noise limits, noise parameter and noise health impact evaluation methods.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

HYBRID INTELLIGENT VIBRATION CONTROL OF RAIL CAR BODY WITH PIEZO ACTUATORS

Emina PETROVIĆ [1]
Ivan ĆIRIĆ [2]
Žarko ĆOJBAŠIĆ [3]
Vlastimir NIKOLIĆ [4]
Ivan PAVLOVIĆ [5]

Abstaract–*The softer, more compliant structure with piezo actuators of railcar bodies with low eigenfrequencies that significantly affect perceived passenger ride comfort is become important issue in design of modern rail vehicles. Recent years various approaches have been taken to reduce comfort-relevant vibrations of the car body. In this paper, for control of railcar structure we are suggesting hybrid intelligent control concept that combine fuzzy logic with particle swarm optimization of fuzzy control parameters for stabilization and active vibration control*

Key words – Intelligent control, particle swarm, piezo actuators, railcar structure.

1. INTRODUCTION

Recently, ride comfort becomes an increasingly important issue of modern railway vehicles. The ride quality of a modern railway vehicle is mainly determined by forces of inertia acting on the car body and therefore on the passenger. These accelerations result from the vibrations of rigid body modes as well as elastic modes of the car body. A common criterion to evaluate the ride quality of a railway vehicle is to measure or to simulate the system response to a real excitation (track irregularities, etc.) in order to obtain time histories of the accelerations on certain points of the car body. Then the weighted root mean square value of the acceleration in the horizontal and vertical direction of the car body is an appropriate measure for the ride quality [1].

$$a_{ISO,rms} = \sqrt{\frac{1}{T}\int_0^T a_{ISO}^2(t)dt} \qquad (1)$$

where $a_{ISO}(t)$ is the frequency weighted acceleration. Weighting filters for vertical and horizontal accelerations are defined in UIC 513 [2].

Whole-body vibrations are transmitted to the human body of the passengers in a bus, train or when driving a car. The ISO 2631 standard gives an average, empirically verified objective quantification of the level of perceived discomfort due to vibrations for human passengers. The accelerations in vertical and horizontal directions are filtered and these signals' root mean squares (RMS) are combined into a scalar comfort quantity. Fig. 1 shows the ISO 2631 filter magnitude for vertical accelerations which are considered. The highest sensitivity of a human, for the heavy metro car, eventuates in the frequency range of f ≈ 4 − 10 Hz. [3].

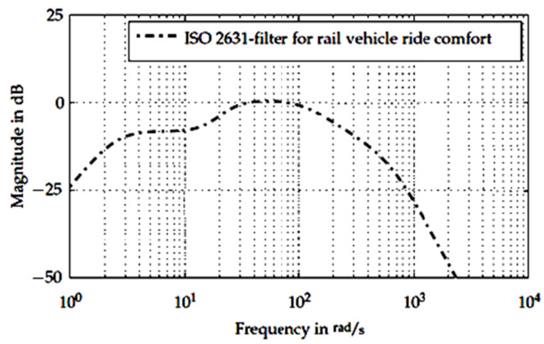


Fig. 1. Filter function according to ISO 2631

The other words, a good ride quality meaning the reduction of the vibration amplitudes of the car body, because the softer, more compliant structure exhibits low eigenfrequencies that significantly affect perceived passenger ride comfort.

Various approaches have been taken to reduce comfort-relevant vibrations of the car body that can be grouped into vibration isolation and vibration

[1] M.Sc. Eng.,Emina PETROVIĆ, Faculty of Mechanical Engineering, Niš, Serbia, emina@masfak.ni.ac.rs
[2] M.Sc. Eng., Ivan ĆIRIĆ, Faculty of Mechanical Engineering, Niš, Serbia, ciric.ivan@masfak.ni.ac.rs
[3] Prof. D.Sc. Eng., Žarko ĆOJBAŠIĆ, Faculty of Mechanical Engineering, Niš, Serbia, zcojba@ni.ac.rs
[4] Prof. D.Sc. Eng., Vlastimir NIKOLIĆ, Faculty of Mechanical Eng., Niš, Serbia, vnikolic@masfak.ni.ac.rs
[5] M.Sc. Eng., Ivan PAVLOVIĆ, Faculty of Mechanical Engineering, Niš, Serbia pivan@masfak.ni.ac.rs

damping approaches.

The isolation approaches include passive, semi-active, and active concepts to decouple the car body from the bogeys and wheel sets (see [4] and [5]).

The vibration damping approach for vibration reduction is the application of an active control system to alleviate the elastic vibrations of the railway car body. Both passive (Hansson et al. [6]) and active control schemes (Kamada et al. [7], Schandl et al. [8]) have already been proposed.

The purpose of this paper is to illustrate the design steps of such an active vibration control system and to focus attention on the performance of this concept. Also for control of railcar structure we are suggesting hybrid intelligent control concept that combine fuzzy logic with particle swarm optimization of fuzzy control parameters for stabilization and active vibration control. This work is based on the results of Popprath et all [1], Schirrer et all [3] and Schirrer & Kozek [10].

2. FLEXIBLE RAIL CAR BODY ANALYTICAL MODEL

For controller design procedure a mathematical model of the flexible rail car body is necessary. More precisely a model of the elastic modes of the car body is needed for this purpose because the elastic modes of the car body can be influenced only by actuator forces. The equations of motions are expressed by a first-order state-space representation obtained by a finite element analysis within the frequency range of interest.

The metro car body structure is directly actuated via locally mounted Piezo stack actuators. Using strain measurement signals, the control law actuates the structure in order to minimize ride comfort-relevant acceleration signals across the car body inner part. Because this system is subject to variations in damping and frequency of the flexible modes is a challenging for control design. The mathematical model of the rail car body, obtained by an FE model and subsequent order reduction steps, considers 17 elastic modes and 12 frequency-response-modes (FRM), as demonstrated in [11].

Figure 2 shows positioning of the actuators and sensors (one of several criteria for optimal actuator/sensor placement) and the principle of how the actuators work is shown in Fig. 3.[9]

The equations of motion are given by the following system of differential equations of order n [9]:

$$\boldsymbol{M}\ddot{\omega} + \boldsymbol{L}\dot{\omega} + \boldsymbol{K}\omega = \boldsymbol{f}(t) \qquad (2)$$

Here **M** is the (n × n) mass matrix, **L** is the (n × n) damping matrix, **K** is the (n × n) stiffness matrix, and **f**(t) is the (n× 1) vector of generalized excitation forces containing excitation as well as control forces.

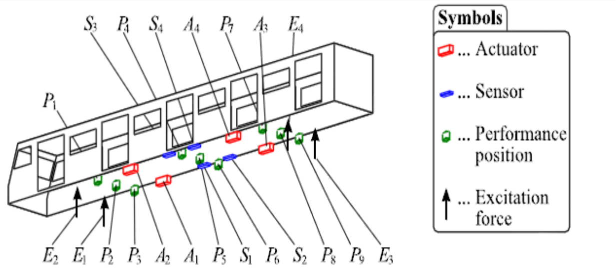


Fig. 2. Flexible rail car body: positions of input and output variables

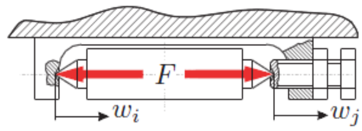


Fig. 3.Piezo-stack actuator mounted in console

A transformation is defined by replacing the (n × 1) vector of generalized coordinates $\boldsymbol{\omega}(t)$ with

$$\boldsymbol{\omega}(t) = \boldsymbol{\Phi q}(t) = \sum_{j=1}^{n} \phi_j q_j(t) \qquad (3)$$

where

$$\boldsymbol{\Phi} = [\phi_1, \phi_2, \ldots, \phi_n]^T$$

is the matrix of eigenvectors of (2). Inserting (3) into (2) and left-multiplying by$\boldsymbol{\Phi^T}$, one obtains a diagonal systemin modal coordinates:

$$\ddot{\boldsymbol{q}} + 2\boldsymbol{\zeta\Omega}\dot{\boldsymbol{q}} + \boldsymbol{\Omega}^2\boldsymbol{q} = \boldsymbol{\mu}^{-1}\boldsymbol{\Phi}^T\boldsymbol{f}(t) \qquad (4)$$

where **μ** is the (n × n) matrix of modal masses, **ζ** is the (n × n) matrix of modal damping's and **Ω** is the (n × n) matrix of undamped eigenfrequencies. Definition of

$$\boldsymbol{x} = [\boldsymbol{q}, \dot{\boldsymbol{q}}]^T \qquad (5)$$

leads to the state space system equation

$$\dot{\boldsymbol{x}} = \boldsymbol{Ax} + \boldsymbol{B_1 d} + \boldsymbol{B_2 u} \qquad (6)$$

and the output equation

$$\boldsymbol{y} = \boldsymbol{C_2 x} \qquad (7)$$

which together form the state space description of (4). In (6) and (7) **A** is the (2n × 2n) system matrix, $\mathbf{B_1}$ is the (2n×l) disturbance input matrix, $\mathbf{B_2}$ is the (2n×m) input matrix, $\mathbf{C_2}$ is the (p × 2n) measurement output matrix, **x** is the (2n × 1) state vector, ***u*** is the (m × 1) vector of control signals, ***d*** is the (l × 1) vector of disturbances (excitation of the car body from secondary suspension) and **y** is the (p × 1) vector of controlled variables. The controlled variables may consist of measured outputs as well as of performance variables.

If one actuator is used, forces are acting in the directions w_i and w_j according to Fig. 4, and if only one excitation force is acting on the structure in the direction w_l, the disturbance input matrix $\mathbf{B_1}$ and the input matrix $\mathbf{B_2}$ are

$$B_1 = \begin{bmatrix} 0 \\ \vdots \\ 0 \\ \phi_1(w_l) \\ \vdots \\ \phi_n(w_l) \end{bmatrix}, B_2 = \begin{bmatrix} 0 \\ \vdots \\ 0 \\ \phi_1(w_j) - \phi_1(w_i) \\ \vdots \\ \phi_n(w_j) - \phi_n(w_i) \end{bmatrix} \quad (8)$$

In (8) $\phi_m(w_j)$is the component of ϕ_m in direction of w_j. When the sensors are collocated with the actuators the output matrix $\mathbf{C_2}$ is proportional to the input matrix $\mathbf{B}_2$ [12],

$$\boldsymbol{C}_2 = \frac{1}{l_s}\boldsymbol{B}_2^T \quad (9)$$

where l_s is the distance between the nodes w_i and w_j in the unstrained state.

Equivalent transfer function descriptions for (6) and (7) are given by

$$\boldsymbol{G}_{su} = \boldsymbol{C}_2(\boldsymbol{sI} - \boldsymbol{A})^{-1}\boldsymbol{B}_2 \quad (10)$$

for the open loop transfer function from actuator action to the outputs and

$$\boldsymbol{G}_{sd} = \boldsymbol{C}_2(\boldsymbol{sI} - \boldsymbol{A})^{-1}\boldsymbol{B}_1 \quad (11)$$

for the open loop action of the disturbances on the outputs.

Augmenting the output equation (7) with a q × 1 performance vector **z** (typically vertical accelerations at various positions), the overall representation becomes

$$\begin{bmatrix} \dot{\boldsymbol{x}} \\ \boldsymbol{z} \\ \boldsymbol{y} \end{bmatrix} = \begin{bmatrix} \boldsymbol{A} & \boldsymbol{B}_1 & \boldsymbol{B}_2 \\ \boldsymbol{C}_1 & \boldsymbol{D}_{11} & \boldsymbol{D}_{12} \\ \boldsymbol{C}_2 & \boldsymbol{D}_{21} & \boldsymbol{D}_{22} \end{bmatrix} \begin{bmatrix} \boldsymbol{x} \\ \boldsymbol{d} \\ \boldsymbol{u} \end{bmatrix} \quad (12)$$

Here $\mathbf{C}_1$ is the q×n performance output matrix and $\mathbf{D}_{11}$,$\mathbf{D}_{12}$, $\mathbf{D}_{21}$, and $\mathbf{D}_{22}$ are the feed-through matrices. The explicit notation of performance variables **z** is reasonable since only strains are measured but the accelerations are used to quantify performance. Furthermore, this system structure is well suited for a robust controller design.

3. FUZZY CONTROLLER DESIGN

In addition to the conventional controller design approach [13], the fuzzy controller design of flexible rail car body was considered in this paper.

Rule based fuzzy logic controllers are useful when the system dynamics are not well known or when they contain significant nonlinearities. Fuzzy logic controllers apply reasoning, similar to how human beings make decisions, and thus the controller rules contain expert knowledge of the system. The big advantages of fuzzy logic control when applied to a flexible rail car body are that the system neither needs to be accurately described nor does it need to be linear. The design process for a fuzzy logic controller consists of determining the inputs, setting up the rules and designing a method to convert the fuzzy result of the rules into output signal, known as defuzzification.

Takagi-Sugeno fuzzy logic controller suggested in this paper is defined as a list of fuzzy control rules, where each rule is defined as:

$$R_c^i\text{: if } \mathbf{x}\text{=}\mathbf{LX}^i \text{ then } \mathbf{u} = g_i(\mathbf{x}),$$

where $\mathbf{LX}^i$m is fuzzy region. Nonlinear formulaton of global fuzzy logic controller is:

$$\mathbf{u} = \sum_i \omega^i(\mathbf{x}) \cdot g_i(\mathbf{x}) \quad (13)$$

where $\omega^i(\mathbf{x})\in[0,1]$ is normalized membership value of some crisp state space vector **x** to fuzzy region $\mathbf{LX}^i$ (i=1,2,...m).

The strain measurement signals drove the fuzzy controller of the actuator forces, in order to keep the magnitude and frequencies of rail car body within the proposed bounds. The measured input signal and its derivate are controller inputs and were normalized and divided in three regions each: low, middle and high. The output MFs of the controllers were constants, namely actuator forces. The first controller output was generated as a result of an interpolation of 3 constant gains based on fuzzy rules.

Tuning of the parameters for the *low*, *average* and *high* input and output values can be done by expert knowledge or after many simulation trials. However, optimal fuzzy controller gain values when there is no adequate expert knowledge can be determined as the result of some heuristic optimization method.

The closed loop system with optimally adjusted fuzzy controller should have a quick response and small overshoot. Such response is of great importance having in mind passenger ride comfort.

4. PARTICLE SWARM OPTIMIZATION OF PARAMETARS OF FUZZY CONTROLER

In this paper Particle swarm optimization was used for numerical calculation of optimal fuzzy controller gains. Using this algorithm is simple, easy to implement and there are just fewer parameters need to be adapted.

It was first introduced by Kennedy and Eberhart in 1995 [14], as new heuristic method inspired by the social behavior exhibited by flocks of birds flying across an area looking for food.

Mathematically, for a given function $f: S\square R$, where $S \subseteq R^D$, find a point $\boldsymbol{x}^*$ such that

$$\min_{x \varepsilon S} f(\boldsymbol{x}) = f(\boldsymbol{x}^*) \quad (14)$$

In the basic particle swarm optimization, particle swarm consists of $n$particles, and the coordinates of each particle represent a possible solution called particles associated with position and velocity vector in D-dimensional space [14].

At each iteration particle move towards a optimum solution, through its present velocity, personal best solution obtained by themselves so far and global best solution obtained by all particles.

The position of ith particle of the swarm can be represented by a D-dimensional vector $\mathbf{x}_i = (x_1, x_2, \dots, x_D)$. The velocity (position change per generation) of the particle $\mathbf{x}_i$ can be represented by another D-dimensional vector $\mathbf{v}_i = (v_1, v_2, \dots, v_D)$. The best position previously visited by the ith particle is denoted as $\mathbf{p}_i = (p_1, p_2, \dots, p_D)$. If the topology is defined such that all particles are assumed to be neighbors and g as the index of the particle visited the best position in the swarm, then p_g becomes the best solution found so far, and the velocity of the particle and its new position will be determined according to the following two equations:

$$\boldsymbol{v}_i^{t+1} = \boldsymbol{v}_i^t + c_1 r_1 (\boldsymbol{p}_i^t - \boldsymbol{x}_i^t) + c_2 r_2 (\boldsymbol{p}_g^t - \boldsymbol{x}_i^t) \quad (15)$$

$$\boldsymbol{x}_i^{t+1} = \boldsymbol{x}_i^t + \boldsymbol{v}_i^{t+1} \quad (16)$$

r_1 and r_2 are random variables in the range [0,1]; c_1 and c_2 are acceleration coefficients regulating the relative velocity toward global and local best [15].

5. CONCLUSION

In this paper, for control of railcar structure we are suggesting hybrid intelligent control concept that combine fuzzy logic with particle swarm optimization of fuzzy control parameters for stabilization and active vibration control.The main advantages of suggested hybrid fuzzy control algorithm are relative simplicity, universal control algorithm and fast response.

The design, manufacturing and experimental modal analysis of the railway vehicle modeldescribed in this contribution sets up many possibilities for the future research on this field.

The designed model and the knowledge about its dynamical behavior makes it nowpossible to develop different control strategies for improved structural damping of the elasticcar body to achieve a high ride quality.

ACKNOWLEDGEMENTS

This research in this paper was supported by the Ministry of Education and Science of Republic of Serbia and DAAD through the project "Intelligent Control of Smart Structure".

The research was supported by the project "Research and Development of New Generation of Highly Energy Efficient Wind Turbines" (No. 35005/2011) funded by the Ministry of Education and Science of Republic of Serbia.

REFERENCES

[1] S. Popprath, C. Benatzky, C. Bilik, M. Kozek, A. Stribersky, J. Wassermann, "Experimental modal analyisis of a scaled car body for metro vehicles ",(2006),The Thirteenth International Congress on Sound and Vibration, Vienna, Austria, July 2-6,2006.

[2] UIC 513, "Guidelines for evaluating passenger comfort in relation to vibration in railway vehicles",UIC, 1994.

[3] Schirrer A., Kozek M., and Schöftner J., "MIMO Vibration Control for a Flexible Rail Car Body: Design and Experimental Validation." Vibration Analysis and Control–New Trends and Developments (2011).

[4] E. Foo and R. M. Goodall, "Active suspension control of flexible-bodied railway vehicles usingelectro-hydraulic and electro-magnetic actuators," *Control Engineering Practice*, vol. 8, no. 5, pp.507–518, 2000.

[5] Stribersky, A., Müller, H. & Rath, B. (1998). The development of an integrated suspension control technology for passenger trains, Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, Vol. 212, pp. 33–42.

[6] Hansson, J., Takano, M., Takigami, T., Tomioka, T. & Suzuki, Y. (2004). Vibration Suppressionof Railway Car Body with Piezoelectric Elements, JSME International Journal Series C 47(2): 451–456.

[7] T. Kamada, T. Tohtake, T. Aiba, and M. Nagai, "Active vibration control of the railway vehicle bysmart structure concept," in *19th IAVSD Symposium - Poster Papers*, S. Bruni and G.Mastinu, Eds.,2005.

[8] Schandl, G., Lugner, P., Benatzky, C., Kozek,M. & Stribersky, A. (2007). Comfort enhancementby an active vibration reduction systemfor a flexible railway car body, Vehicle System Dynamics 45(9): 835–847.

[9] M. Kozek, C. Benatzky, A. Schirrer , A. Stribersky, (2008), "Vibration Damping of a Flexible Car Body Structure Using Piezo-Stack Actuators", Proceedings of the 17th World Congress The International Federation of Automatic Control Seoul, Korea, July 6-11, 2008.

[10] Schirrer, A. & Kozek, M. (2008). Co-simulation as effective method for flexible structure vibration control design validation and optimization, Control and Automation, 2008 16th Mediterranean Conference on, pp. 481 –486.

[11] Schandl, G. (2005). Methodenuntersuchung zur aktiven Schwingungsreduktion eines Schienenfahrzeugwagenkastens, PhD thesis, Vienna University of Technology, Vienna.

[12] A. Preumont. Vibration control of active structures: an introduction. Kluwer, 1997.

[13] Ćirić I., Ćojbašić Ž., Nikolić V., Petrović E., "Hybrid Fuzzy Control Strategies for Variable Speed Wind Turbines", Facta Universitatis, Series: Automatic Control and Robotics, Vol. 10, No 2, (2011), pp. 205 – 217.

[14] Kennedy and Eberhart., Particle swarm optimization. IEEE International Conference on Neural Network,(1995), 1942-1948

[15] Qinghai Bai., Analysis of Particle Swarm Optimization Algorithm. *Computer and Information Science, Volume,*3 (2010), No.1.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '14

30 YEARS OF THE EXPLOITATION OF LOCOMOTIVES TYPE DVM12

Marko DJUKIĆ [1]

Abstract *– In 2014 it will be 30 years from the beginning of the exploitation of diesel-electric locomotives type DVM12. This type of locomotives was developed in the 1980s in the Ganz-MAVAG factory based on the concept of the DVM2 locomotives for the needs of former Yugoslav railways, that is ŽTP "Beograd" (JŽ 641.3) and several industrial companies in former Yugoslavia and Hungary. The paper shows a brief history of supply, the introduction into traffic and exploitation of locomotives type DVM12.*

Keywords – Diesel locomotive, exploitation, history.

1. INTRODUCTION

The locomotives type DVM12 (hun. *Dízel-Villamos Mozdony 12*) were manufactured in the *Ganz-MÁVAG* factory from Budapest for the needs of Yugoslav railways and several industrial companies in former Yugoslavia and Hungary. They were designed for shunting service although they could be used both for traction of light freight and passenger trains on plain lines without train heating. The first locomotive was manufactured in 1984 and up until 1988 which was the year the last one was made a total of 40 locomotives were manufactured (table 1.).

Table 1. List of delivered locomotives type DVM12

Purchaser	Year of manufacture	Number of locomotives	Locomotive numbering
Yugoslavia-JŽ	1984	15	641.301-315
	1986-1988	16	641.316-320, 323-332, 335
Yugoslavia-industry	1986-1987	4	641.321, 322, 333, 334
Hungary-industry	1986-1987	5	A25.101, 102, 103, 104, 106
	Total:	**40**	

2. THE DEVELOPMENT OF LOCOMOTIVES TYPE DVM12

The locomotives type DVM12 were developed during the 1980s in the *Ganz-MAVAG* factory based on the concept of locomotives type DVM2 (926 locomotives type DVM2 were manufactured between 1954 and 1977 for the industrial companies and railways in Hungary, mostly for export – table 2.), using a well known mechanical part with certain modifications and modern electrical equipment. A new type of *SEMT Pielstick* 8PA4V-185VG diesel engine was built (manufactured in the *Ganz-MÁVAG* factory, with the license of the French company), main generator, power control system, compressor, electrical equipment, etc.

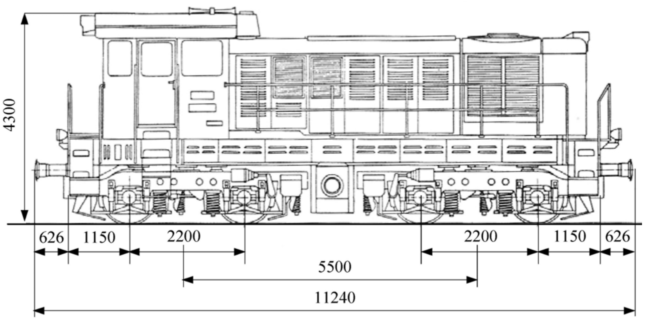


Fig.1. Locomotive type DVM12

The power of *SEMT Pielstick* 8PA4V-185VG diesel engine is 982 kW, but it was limited to 660 kW because of the compatibility with the characteristics of the main generator. Having in mind that the power of *Ganz-Jendrassik* XVI Jv 170/240 diesel engine, that was built in the locomotives type DVM2, is 441 kW, the traction characteristics of locomotives type DVM12 and DVM2 differed significantly. The maximum speed of 80 km/h remained the same.

The locomotives type DVM12 were delivered in two subtypes: DVM12-1 (manufactured in 1984) and DVM12-2 (manufactured from 1986 to 1988) with the same traction characteristics, but with slightly different equipment.

[1] Marko DJUKIĆ, MSc, "Serbian Railways" JSC, Nemanjina 6, Belgrade, Serbia, marko.djukic@srbrail.rs

Table 2. List of delivered locomotives type DVM2

Purchaser	Year of manufacture	Number of locomotives	Locomotive numbering
Prototype	1954	2	M424.5001, 5002
Hungary-MÁV	1957-1969	166	M44.001-166
	1969	5	M44.201-205
	1970	24	M44.501-524
Hungary-GySEV	1969-1971	5	M44.303-307
Hungary-industry	1963-1977	89	A25.004-013, 017-020, 022-040, 042-085, 088-099
Czechoslovakia-ČSD	1957	5	T455.001-005
China-CR	1957-1959	17	ND15.101-117
	1965	8	unknown
China-industry	1959	1	unknown
Albania-HSH	1959	1	unknown
Poland-PKP	1958	10	Lwe58.01-10
	1961-1968	263	SM41.01-263
Poland-industry	1961-1968	31	S101-131
	1963-1968	11	SM41.A-I, K-L
	1966	2	SL-3, 4
	1966-1971	64	SM41.979, 1016-1020, 1154-1160, 1164-1169, 1263, 1274-1276, 1325-1334, 1380-1383, 1422-1434, 1577-1586, 1602-1605
	1963	1	unknown
Yugoslavia-JŽ	1960-1961	15	641.001-015
	1971-1972	45	641.101-145
	1970	20	641.201-220
Bulgaria-BDŽ	1965-1968	65	51.02-66
Bulgaria-industry	1962-1970	41	DE60.01-41
	1965	1	DE60.01
	1971-1973	29	51.108-136
Turkey-industry	1976	5	TCDF 9-13
	Total:	**926**	

The manufacturing of locomotives type DVM12 lasted a relatively short time. Having in mind that in December, 1987 the *Ganz-MAVAG* factory disbanded into several independent companies the further research of the development of the locomotives of this type was not done.

3. THE LOCOMOTIVES DELIVERED TO YUGOSLAV RAILWAYS

The former Yugoslav Railways (JŽ) acquired 80 locomotives type DVM2 (table 2.) for the then ŽTP "Beograd", now Serbian Railways (ŽS). The locomotives were classified into 3 subclasses: JŽ 641.0, 641.1 and 641.2 which were each slightly different. Because of the positive experience with the locomotives type DVM2 in the beginning of the 1980s ŽTP "Beograd" decided to purchase more modern locomotives type DVM12 of which the subclass JŽ 641.3 was formed. It should be mentioned that before that there was the remotorization of locomotive JŽ 641.012 that was done in 1982 in the *Ganz-MAVAG* factory by building in the *SEMT Pielstick* 8PA4V-185VG diesel engine manufactured in the above Hungarian factory.

With the withdrawal of the locomotives type DVM2 in the late 1980s and during the 1990s the locomotives type DVM12 became the leading type of ŽTP "Beograd" shunting locomotives, although they were often used both for the traction of light freight and passenger trains on lines with lower axle load.

On May 1^{st}, 2014 the active fleet of ŽS consisted of 29 locomotives 641.3. Their arrangement by depots is shown in table 3. The locomotives with the valid revision are typed in bold.

Table 3. The arrangement of locomotives ŽS 641.3 by depots

Depot	Locomotive number
Beograd	**305**, **306**, 309, **310**, **312**, 313, 317, 319, 323, 326, **327**, 328, 329, 332
Zaječar	302, 303, 304, **318**, 320
Lapovo	308
Kraljevo	**330**
Niš	307, 311, 316, **325**, 331, **335**
Ruma	**314**
Zrenjanin	**324**

The locomotive 641.301 is in *Šinvoz* factory in Zrenjanin waiting to be scrapped while the 641.315 has already been scrapped.

Fig. 2. ŽS 641.332 (Photo: Marko Djukić)

Within the regular repair, which was realized in factory *Šinvoz,* the modification of locomotives 641.305 and 641.306 (in 2006) and 641.310 (in 2007) was done by introducing the microprocessor control. According to the same program the locomotives 641.314, 641.327 and 641.335 were modified in 2011 in factory *MIN* from Niš.

Fig. 3. ŽS 641.305 (Photo: Marko Djukić)

4. THE LOCOMOTIVES DELIVERED TO THE INDUSTRIAL COMPANIES IN FORMER YUGOSLAVIA

The industrial companies in former Yugoslavia were delivered 4 locomotives for the needs of:

- *Đuro Salaj* paper factory in Krško - 641.321 and 641.333;
- *UNIS* metal industry in Vogošća - 641.322;
- *Feronikl* factory in Glogovac - 641.334.

During the first decade of the 2000s the locomotives 641.321 and 641.333 were sold to the Italian construction company *Salcef* where they were renumbered into 2041.321 and 2041.333, and later into 2045.321 and 2045.333, respectively. During the last years these locomotives were engaged in the repair of tracks in Croatia.

Fig. 4. Salcef 2041.321 (Photo: Marko Djukić)

The locomotive 641.334 is in factory *Šinvoz* in Zrenjanin awaiting the regular repair.

5. THE LOCOMOTIVES DELIVERED TO THE INDUSTRIAL COMPANIES IN HUNGARY

The industrial companies in Hungary were delivered 5 locomotives for the needs of:

- Chemical industry *Borsodi Vegyi Kombinát* (BVK) - A25.101;
- Oil industry *Nagyalföldi Kőolajipari Vállalat* - A25.102 and A25.103;
- Chemical industry *Tiszai Vegyi Kombinát Rt.* (TVK) - A25.104;
- Oil industry *Dunai Kőolajipari Vállalat* - A25.106.

All locomotives that were delivered to the industrial companies in Hungary are in exploitation. The locomotive A25.101 operates in factory *Borsod Chem Rt.* (former *BVK*) in Kazincbarcika; A25.102 and A25.103 in company *MOL Rt.* in Algyő; A25.104 in factory *TVK* in Tiszaújváros; A25.106 in company *MOL Rt.* in Nyírbogdány.

Fig. 5. MOL A25.102 (taken from www.benbe.hu)

6. CONCLUSION

The locomotives type DVM12 were developed in the early 1980s in order to create a more modern type of DVM2 locomotives. Unfortunately, the manufacturing of the locomotives type DVM12 didn't last long and thus couldn't reach the amount of the original type DVM2.

In its period of exploitation the locomotives type DVM12 had a significant role in carrying out shunting operations and traffic on non-electrified lines of Serbian railways. In the last ten years or so an increase in the degree of immobilization and the reduction of reliability and economy of the service of these locomotives is seen as a result of inadequate maintenance and the problem of obtaining the suitable spare parts.

It is realistic to expect that the locomotives are in exploitation for another 10 to 15 years. The possibility of the locomotive remotorization should be considered in order to extend their operating life.

REFERENCES

[1] Gábor, C., Gombos, I., Meszár, A., Szabó, J., *50 éves a magyar vasút M44 sorozatú mozdonya 1957-2007*, MÁV Szolnoki Járműjavító Kft., 2007.

[2] Dallos, F., *A magyar szénhidrogénipar gazdálkodó és irányító szervezetei a MOL Rt. megalakulása elôtti idôszakban: 1933. VI. 8. és 1991. X. 1. között*, Kôolaj és Földgáz, Vol 34 (134), No. 8, Budapest, 2001.

[3] Djukić, M., *55 Years of Type DVM2 Locomotives Exploitation*, XV International Scientific-Expert Conference on Railway, Niš, 2012.

[4] Lánczos, P., Süveges, L., Szórádi, E., Villányi, G., *Fél évszázados a MÁV M44 sorozatú dízel-villamos tolatómozdonya és a Bah négytengelyes elővárosi személykocsi*, Magyar Vasúttörténeti Park Alapítvány, Budapest, 2008.

[5] Milićević, Z., Perović, N., *Dizel-električne lokomotive 641-300*, Zavod za novinsko-izdavačku i propagandnu delatnost JŽ, Beograd, 1993.

[6] *Author's personal archive.*

THE INFLUENCE OF THE RAILWAY FLEET MODERNIZATION ON THE ENERGY EFFICIENCY

Igor KORUNOSKI [1]
Kire DIMANOSKI [2]
Gligorche VRTANOSKI [3]

Abstract – *The modernization of the fleet has a significant impact on the improvement of the energy efficiency of the railway system. The modernization of all types of rolling stock in different ways contribute to improved performance, but the biggest impact on energy efficiency has the modernization of traction vehicles which are direct consumers of energy. In this paper through a "case study" has been presented the modernization of DMU Series 712, produced by the Spanish manufacturer MACOSA, the impact on energy consumption and therefore energy efficiency and the improvement of the safety and quality of services in passenger transport will be presented.*

Keywords* – *Modernisation, energy efficiency, energy consumption, DMU.

1. INTRODUCTION

Macedonian Railways Transport JSC in its passenger fleet has several Diesel Multiple Units MACOSA Series 712 produced between 1975 and 1979. They are used in Macedonian passenger rail traffic. Their long-term exploitation necessitated the modernization. During the regular general overhaul of the DMUs, several changes are made and new systems where introduced. These interventions significantly have changed the basic design of the train and increased the level of safety and comfort for passengers. The following work operations where made:

- Completely new interior lighting (replaced the old internal neon lighting with the new LED lighting);
- New sound system;
- Installation of LCD TVs in every car with the steering command in the driver cabin of the train;
- Installing CCTV for security with continuous monitoring and surveillance monitor in the driver cabin;
- Installing an alarm system against theft and damage;
- Installing fire alarm system.

2. STRUCTURE OF THE ROLLING STOCK FLEET OF MACEDONIAN RAILWAYS TRANSPORT JSC

Macedonian Railways Transport JSC is a railway operator in Republic of Macedonia, which provides services for carriage of passengers and goods on the national and international level. In order to perform the basic services for the carriage of passengers and goods different types of traction vehicles are used. Those vehicles are presented in the following tables:

Tab. 1. Macedonian Railway Transport Company – Rolling Stock Fleet

	Locomotives				Other vehicles			
Year	Total	Electric	Diesel	Shunters	Coaches	EMU/DMU	Freight wagons	Passenger wagons
2012	**43**	**16**	**14**	**13**	**48[1]**	**10**	**1011**	**68**

The series and main features of electric locomotives are reported in the following Table.

Tab. 2. Electric Locomotives Features

Class	Use	Units (Total)	Units (Operational)	Factory Year	Revamping Year	Power (kW)	Max. Speed (km/h)
441	Service	8	4	1968-1987	2001-2011	3400-3860	160
442	Service	3	2	2001	2002-2011	3860	160
461	Service	3	3	1978	2006-2008	5100	150
462	Service	2	2	2009	-	5100	120

[1] Igor KORUNOSKI, Macedonian Railways Transport JSC, Skopje, Republic of Macedonia, korun101@yahoo.com
[2] Kire DIMANOSKI, Macedonian Railways Transport JSC, Skopje, Republic of Macedonia, kdimanoski@yahoo.com
[3] Gligorche VRTANOSKI, UKIM Faculty of Mechanical Engineering, Skopje, Republic of Macedonia, gvrtanoski@gmail.com

The series and main features of diesel locomotives are reported in the following Table.

Tab. 3: Diesel Locomotives Features

Class	Use	Units (Total)	Units (Operational)	Factory Year	Revamping Year	Power (kW)	Max Speed (km/h)
661	Service	14	9	1961-1972	1998-2011	1454	120
667	Shunting	2	1	1981	1988-2003	882	
621	Shunting	2	1	1962	-	205	
642	Shunting	7	7	1962-2010	2001-2006	606	
643	Shunting	1	-	1967	2009	680	
734	Shunting	1	1	1957	2002	478	

The series and main features of EMUs/DMUs are reported in the following Table.

Tab. 4: Electric/Diesel Multiple Units Features

Class	Units (Total)	Units (Operational)	Factory Year	Revamping Year	Engine	Power (kW)	Max Speed (km/h)
412	4	2	1985-1986	1991-2006	Electric	1360	130
712	6	4	1977-2005	1988-2012	Diesel	412-522	120

The average age of the fleet is relatively high compared to the EU railways. According the UIC statistics the rolling stock over 35 years of age is belonging to one statistical group. However, it is worth nothing when the fleet often is more than 25-30 years, especially if we take in mind that the general overhauls extends the life span of vehicles for one to two decades. Old vehicles, particularly those which are not modernised often show lower energy performance (have high specific consumption for traction etc.), high emissions of gasses and higher costs for operation. The following tables are presenting the age structures of the fleet of the railways in EU and the Balkan's railways according to statistics presented by the UIC in 2012. If we analyse the use of the fleet is worth noting if the most of the diesel locomotives are used for passenger traffic, while the vice versa situation applies to the use of electric locomotives. This is justified by the incomplete electrification of the Macedonian railway network. The railway network is electrified along Corridor X, where the freight traffic on the north-south axis of the Balkan region is most common. Passenger trains, instead, often are pulled by diesel locomotives, to ensure proper and consistent service between major destinations, sometimes also on electrified sections. This happens when a train must operate through mixed sections (electrified / not electrified) to provide service for the transport of passengers, and this is the most effective way of execution of this transport through the use of diesel fleet, although not particularly convenient in cost and emissions. This kind of use has a negative impact on the type of diesel fleet, actually the large diesel locomotives are equipped with engines with large installed power suitable for traction of heavy (freight) trains and definitely over-dimensioned for passenger trains. The situation could be improved by extending the electrification of the Macedonian railway network or by using diesel traction with less installed power that adequate traction for passenger trains, such as DMU (Diesel Multiple Units) or four-axle and less power diesel locomotives. The following table shows a specific energy consumption / cost for each type of rolling stock. The strong side of the DMU and EMU compared with locomotives is pretty clear. Less weight, smaller engines with lower installed power leads to lower energy consumption. With the increase of their use in transportation of passengers and putting the focus on the use of large diesel and electric locomotives for freight traffic, where most freight demand more power for traction leads to a significant improvement in energy efficiency of the fleet. Also an coherent investment strategy for renewal and purchase of fleet in that direction is welcome, it would provide further impetus to improve performance.

2.1 Comparison with the EU countries

Different railways in Europe operate on networks of different sizes and performances, showing different results in terms of efficiency in energy use. However, power consumption can be compared between different countries just assuming uniformity, consistency and methodology of measures for comparison. The project Railenergy by UIC shows uniform data on consumption of railways respectively while presenting a set of key indicators. The effectiveness of the operation, including the technical characteristics of the railway system and the attractiveness of the services are represented by:

- Traction energy consumption per run - kWh / gross tkm or L / gross tkm for freight and passenger traffic;
- Executed transport energy consumption - kWh / road-km or L / road-km for passenger traffic and kWh or L / net ton km for freight.

In specific cases because of the absence of these data there is a need to use the general data. They can be calculated as the total traction energy (kWh/gross ton km), and compared with similar European cases.

The value of Macedonia is calculated by taking into account the prediction that in the passenger transport the average passenger weights 80 kg.

3. MODERNISATION OF DIESEL MULTIPLE UNIT MACOSA SERIES 712

Given that the use of EMU and DMU for passenger transport is far more efficient way to utilize the fleet and the use would mean a considerable saving of energy that makes this way of operation of the passenger transport energy efficient. Although the use of EMU and DMU itself is energy efficiency but considering that the fleet of Macedonian Railways Transport JSC consist of relatively old rolling stock, then the improving of the energy efficiency would contribute to an even better performance. Besides improving energy efficiency, modernization of DMU and EMU contributes to improved interior comfort, ambiance and performance. This can be a reason for greater attractiveness and appeal to passengers in same time resulting with more passengers and better utilization of the units in final case resulting in greater energy efficiency. In this context below is presented the modernization of DMU owned by MRTJSC which will be analysed as a practical example to improve energy efficiency. With the general overhaul the DMU is completely reconditioned all systems of the train, as the diesel engines, compressors, transmission, electrical installation, braking system and other sub-systems. The general overhaul and modernization of the DMU was made in MR Transport JSC Skopje.

3.1. LED lightening

The basic method of interior lighting of the train Series 712 is with use of neon lights. The poor lighting effect, the short use life, especially the energy inefficiency caused the need for replacement of the existing lighting system with modern LED lighting. The current electrical installation is used where electrical converters are installed for converting of the power from 24 VDC to 12 VDC. The LED lights are installed in the form of rods in three carriages, interspace and toilets. A 110 LED lights rods of 1 m length are installed. According the control measurements that where performed the reduced electrical consumption of energy is by 50% compared to the previous system. This shows that this measure achieved the goal of energy efficiency, and the effect of light is far better than neon.

3.2. Sound system

The basic model of DMU Series 712 possessed sound system, but over the exploitation that system was damaged and removed. In this modernization of the attic of the train a new cable network RR 2 x 0.75 was installed. The transition between the carriages was made with connectors and distribution boxes. In the two driver cabins the control system is situated (CD player, amplifier). The command is independent from the both driver cabins depending in which direction the train moves. Throughout in the train are installed 23 speakers in total with a total power of 250 W at maximum load.

3.3. LCD TV

In the space where the existing main electrical closet on the train is, a set of the main distribution board is installed. With the installation of the inverter the existing electric voltage of 24 VDC is converted to 220 VAC. Through the circuit breakers a network created which leads to more outlets of power. A signal cable network connecting the TV series is installed as same as seven LCD televisions, two in each car and at the section dedicated to first class. TV signals comes from driver cabins where CD player and amplifier are. The signal comes from the splitter which splits the TV receivers.The TVs through the connectors are supplied with a voltage of 220 VAC directly from the main switchboard. The video can be played from both driver cabins through the USB disk in the amplifier or CD.

3.4. CCTV

Throughout the train in the attic a signal cable network is installed and serves to transfer information from video cameras to the DVR. Eight cameras are installed, two in each car, in the section dedicated to first class and one in the cargo. In both driver cabins two monitors are set which allow to driver in real time to monitor the situation in the passenger compartment of the train. The entire content of the video surveillance 24 hours are recorded and stored in the DVR. The CCTV through the cable PP 2 x 0,75мм² is powered with 12 VDC. The power comes directly from the main switchboard.

3.5. Anti-theft and fire protection alarm system

The Diesel Multiple Unit is secured from theft and damage by fire. Throughout the train by the signalling network seven Motion sensors are installed, by two in each car and one in the section dedicated to first class. Also seven sensors against fire are installed. The connection of the sensors is through cable RR 12 x 0.22 mm² and 6 x 0.22 mm². The alarm unit is located in the main junction box. Above the door in the three carriages three sirens that signal when the sensor emit loud sound are installed too.

4. THE EFFECTS OF THE MODERNISATION OF THE DMU TOWARDS ENERGY EFFICIENCY

The effects of the modernization of the DMU towards the energy efficiency are high. From the November 2012 MZ Transport for passenger transport used to use two DMU and the remaining transportation of passengers was served by diesel locomotives series 661. With the modernisation and putting in to service the two overhauled DMU the energy efficiency was significantly improved. Table 11 shows a significant reduction in consumption of oil and grease. During the period of one year (from 01.08.2012 to 01.08.2013) the lubricants consumption is reduced by about 50%. While for the same time period the oil consumption is reduced by about 30%. This data shows that at the time of putting in to service of the two reconditioned and modernized DMU’s a great energy efficiency and cost savings are made for the company.

5. CONCLUSION

Taken in consideration that in fact Macedonian Railways Transport JSC owns old traction and towed vehicles, the procedure for modernization of existing rolling stock it is of particular importance for the company. The financial savings are huge as same as the benefits felt by passengers themselves as users of railway passenger traffic. It can be concluded that the investment needed to modernize the DMU returns very soon and only as a result of savings in consumption of oil and lubricants, and not to neglect the fact that maintaining the DMU is considerably cheaper and simpler unlike diesel locomotives series 661 which are used for traction in the passenger rail traffic.

The introduction of the new systems in the DMU is to increase the level of safety, comforts and security of the DMV.

REFERENCES

[1] M. Steiner, R. Manser: "Energy Storage in Railway applications ", 2nd BOOSTCAP Meeting 2001

[2] Fribourg (CH) Kilibrada M., Zecević S., Upravljanje kvalitetom u logistici, Saobraćajni fakultet, Beograd, 2008

[3] MACOSA series 712, original manufacturer technical documentation, 1979

[4] F. Hentschel, K. Mueller, M. Steiner, "Energy Storage on Urban Railway Vehicles",UIC Railway Efficiency Conference May 2000

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

MEASURING ACCELERATIONS FRAME TRAM BOGIES T81 IN ORDER TO ESTABLISH THE REASONS FOR THE EMERGENCE AND DEVELOPMENT OF CRACKS

Emil M. MIHAYLOV [1]
Emil IONTCHEV [2]
Dobrinka ATMADZHOVA [3]

Abstract *– This paper refers to the frames of tram bogies T81, fitted on operating trams types T6M 700 and T8M 700M in Sofia. In the material are described the measurements of the accelerations in the bogie frame. A method for processing the received data is described and analyzed. Based on this analysis, it is found that one of the reasons for appearance and development of cracks in the bogie frame are the large values of the accelerations and the resulting deformation and material fatigue.*

Keywords **– Tram, bogies, wheelset, wheels, acceleration, accelerometer.**

1. INTRODUCTION

In recent years an increasing number of cracks are found in the crossbar of the frame at the tram bogies T81. About 80 % of all bogies undergoing major repair have cracks. The cracks are concentrated in two sections - at each end of the crossbar below the weld.

In this material are published the results from a research on the impact of bumps in the railroad on the undercarriage of the trams and particularly to the bogie frame. Accelerations are measured in the frame and based on that are made calculations on the generated by them internal stresses using the finite element method and the program Autodesk Inventor Pro 2012.

2. PROBLEM

The frame of the tram bogie T81 is open type, it has an H-shaped spatial form. At both ends of the longitudinal beams are shaped the upper cups of the spring sets of the axle spring rate (ASR). In the middle of the longitudinal beams along the crossbar are formed the bottom cups of the springs from the CSR (*Fig. 1.a.*).

In the modified design the cups are with a closed top, and the new cups, of the already shorter springs lie on the upper sheet of the longitudinal beams (Fig. 1.b.).

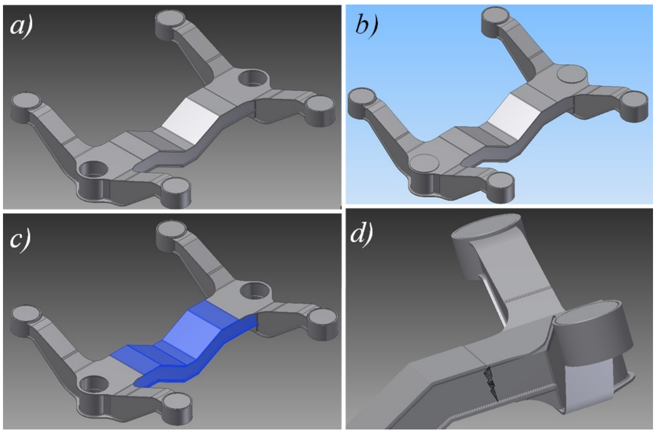


Fig.1. Tram bogie frame T 81

In Figure 1.c. in blue is shown the crossbar of the frame, and in Figure 1.d. is shown the location of the occurrence of cracks - along the weld between the upper sheet of the transverse and longitudinal beams.

According to the observations a crack first appears in the weld between the upper sheets of the transverse and longitudinal beams, then the crack starts developing randomly on the vertical sheets. In picture 1.a. is shown a crack in the weld and on picture 1.b. - The development of cracks in the vertical wall of the bar.

[1] Emil MIHAYLOV, M.Sc., PhD Student, University of Transport, 158 Geo Milev Street, Sofia 1574, Bulgaria, emm_1968@abv.bg
[2] Emil IONTCHEV, PhD, University of Transport, 158 Geo Milev Street, Sofia 1574, Bulgaria, e_iontchev@yahoo.com
[3] Dobrinka ATMADZHOVA, PhD, University of Transport, 158 Geo Milev Street, Sofia 1574, Bulgaria, atmadzhova@abv.bg

Picture 1. Occurrence of crack on the weld and developments in the vertical sheets.

3. MEASURING THE ACCELURATIONS IN THE FRAME

For registering of the accelerations in the frame were used two measuring systems. The location of their installation on to the bogie frame is shown in Figure 2. Position 1. is the system for measuring accelerations in the cup above the spring of the ASR at the right wheel of the first wheelset. With position 2. is marked the system of measuring accelerations above the endangered section.

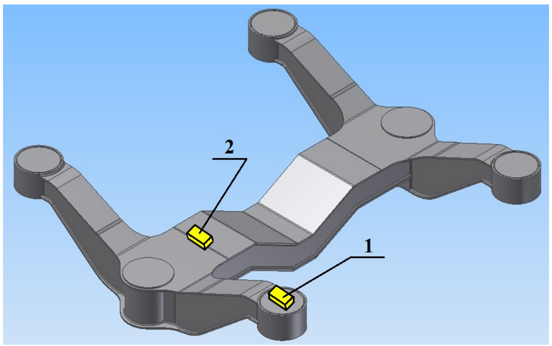


Fig.2. Locations of the measuring instruments.

The accelerometer (1) is shown in picture 2. a sensor from the company Analog Devices - ADIS16405 was used, which provides an opportunity to measure three axes of linear acceleration, angular velocity and magnetic induction of the Earth's magnetic field. The measurement range of the accelerations is ± 18g, at angular speed ± 300 ° / sec, magnetometer ± 2,5 g. The maximum operating frequency is 819,2 Hz. To locate the position and speed of the vehicle in the system is built-in a receiver of signals from the two global navigation systems - GPS and GNSS. Its type is LEA 6S, manufactured by the company *ublox*. To the inertial data is added the location data from the GPS / GNSS and both are simultaneously recorded on a SD card. Simultaneously, the navigation data is transmitted over a GPRS channel to a remote server.

Picture 2. Accelerometer placed on the cup of the spring from the ASR..

The second system (2) is made of a personal computer and a system for development by the company ST [1]. It is able to measure accelerations in three axes in the range ± 2g, ± 6g, with a frequency from 40 to 2560 Hz.

4. RESULTS FROM THE MEASUREMENTS

The route (Fig. 3.a.) includes sections with different track condition.

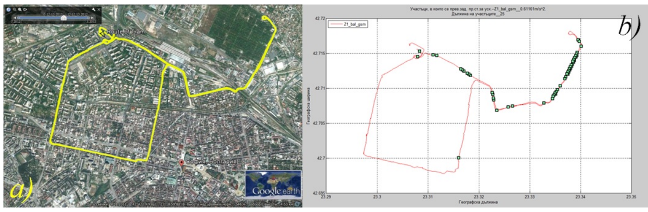


Fig.3. Route of the measurement.

The first part of the route the railroad is in good condition and the second part are the areas with poor railroad conditions.

In Figure 3.b. are shown the locations where the effective values of the accelerations are above a certain threshold value determined by the algorithm described in [2]. Cluster of sites which exceed the threshold value are observed in the second part of the route where the railroad is made of low channel rails embedded in panels. The values the accelerations in the cup of the ASR were recorded at a frequency of 240 Hz, and the accelerations in the longitudinal beam with a frequency of 160 Hz. Afterwards, the received signals are processed with programs developed in the programming environment Matlab. The peak and the effective value of the accelerations are determined, their spectral density is also determined.

The peak value of the acceleration is determined by looking for the difference between the maximum and minimum values of the acceleration in a window with a length of one second. The resulting peak values of the acceleration of the cup of the spring from the ASR are shown in Figure 4. And in Figure 5.are shown the effective values of the acceleration.

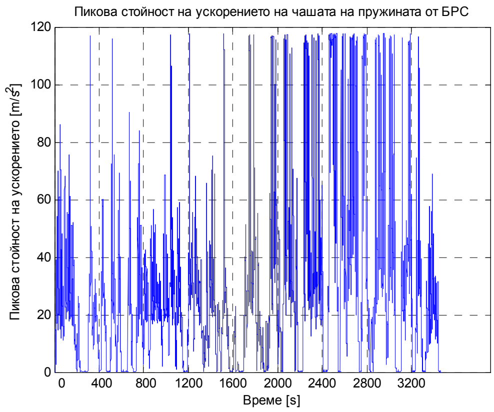


Fig.4. Peak value of the accelerations on the cup of the spring from the ASR.

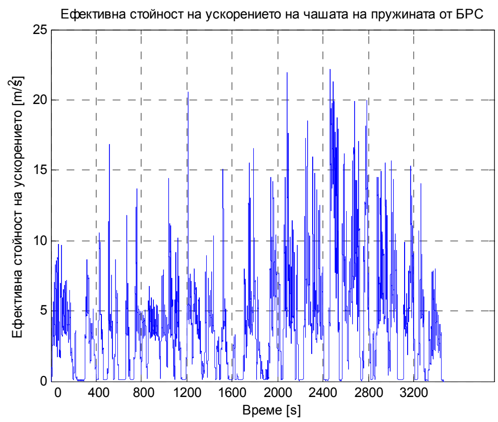


Fig.5. Effective value of the accelerations on the cup of the spring from the ASR.

The effective value of the accelerations are determined by the equation:

$$RMS\{A(n)\} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} A^2(n)} \qquad (1)$$

Where N - number of readings in the window, A - acceleration value for the n-th report. The window used for determining the the effective value is also with a 1 second duration.

The results obtained after processing the signals indicate that the second part of the route (after 1800th second) the values of the accelerations are much higher. There appear the more dangerous low-frequency vibrations.

5. INFLUENCE OF THE FORCES CAUSED BY THE ACCELERATIONS ON THE FRAME OF THE BOGIE

In Figure 6. is a diagram to the static forces acting on to the bogie frame. Where Q is the static load of the car body transmitted to the over-spring beam via the central bearing, Q / 2 is distributed static load by CSR and Q / 4 is the static load on each of the sockets.

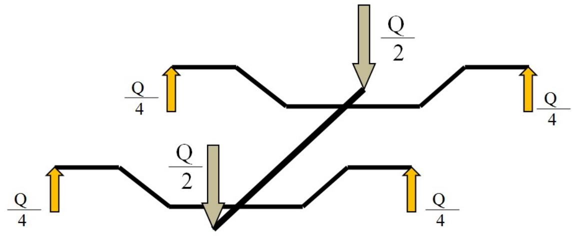


Fig.6. Scheme of the static load of the bogie frame.

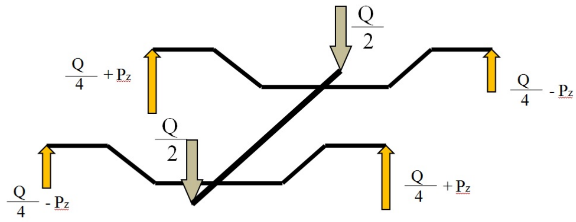


Fig.7. Scheme of the forces whenthe front right wheel is crossing a bump in the road.

When one of the wheels passes through a random bump in the road (Fig. 7.) depending on its shape (rising or sinking of the ground), emerge forces which get summed up with the existing static forces. Torsional tensions that have emerged in the frame are transmitted in the structure diagonally symmetric [3], and tend to deform the bogie frame in the scheme shown in Figure 8. Possible deformations of the frame of the bogie under the effect of the forces of static load and the forces caused by the unevenness of the road are shown Figure 9.

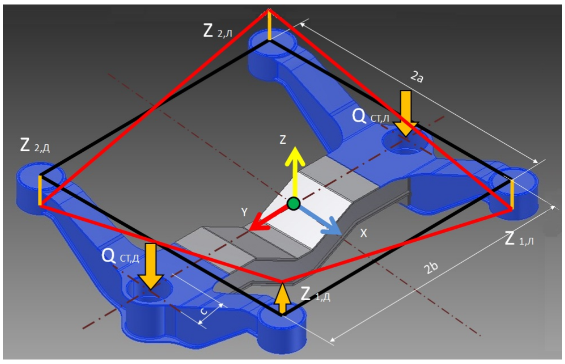


Fig.8. Scheme of the twisting of the frame.

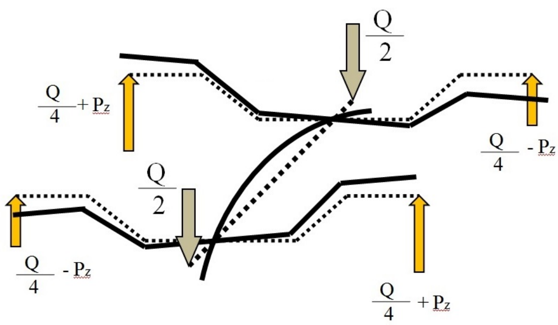


Fig.9. Deformation of the frame under the action of the forces caused by unevenness of the road.

After the passing of the first wheel through the bump in the road immediately after that the rear wheel also passes through it. Then follows a new twist to the bogie frame according to Figure 8. then the forces all have the same value but with opposite signs, i.e., follows a new twist on the beam in the opposite direction. The intensity of the process of successively twisting in opposite directions depends on the speed. The period is the time need for the two right wheels to pass over the same bump. At a speed of 3 m/s the time for the two right wheels of the bogie to pass over the same bump is about one second.

The crossbar beam of the bogie frame is subjected to a large number of cycles with loads the block at various levels, which leads to a strong reduction of the fatigue strength of the material.[4]

The values obtained for the stresses in the beam calculated with maximum values of accelerations exceed the stress values for the material and its border of drag out.

P_z values obtained after calculation are used to analyze the internal stresses in the finite element method using Autodesk Inventor Pro 2012. Analysis was made with the values obtained from the average and maximum acceleration under load.

In Figure 10. are shown the results of the calculations of the internal stresses in the bogie frame from the average values of the accelerations in scale with a maximum value of 200 MPa.

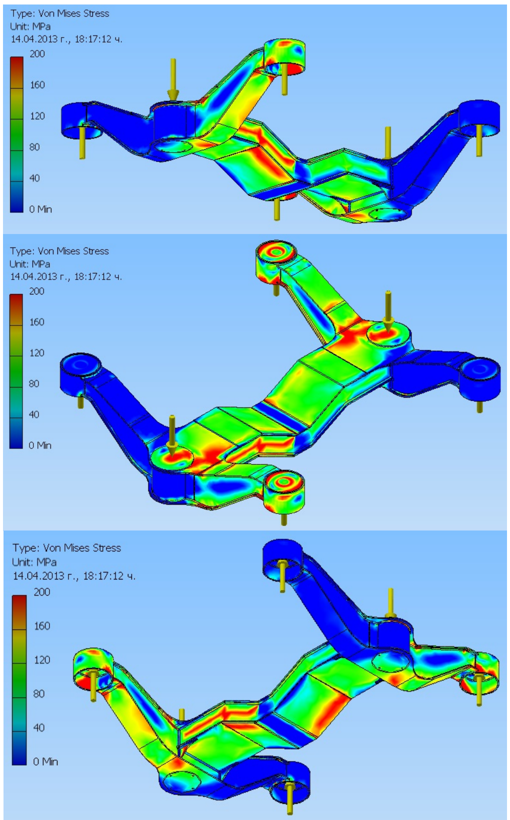


Fig.10. Tensions in the bogie frame, with an average values of acceleration.

Figure 11. Shows the results of the internal stresses in the frame at maximum acceleration, on a scale with a maximum value of 1400 MPa.

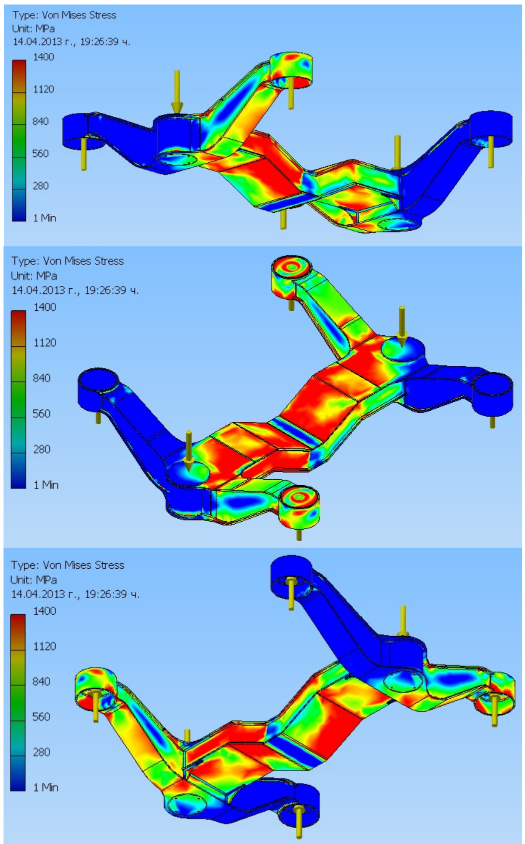


Fig.11. Tensions in the bogie frame at maximum acceleration.

Figure 10. And 11. clearly shows that the highest levels of internal stress in the crossbar are in the area of the occurrence and development of cracks.

6. CONCLUSION

The data published in this paper confirm that the track condition is one of the reasons for the emergence and intensive development of cracks in the crossbar of the bogie frame.

REFERENCES

[1] www.st.com, UM0285, User guide, EK3LV02DL Evaluation Kit, September 2006

[2] Iontchev E., Simeonov Iv., Miletiev R., *GSM/GPS/INS system for urban railway monitoring based on MEMS inertial sensors*, Proceedings of the 22nd Micromechanics and Microsystems Technology Europe Workshop, Tonsberg, Norway, 19-22 June 2011, pp. D81

[3] Ружеков Т., Пенчев Ц., Димитров Е., „*Теория и конструиране на железопътна техника*", ВТУ, София, 2011 г.

[4] Пенчев Ц., Атмаджова Д., „*Якост и дълготрайност на автомобилна и железопътна техника*", ВТУ, София, 2007 г.

THE BULGARIAN STATE RAILWAYS EXPERIENCE IN DETERMINING FATIGUE STRENGTH OF ROLLING STOCK STRUCTURES

Dobrinka ATMADZHOVA [1]

Abstract *– The mandatory tests of newly built railway cars have been implemented in the Bulgarian state Railways (BDZ) since 1966. The application of UIC/ORE B12/RP17 began in R-modification method (diagram Moore - Commerce - Jasper) in 1978. The UIC method of Goodman diagram became applicable in 1980, as determination of extreme values of the dynamic stress was performed as follows: by actual manifestation until 1982; 1982 - 1988 years – by "three Sigma" rule in the period 1982-1988 and by the method of SNCF since 1988. Although the UIC method is primarily intended for testing, it can also serve for calculations at the design stage. The paper examines the BDZ experience to determine fatigue strength at the stages of design and testing of rolling stock structures.*

Keywords – Railway vehicles, strength, fatigue, durability, testing and design.

1. INTRODUCTION

Determining the fatigue strength is achieved in stages of design and testing of rail vehicles.

The main factors (or variables), we operate are classified into two groups - resistivity and load as:

- the group of factors "resistivity" R is determined by the boundaries of: fatigue σ_{-1}, τ_{-1}, destruction σ_B, τ_B, yield stress σ_s, τ_s ... of material, i.e. R (σ_{-1}, τ_{-1}, σ_B, τ_B, σ_s, τ_s …);

- the group of factors "load" T is determined by the stresses: equivalent σ_{eq}, σ_{max}, τ_{max} and amplitude σ_a, τ_a, the asymmetry of the cycle r, etc., i.e. T (σ_{eq}, σ_{max}, τ_{max}, σ_a, τ_a, r …).

2. COMPUTATIONAL METHODS

Although all of the aforementioned factors that are probabilistic in nature (because they manifest themselves as "not being completely determined" but with some dispersion), the computation methods, which are involved, are usually based on deterministic but not on probabilistic approach, nevertheless that it is able to provide higher accuracy. It is because at the stages of design (construction) and feasibility studies, due to the extremely limited amount of information, the traditional deterministic approach is not only preferable to the probability one but in most cases it is the only approach possible to implement.

Based on the hypothesis of Palmgren-Miner related to linear summation of faults

$$\Sigma n_i/N_i = a \quad (1)$$

and Wöhler's law

$$N_i\sigma_i^m = N_{\text{Б}}\sigma_{-1D}^m \quad (2)$$

The formula obtained

$$\sigma_{-1D} = \sqrt[m]{\frac{1}{a.N_{\text{Б}}} \sum_{\sigma_i \geq 0,5\sigma_{-1D}}^{\sigma_m} n_i\sigma_i^m} \quad (3)$$

is an output one both for manufacturing and wagons and rolling stock in general. The main indications are: σ_{-1D} – fatigue limit of the piece; $N_{\text{Б}}$ – basic number of cycles (10^7); a – coefficient of accumulation ($a_{\text{средно}}$ = 1); m – power factor; σ_i and n_i – stress and number of cycles of the i-th degree.

Formula (3) adapted for application to transport objects with limited amount of information and a specified value of the safety factor λ is usually applied in the form:

$$\sigma_{-1D} = \lambda\sqrt[m]{\frac{L}{a.N_{\text{Б}}.\ell} . \sum_{\sigma_i \geq 0,5\sigma_{-1D}}^{\sigma_m} \left|n_i\sigma_i^m\right|_\ell} , \quad (4)$$

where: L is the distance traveled by the vehicle in km for the specified period of service (job), for example the whole amortization period, the period to overhaul, etc.; ℓ - length in km of a representative section (ℓ << L) characterized by a spectrum of load, which is in the real section L for the entire period of operation.

Formula (4) is applied most often after tests carried out in order to check for the satisfaction of the conditions of fatigue strength based on information

[1] Dobrinka Atmadzhova, Professor, PhD, University of Transport (VTU Todor Kableshkov), 158 Geo Milev Street, Sofia 1574, Bulgaria, atmadzhova@abv.bg

gathered from them. In rare cases, it is applied at the stage of design to perform fatigue-strength calculations based on virtual representative section. This formula and the method based on it, in fact are principally not different from the method of British Railways (BR) to predict the service life of rail rolling stock in the part of "analysis of the effect of damaging by loads". Indeed, (4) where λ =1 and a = 1 can be represented by the ratio:

$$\frac{\ell}{L}=\frac{\sum\limits_{\sigma_i \geq 0{,}5\sigma_{-1D}}^{\sigma_m}\left|n_i\sigma_i^{\ m}\right|_\ell}{a.N_Б.\sigma_{-1D}^{\ m}}, \tag{5}$$

known by the name "relative damage" or "relative resource", which, related to 1 km mileage (i.e. with $\frac{\ell}{L}/\ell$) according to the given one in the method of BR definition, represents the reciprocal value of the distance, i.e. 1/L, where the very mileage L with the identical expression resulting from (4) is determined from:

$$L=\frac{\ell.N_Б.\sigma_{-1D}^{\ m}}{\sum\limits_{\sigma_i \geq 0{,}5\sigma_{-1D}}^{\sigma_m}\left|n_i\sigma_i^{\ m}\right|_\ell} \tag{6}$$

3. MANDATORY TYPE TESTS INCLUDING ASSESSMENT OF FATIGUE STRENGTH BY EXPERIMENTAL AND THEORETICAL NON-DESTRUCTIVE APPROACH

The mandatory tests of newly built wagons in Bulgaria have been introduced since 1965-1966, when the equipment of Wagon Lab with devices supplied from the USSR was finished and the testing device for stationary tests on wagon structures was built up. In this initial stage (until 1978) the strength assessment of static bench tests was performed by the standards of UIC while for the train (road) tests the USSR standards of wagon manufacturing were used to assess, even though indirectly and not so strictly, not only the classical strength but also the fatigue strength (or durability) of structures. Internal (created in NRIT-BDZ) regulations, standards, etc. based on own examinations were also applied.

The implementation of the uniform UIC/ORE method in modification R-method (diagram Moore-Commerce-Jasper) based on bulletin ERRI (ORE) B12/RP17 from 1977 began in 1978 [1]. It provides theoretical and experimentally verifiable complete assessment of fatigue strength (durability) in a form convenient for direct application, taking into account production, technological and other factors in real conditions of production and operation of wagons. In 1980, based on the bulletin published, this method began to be applied using the diagram of Goodman-Smith (or Goodman) and later, in accordance with the official regulations of ERRI (ORE), several clarifications and changes were brought in it, e.g.:

1. The definition of the minimum and maximum value of the total stress as well as the dynamic stress determining them based on the mandatory mathematical statistical processing with the rule of "three Sigmas", i.e. $\sigma_{dmax} = m(\sigma_d) + 3S_{\sigma d}$; $\sigma_{dmin} = m(\sigma_d)-3S_{\sigma d}$. Later, in 1989, this rule was substituted with the condition to determine σ_{dmax} and σ_{dmin} with a probability level P = 99,865%, 0,135% respectively.

2. The graphical determination of $\sigma_{d\,max} \equiv \sigma_{d|99{,}865\%|}$ and $\sigma_{d\,min} \equiv \sigma_{d|0{,}135\%|}$ with scales of construction especially selected by the method of SNCF: only for authoritative strains.

The so-called experimental-theoretical non-destructive approach is briefly characterized by well-established methods and programs, which are used to carry out defining[1] tests on a test sample[2] made to work under operating conditions in characteristic modes (train, shunting, Loading and Unloading Operations - LUO, etc.). At that strains and dynamic wheeled indices as well as the factors of "load" (strength, speed, acceleration, ...), which caused them are measured (or registered, reported, observed); the information collected from the tests is processed and the results obtained for different features (strain, acceleration, etc.) are compared with the admissible values of established criteria that are theoretically grounded and tested in practice.

It is the experimental and theoretical non-destructive approaches that all required (by government and departmental regulations) type tests have been performed through, including: strength, general dynamic and braking tests.

The main test facilities at the institute NRIT are:

a) Wagon laboratory for strength and dynamic tests, which has equipment with a capacity of not less than 48 channels, of which 36 amplifying; after 1979 it was reequipped with new apparatuses having greater capabilities, including automatic information processing.

b) Wagon laboratory for brake tests of train sets, locomotives and separate wagons also equipped with multi-devices capable of parallel registration of forces, pressure, acceleration, etc. in train and stationary mode.

c) The testing device for static testing of wagons that performs only some supporting functions with other types of testing is not examined here.

d) Other (supporting):

- facilities for turning "bogie-body" to measure the

[1] Defining studies are those which determine the basic characteristics of waggons: fatigue-strength, dynamic, braking, without destruction.

[2] The samply tested is most often a prototype but in some cases it is one of regular production, operation, etc.

stiffness and torsion and "wheel-rail" loading of rail vehicles;

- stationary laboratories for strength and dynamic tests, brake tests, etc.

Finally, regarding the mandatory type tests of wagons carried out until now using experimental and theoretical non-destructive approach it can be concluded that all (over 30) structures subjected to these tests and being in series production for the BDZ and export (from 1965 until the cease of this activity after the democratic changes) showed no mass defects in long-term operation. These tests, undoubtedly, contributed not only to ensuring regular production of wagons and increasing their reliability in operation, but also to creating developments of scientific and technological achievements, e.g.:

- identification, study and creation of theory of torsion vibrations of wagon structures;
- reducing the intensity of wear-out of flanges and rails and producing a bogie with radial entry into curves;
- a system of rapid unloading (stripping) oil from rail tankers, etc.

The test facilities created by the staff of the National Research Institute for Transport Ltd. (NRIT) in Sofia with the BDZ as well as the corresponding research methods and approaches, are mostly unique and many of them were patented as inventions.

4. BENCH TESTS ON FATIGUE STRENGTH

The bench tests on fatigue strength are held mainly by destructive approach as depending on the quality "durability" of the tested sample their duration is limited by the destruction[3] of the sample or by reaching a specified number of cycles.

The first bench tests of wagons in Bulgaria were conducted in 1970. Then, due to the transition to a new brand of steel for wagon manufacturing, it was decided to test its durability in a real (natural) structure of wagon (particularly of a tank) with longitudinal impact loads of a large number of cycles (500 000). It was possible due to the extremely high productivity of the device and its ability to operate in an automatic mode with relatively low energy consumption. A brief explanation of its structure and the main principle of operation will be given below.

The device of impact tests of wagons (Fig. 1) built in NRIT with the BDZ in 1969 is characterized by a flat and straight track section where there is a rope 1 stretched longitudinally on both sides guided by rollers 2, which in turn are mounted on the energy absorbing devices 3 in pillars 4 located at the four corners. Prior to each impact test the active wagon A, which is initially attached (bonded) to the rope, is accelerated to a specified speed and at the moment immediately before impact contact with buffers, it is automatically disconnected (released) and then after the impact the start position of wagons is restored (also automatically!).

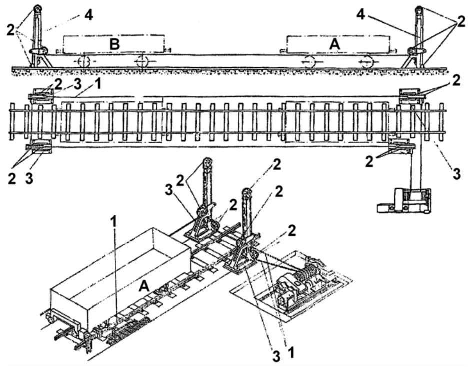


Fig.1 Device of impact tests of wagons.

The testing device is able to work with both with hand control and in automatic and semi-automatic mode according to three different programs (or schemes):

- by a traditional programme characterized with one active (accelerated) wagon and one passive wagon (Fig.1);
- by a programme with two active wagons accelerated into oncoming traffic;
- by "shuttle" programme characterized with two passive wagons and one active wagon between them, which is accelerating now in one, then in another direction.

The bench tests of wagon bogies under the requirements of UIC code 510 and code 515 in regard to fatigue strength with destruction were carried out first in the period 1986-1988. It was then when a model bogie of passenger carriage of type T73AD and a freight wagon Y25Cs were tested. Subsequently, in different periods several models of bogies family Y25, including also modifications "R" and "L", were tested.

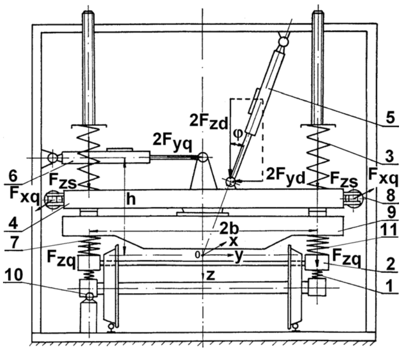
As it is known, according to the UIC requirements [2], the bench tests of bogies are performed at two stages:

- first stage – static tests;
- second stage – tests of fatigue strength,

as the obligatory condition is: the second stage is performed if the requirements at the first stage are met. Here we will put the accent on the second stage.

The tests of fatigue strength were conducted using two different devices: for bogies of freight and passenger wagons. The tests of freight wagon bogies corresponded exactly to the requirements of UIC code 510 for applying power of five components on each side of the frame beam: vertical static F_{zs}, vertical quasi F_{zq}, vertical dynamic F_{zs}, quasi horizontal (transverse) F_{yq} and horizontal dynamic (transverse) F_{yd}, as the structure of the testing device meets those requirements.

[3] The destruction may be up to a specific, predetermined level or to such a state that does not allow the continuation of testing.



1 – spring first degree; 2 – frame-side; 3 loading springs for static load; 4 – loading bar; 5 – inclined service cylinder; 6 and 8 – horizontal service cylinders; 7 and 11 – springs second degree; 9 – over-spring beam; 10 - support.

Fig. 2 Scheme of a device of testing the fatigue strength of a frame and over-spring beam of T73AD bogie

Regarding the methodology and the device (Fig. 2) for testing a passenger carriage bogie, taking into account the results of previously performed train (track) tests, it was considered necessary that [3]:

1) Over-spring beam (9) (Fig. 2) of the bogie should be included in the bench tests together (in parallel) with the frame without breaking the requirements of UIC related to the frame tests.

2) An extra pair of forces F_{xq} should be applied by service cylinders (8) (Fig. 2) with a quasi-static effect in longitudinal direction in order to simulate the friction "wheel-rail" forces in the same direction where the torque is seeking to obliquely deform the frame seen in plan.

According to the scheme of bench testing a passenger bogie in NRIT (Fig. 2), by service cylinder (5) (120kN) mounted at an angle, (4) vertical and horizontal dynamic components horizontal and quasi-static forces F_{zd} and F_{yd}, are exercised by means of the loading beam. The service cylinders (6) and (8) (40kN) are used to exercise the horizontal quasi-forces $2F_{yq}$ and F_{xq}; as by the action of $2F_{yq}$ vertical quasi-static forces F_{zq} are created. The vertical static load is implemented by coil springs (3) and the bogie springs, of the axle-box spring degree (1) and of the central one (11), are blocked in order to save energy and increase the frequency of loading.

The devices for testing passenger and freight bogies are given in Fig. 3 and Fig. 4.

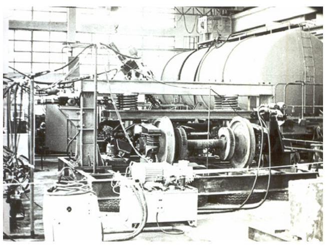


Fig. 3. General type of a device for testing dynamic fatigue of passenger bogies.

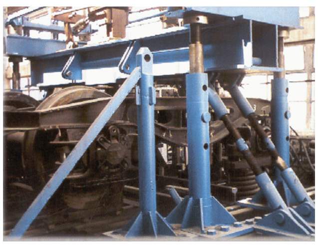


Fig. 4. General type of a device for testing dynamic fatigue of freight bogies.

The section modulus of turning "carbody-bogie" is measured by the stand (Fig. 5), which is a rotating platform 2 with rails 1 (maximum angle of 12°), building on the thrust bearing 4-driven system hydraulic power cylinders 3, which powered by hydraulic station. During rotation measured torque M and angle-ψ, forming diagram "ψ-M." The stand is used for testing the durability of a large number of cycles.

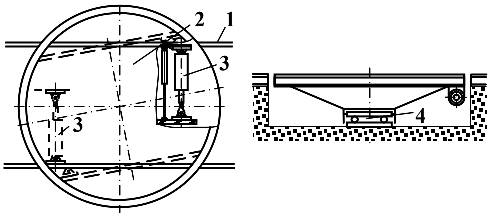


Fig. 5. Stand for measuring section modulus of turning "carbody-bogie".

In 1980-1991, using the improvised testing facilities in NRIT, fatigue tests on models (samples) were implemented for:

- side walls (particularly for their bearing pillars) and doors of wagon Eas;
- doors and windows of a passenger carriage;
- the "body-bogie" connection of a passenger wagon using own methodologies of this istitute.

5. CONCLUSION

1. The mandatory tests (strength, general dynamic and braking) for the newly built rail structures with indirect assessment of fatigue strength by the non-destructive approach have been introduced in Bulgaria since 1965.

2. The direct assessment of fatigue strength (based on tests as in the preceding point) has been applied since 1978 in compliance with UIC / ERRI B12RP17-1977.

3. The bench tests of fatigue strength by destructive approach on bogies of freight and passenger cars according to the requirements of UIC code 510 and 515 has been applied since 1986.

4. All newly constructed structures of wagons in Bulgaria, which have undergone mandatory tests, have shown no mass defects in long-term operation.

REFERENCES

[1] ERRI(ORE) QUESTION B12 Standardisation des Wagons Rapport №17, Utrecht 1977-1980.

[2] UIC – 510, 515.

[3] Petrovic D., M. Bizic, M. Djelosevic, Determination of dynamic sizes during the process of impact of railway wagons, Archive of Applied Mechanics, DOI: 10.1007/s00419-011-0549-5, (2011).

[4] Petrovic D., M. Bizic, Improvement of suspension system of Fbd wagons for coal transportation, Engineering Failure Analysis 25 (2012) doi:10.1016/j.engfailanal. 2012.05.001.

[5] Bizic M., D. Petrovic, Z. Djinovic, M. Tomic, Experimental Testing of Impact of Railway Wagons, Experimental Techniques, July 2012, doi:10.1111/j.1747-1567.2012.00850.

[6] Penchev T. Atmadzhova D. Strength and durability of automobile and railway equipment, S. 2007

Traffic and Transport

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

ASSESSING ACCIDENT SEVERITY RISK AT RAILWAY CROSSINGS IN SERBIA BY USING A MULTINOMIAL LOGIT MODEL

Sandra KASALICA [1]
Dušan JEREMIĆ [2]
Marko BURSAĆ [3]
Goran TRIČKOVIĆ [4]

Abstract – *This study used a multinomial logit model for modelling the accident severity on railway crossings in Serbia. The road sign warning device, exposure to traffic and maximum train speed at a given crossing were significantly associated with probability of accident frequency and significantly influenced the expected total number of fatalities or injuries caused by traffic accidents. Sensitivity analyisis is conducted to evaluate the effect of an explanatory variables changes on different accident severities.*

Keywords – Railway traffic safety, Railway crossing, Accident severity, Multinomial logit model.

1. INTRODUCTION

In the last few years, more collisions and severe crashes with a considerable material damage at railway crossings have been reported by the Serbian Rail Administration. For example, from 2007 through 2011, 312 accidents occurred at 2,138 railway crossings in Serbia. These accidents resulted in 59 fatalities and 130 injuries [1]. Currently more than 74% of the 2,138 railway crossings in Serbia are of passive control type (St. Andrew's cross and Stop sign). Therefore, investigations of the risk factors that may be associated with accident at railway crossings are vital in order to identify the crossings for future safety improvement.

The generalized logit model was used to explore the key factors that may be responsible for different degrees of accident severity at railway crossings [2]. A zero inflated Poisson regression model is used to describe the relationship between the extra zero count fatality or injury data and explanatory variables on railway crossings in Taiwan [3]. In this paper the analysis of accident severity is performed using a multinomial logit model.

2. DATA DESCRIPTION

The data supporting this research came from two sources; (1) Accident database of Serbian railway crossings (2007-2011) [4] and (2) the Serbian railway crossing inventory database (2007-2011) [5]. The available historical accident data set for modelling accidents at railway crossings were collected from 2007-2011 (5 years of accident information) [4] and provides the information about the time, location and conditions of accident for 2,138 railway crossings, but we observed 745 crossings.

Dependent variable accident severity is defined as an average impact per accident. The average impact is a weighted average of deaths and injuries in each accident. In this paper the accident severity is characterized as equivalent fatality. We equalized three injuries as an equivalent of one death according to Regulation on personal compensation (Official Gazette of the Republic of Serbia no. 34/2010) [6].

The accident frequency is the number of accidents that took place at a given time period. It is a countable variable that in our observations takes values from 0 to 5. The frequency of these values is given in Tab. 1. It represents the number of accidents that took place at observed 745 crossings in the period from 2007 through 2011. In this period of time, at 514 (69%) crossings there were no accidents, and at the remaining 231 (31%) crossings there were 312 accidents in total. This dependent variable accident severity is further categorized into three levels: Y=0 (i.e., accident severity of 0), Y=1 (i.e., accident

[1] Sandra KASALICA, Ph. D, Railway College of Vocational Studies, sandra.kasalica@gmail.com
[2] Dušan Jeremić, M Sc, Railway College of Vocational Studies, dusan.jeremic@vzs.edu.rs
[3] Marko BURSAĆ, B Sc, Railway College of Vocational Studies, marko.bursac@vzs.edu.rs
[4] Goran TRIČKOVIĆ,Spec. App. Eng. Traffic, Railway College of Vocational Studies, tricko86@gmail.com

severity of 1) and Y=2 (i.e., accident severity of 2). In other words, accident severity is 0 if there were no injuries or fatalities, it takes value 1 if there were less than 3 injuries per accident, and it takes value 2 if there were 3 or more injuries (or 1 fatality) per accident. The frequency of these values is given in Tab. 1.

Tab. 1. Observed accident frequency and accident severity frequency of Y=y

Accident frequency level	Observed frequency	Accident severity level	Observed frequency
$y = 0$	514	$y = 0$	633
$y = 1$	180	$y = 1$	72
$y = 2$	35	$y = 2$	40
$y = 3$	6		
$y = 4$	6		
$y \geq 5$	4		

The Serbian railway crossing inventory database (2007-2011) [5] contains the characteristics of each railway crossing and its traffic conditions. Let $\mathbf{x} = (x_1, x_2, x_3, \ldots, x_{17})$ be a 17–variable vector corresponding to a railway crossing. Here, x_1 denotes railway category which is 1 for main lines, and 0 for other lines. x_2 (EXPO) denotes geometric mean of number of trains per day and average annual daily traffic volume (AADT). x_3 denotes maximal train speed at a given crossing. x_4 is a binary variable for number of tracks, which is 1 for single track and 0 for multiple track. x_5 denotes crossing surface type, which is 1 for asphalt, concrete panels and rubber panels and 0 for cobblestone, wood planks and gravel. $(x_6, x_7, x_8, x_9, x_{10})$ is used to denote road type, which is $(1,0,0,0,0)$ for main road; $(0,1,0,0,0)$ for regional road; $(0,0,1,0,0)$ for rural and local; $(0,0,0,1,0)$ for farm and non-categorised and $(0,0,0,0,1)$ for street. x_{11} is a binary variable for crossing width, which is 1 for 6m or less and 0 for more than 6m. x_{12} is binary variable for sight triangle, which is 1 if exists and 0 if it doesn't exists. x_{13} is binary variable for crossing angle, which is 1 for angle from 60° to 90° and 0 for less than 60°. $(x_{14}, x_{15}, x_{16}, x_{17})$ is used for warning devices which is (1,0,0,0) for road signs; (0,1,0,0) for flashing lights; (0,0,1,0) for full gates and (0,0,0,1) for half-gates.

3. MULTINOMIAL LOGIT MODEL

The analysis of accident severity is performed using a multinomial logit model. Multinomial logit models have gained popularity for this type of data mainly because they can account for the dependent variable's ordinal nature.

Let $\pi_j(\mathbf{x}) = P(Y = j; \mathbf{x})$ be the probability of $Y = j, j = 0, 1, 2$. The multinomial logit model is given as follows [2]:

$$\text{logit}[\pi_j(\mathbf{x})] = \log\frac{\pi_j(\mathbf{x})}{\pi_0(\mathbf{x})} = \alpha_j + \mathbf{x}\beta_j, \ \ j = 1,2. \quad (1)$$

Here α_j is the intercept parameter, and $\boldsymbol{\beta}_j = (\beta_{j\alpha_j 1}, \beta_{j2}, \ldots, \beta_{j17})^T$ is 17- dimensional vector of regression parameters for j – the value of dependent variable. From Eq. (1) taking $\alpha_0 = 0$ and $\beta_0 = \mathbf{0}$ we obtain:

$$\pi_j(\mathbf{x}) = \frac{\exp(\alpha_j + \mathbf{x}\boldsymbol{\beta}_j)}{\sum_{k=0}^{2}\exp(\alpha_k + \mathbf{x}\boldsymbol{\beta}_k)}, j = 0, 1, 2 \quad (2)$$

The analyses have been done using the Rfunction *multinom* [7]. Here we also used the Akaike information criterion (AIC) stepwise procedure. The parameters were estimated using the maximum likelihood estimate (MLE) method. The results were presented using the function *mlogic.display* [8]. The coefficients for the final model accident severity are presented in Tab. 2.

4. MODEL APPLICATIONS

The predicted probability of accident severity, given a set of values in the explanatory variables, can be calculated by plugging MLEs $(\hat{\alpha}_j, \hat{\beta}_j)$, $j = 1, 2$ (Tab. 2.) and $(\hat{\alpha}_0, \hat{\boldsymbol{\beta}}_0) = (0, \mathbf{0})$ into Eq. (2) as follows:

$$\hat{\pi}_j(\mathbf{x}) = \hat{P}(Y = j;\ \mathbf{x}) = \frac{\exp(\hat{\alpha}_j + \mathbf{x}\hat{\boldsymbol{\beta}}_j)}{\sum_{k=0}^{2}\exp(\hat{\alpha}_k + \mathbf{x}\hat{\boldsymbol{\beta}}_k)},$$
$$j = 0,1,2. \quad (3)$$

Sensitivity analyisis is conducted by using Eq. (3). We can evaluate the effect of the change of an explanatory variable on interest on the probability of severity of accidents, given that the other variables are held at their sample means or at certain levels.

4.1 Sensitivity analysis

By using Eq. (3) here we obtain the predicted probabilities of different accident severities at the different numbers of daily trains and different maximal train speed at a given crossing for two level of traffic control, road sign and half-gate.

Fig. 1 shows the plots of predicted probabilities of accident severity level $Y = j, j = 0$ vs. the number of daily trains in the range of 10 to 80 trains, Fig. 2 of $Y = j, j = 1$ and respectively Fig. 3 of $Y = j, j = 2$, for two level of traffic control, road sign and half-gate. For plots of predicted probabilities of different accident severity level vs. the number of daily trains in Figs. 1, 2 and 3. we hold the train speed on 71.5 km/h, anualy daily traffic on 1,540 at their sample mean in data set, road tipe as mainline, crossing width is 1 (6 m or less) and crossing angle is 1 (from 60° to 90°).

Fig. 1. shows that the probability of Y = 0, decreases with the increase in the number of daily trains. Moreover, the probability of Y = 1 increases slowly as the number of trains increases (Fig. 2.).

Tab. 2. Multinomial logit model result for accident severity

Independent variable	Severity level (y = 1)		Confidence interval	Severity level (y = 2)		Confidence interval
	Coefficients/SE		RRR (95% CI)	Coefficients/SE		RRR (95% CI)
Intercept	-5.76	0.694***	-	-5.55	0.826***	-
VOSIG(x_{14})	1.33	0.385***	3.78(1.78,8.04)	0.65	0.428	1.92(0.83,4.44)
VOBR(x_{16})	-1.28	0.667	0.28(0.08,1.03)	-1.93	1.051	0.15(0.02,1.14)
SIRPPB(x_{11})	1.26	0.297***	3.53(1.97,6.31)	1.20	0.378**	3.33(1.58,6.98)
MBRZ(x_3)	0.22	0.068**	1.24(1.09,1.42)	0.12	0.083	1.12(0.95,1.32)
EXPO(x_2)	0.08	0.015***	1.08(1.05,1.11)	0.05	0.017**	1.05(1.02,1.09)
BRKOLB(x_4)	-0.87	0.427*	0.42(0.18,0.97)	-0.36	0.463	0.70(0.28,1.73)
KATPRM(x_1)	-0.39	0.311	0.67(0.37,1.24)	0.74	0.430	2.09(0.90,4.87)
Residual Deviance: 668.53						
AIC = 700.53						

Level of significance: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

However, the probability of Y = 2 increases quickly with the increase in the number of daily trains (Fig. 3.). The predicted probability result on different accident severity levels indicate that more severe accidents are observed as the number of daily trains increases. It suggests that if warning devices are upgraded from road signs to half gates on railway lines on which train frequencies are or will be increased, signifficant reduction in less severe accidensts would occur. However, efects of such upgrade will not affect more severe accidents.

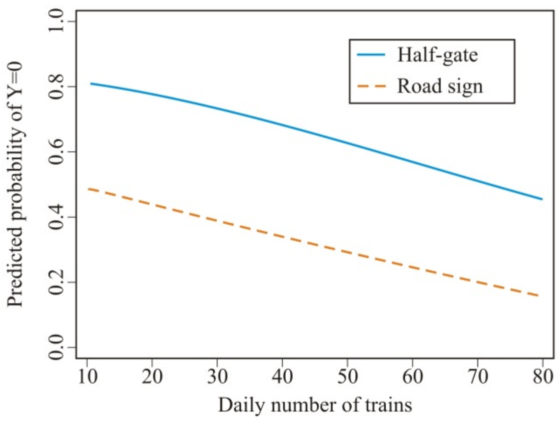


Fig.1. Predicred probabilities of accident severity $Y = 0$ as the number of trains increases (in range from 10 to 80) comparing two different protection systems

Fig. 4. shows the plots of predicted probabilities of accident severity level $Y = j, j = 0$, vs. the maximal train speed which is in range from 20 to 120 km/h, Fig. 5. of $Y = j, j = 1$ and respectively Fig. 6. of $Y = j, j = 2$, for two level of traffic control, road sign and half-gate. For plots of predicted probabilities of different accident severity level vs. the maximal train speed in Figs. 4, 5 and 6, we hold the number of daily trains on 26, anualy daily traffic on 1,540 at their sample mean in data set, road tipe as mainline, crossing width is 1 (6m or less) and crossing angle is 1 (from 60° to 90°).

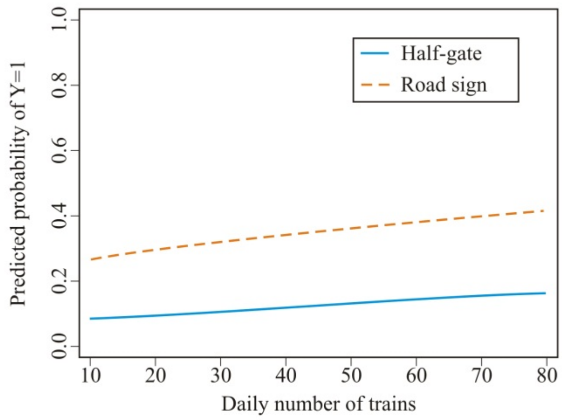


Fig.2. Predicred probabilities of accident severity $Y = 1$ as the number of trains increases (in range from 10 to 80) comparing two different protection sistems

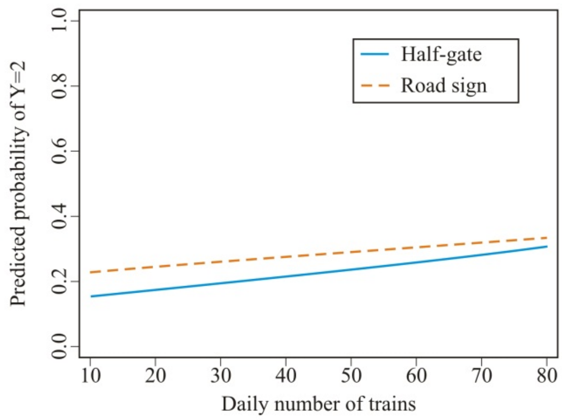


Fig.3. Predicred probabilities of accident severity $Y = 2$ as the number of trains increases (in range from 10 to 80) comparing two different protection sistems

Fig. 4. shows that the probability of Y = 0, decreases with the increase the maximal train speed. Moreover,

the probability of Y = 1 increases slowly as the maximal train speed increases (Fig. 5.). However, the probability of Y = 2 increases quickly with the increase in the maximal train speed (Fig. 6.). The predicted probability result on different accident severity levels indicate that more severe accidents are observed as the maximal train speed increases. It suggests that if warning devices are upgraded from road signs to half gates on railway lines on which train speeds are or will be increased, signifficant reduction in less severe accidensts would occur. However, efects of such upgrade will not affect more severe accidents.

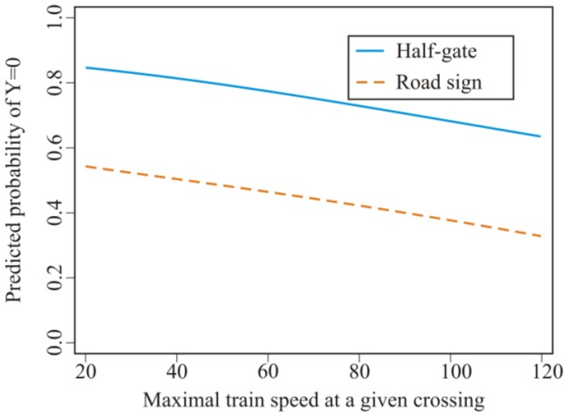


Fig.4. Predicred probabilities of accident severity $Y = 0$ as the maximal train speed at a given crossing increases (in range from 20 to 120 km/h) comparing two different protection systems

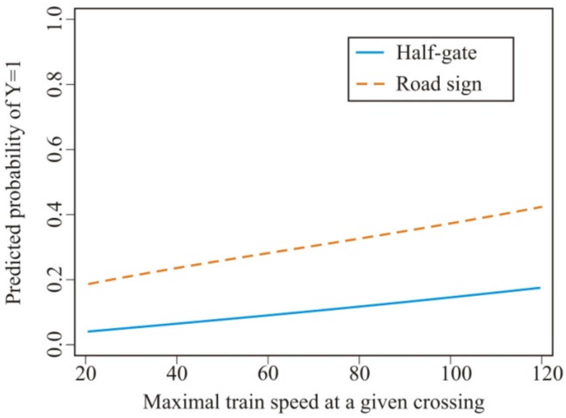


Fig.5. Predicred probabilities of accident severity $Y = 1$ as the maximal train speed at a given crossing increases (in range from 20 to 120 km/h) comparing two different protection systems

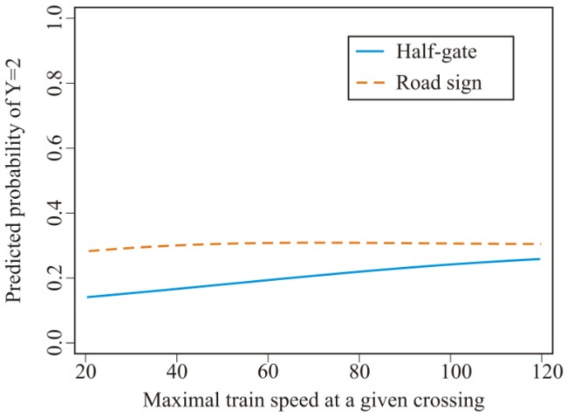


Fig.6. Predicred probabilities of accident severity $Y = 2$ as the maximal train speed at a given crossing increases (in range from 20 to 120 km/h) comparing two different protection systems

5. CONCLUSION

Data points used in this study i.e. accident reports and railway crossing's characteristics were extracted from two official data-bases containing actual events and site descriptions. Multinomial logit model were used for the assessment of accident severity. We also conduced sensitivity analysis to evaluate the effect of the number of daily trains and maximal train speed on accident severity.

REFERENCES

[1] Serbian Rail Administration. Statistics on accidents on Serbian railways 2011; in Serbian.

[2] Hu, Shou-Ren., Li, Chin-Shang., and Lee, Chi-Kang. (2010). "Investigation of key factors for accident severity at railroad grade crossings by using a logit model." *Safety Science,* 48(2), 186-194.

[3] Hu, Shou-Ren., Li, Chin-Shang., and Lee, Chi-Kang. (2011). "Assessing Casualty Risk of Railroad-Grade Crossing Crashes Using Zero-Inflated Poisson Models." *Journal of Transp. Engineering,* 137(8), 527–536.

[4] Serbian Rail Administration. Accident database of Serbian railway crossings (2007-2011), Serbian Railways; in Serbian.

[5] Serbian Rail Administration. The Serbian railway crossing inventory database (2007- 2011), Serbian Railways; in Serbian.

[6] Official Gazette of the Republic of Serbia no. 34/2010; in Serbian. Regulation on personal compensation.

[7] Venables, W. N., and Ripley, B. D. (2002). *Modern applied statistics with S*. Fourth Edition. Springer, New York. ISBN 0-387-95457-0.

[8] Chongsuvivatwong, V. (2012). *epicalc: Epidemiological calculator. R package version 2.14.1.6*. http://CRAN.R-project.org/package=epicalc.

ANALYSIS OF RAIL AND ROAD INFRASTRUCTURE FOR POSSIBLE USE OF CAR HANDLING SYSTEMS

Vladimir REDŽOVIĆ [1]

Abstract *– This paper presents an analysis of the current state of use of the car handling systems or car shuttle trains in Switzerland and in Germany. Due to the differences between the performances of these car handling systems conclusions and factors that are important for the future of those transport systems will be drawn and defined. On this basis the guidance for the consideration of the possible use of available capacity of the railway and optimization of the expansion of road networks will be given. The goal is to optimize and to reduce the constructional costs for both the road network and the railway as much as possible. Optimizing the combined use of road and rail infrastructure could provide a big contribution to environmental protection at the same time.*

Keywords – car handling systems, rail infrastructure, environmental protection, constructional costs.

1. INTRODUCTION

The Swiss are successfully applying car handling systems for passenger and vehicle transport since 1926, for example in Kandersteg a place near the capital of Switzerland 40 million vehicles have been taken care of by the car shuttle train.

Fig.1: Car shuttle train (Switzerland) (source: BLS Switzerland)

In Germany similar car handling systems are to be abolished for economic reasons after many years of operation and the offer of the rail system is gradually reduced.

Car trains are driving through Germany since 1930. The first train drove 33 hours from Hamburg to Base. At the time a freight train was used to transport the vehicles. Passengers travelled with a separate train. The first proper car trains ran from 1956 on. During that year 930 vehicles were transported. The increase of vehicles being transported was steady until the beginning of the seventies. In 1973 185 thousand vehicles were transported on the 114 international routes and the 49 German routes.

Fig.2: Car train (Germany) (source: photo: Frank May (dpa))

When the Deutsche Bahn found that this type of traffic was not profitable for them in 1978 40% of the offered routes were reduced. Through these reductions in offers and through the booming deals in air traffic this type of travel and vehicle transport have become less attractive and therefore difficult to maintain. In addition, roads and highways are expanded to a further and better standard which leads to a greater comfort in travel. It has become rather problematic for the Deutsche Bahn to find solutions that represent a competitive alternative to traveling by car. This

[1] Dr.-Ing.Vladimir REDŽOVIĆ, WAM Planer und Ingenieure AG, Florastrasse 2, CH-4502 Solothurn, Switzerland, +41 32 625 27 33, vladimir.redzovic@wam-ing.ch

situation has led to a situation where the few customers requesting a car train are handled by car transporting trucks instead of car trains.

Fig.3:car-truck transport / Deutsche Bahn AG (source:“obs/Jörg Gläscher / Deutsche Bahn AG“)

2. TRANSPORT SYSTEM THE AND ITS FEATURES

A comparison of the two transport systems the car train in Germany and the car shuttle train in Switzerland shows significant differences. What are the systems features that enable economic operation of Swiss car shuttle trains and why does it not work with the German car train? In comparison to the German car train the Swiss car shuttle train has got one feature which significantly improves acceptance on behalf of car drivers. The car shuttle train is based on a direct integration of the car transportation by rail within the travel route. The train ride is part of the journey between the place of departure and the destination. It is not required to take a additional ride to the rail station as it is required for German car train a relatively complex process of the train ride.

The most important and decisive difference is the duration of the travel. Whereas the journeys of the systems in Switzerland are relatively short with a duration of less than 30 minutes and have a relatively high clocking of trains and therefore have short waiting times the journeys with the German car train take a few hours mostly during night. This means that the complexity of the journey with a car train leads to less attraction and less acceptance of this type of mobility and might as well come to an end.

3. ACCEPTANCE AND INFLUENCING FACTORS

The features of the transport system in Germany and in Switzerland and the analysis of their achievements and performance figures in transported vehicles let us define a set of important influencing factors. The most important factors are:

- travel time / driving duration
- price
- traffic safety
- comfort.

The above-mentioned four factors directly influence the decision of a car driver on the use of this transport option. These factors can, if they are taken into account, provide the opportunity to adapt the transport system and develop in a way that their function, acceptance and efficiency can be increased followed by a rise in the number of vehicles transported.

The driving duration and travel time can be reduced by optimizing the loading processes and faster trains.

By increasing the number of transported vehicles and the optimization of journeys, prices can be kept low at the same time.

Traffic safety is great in these transport systems and even greater if compared with the traffic safety of regular road traffic.

The comfort is greater or at least equal. The passengers remain in their own vehicles during the train ride and therefore do not have to control the vehicle. So the comfort can be estimated even greater.

4. BENEFITS

The car handling systems have a couple of benefits and should be offered as much as possible. As it was previously mentioned this transport system offers the following benefits:

- greater traffic safety
- reduction of road traffic
- economic effects
- train economy
- environment sparing

The interruption of a journey through the loading of the vehicle to the wagons and the combined journey by train provides a certain dynamics and provides the driver with a recovery period. This increases traffic safety.

The more vehicles are transported by rail, the more the road traffic is reduced. This is followed by many positive economic effects. The rail company benefits of the usage of existing capacity and infrastructure. The roads do not have to be further developed nor broadened, which can save both costs and area for road construction. This in turn has positive effects on the environment in terms of both exhaust emissions and in terms of noise and the use of the free space.

5. USE POTENTIAL

These transport systems are used where ever they are beneficial to car passengers in comparison to the use of a road. It becomes beneficial if the alternative is not much better with respect to the travel time (speed) the prices and other factors. The following conditions must be fulfilled similar to the car shuttle system in Switzerland:

- high frequency of trains (low latency)
- short travel time
- uncomplicated loading and continuing of the travel
- reasonable pricing (value for money)
- less attractive alternatives (length, time fuel and costs)

6. STATE ANALYSIS

Starting point for all solutions in traffic is the analysis of the current traffic situation regardless of whether it is motivated by the search for solutions to current traffic problems or part of a future-oriented planning of traffic. In both cases, the solution is depending on the one hand on the existing traffic infrastructure and on the other hand on the objective a solution is searched for. If a current traffic analysis shows that it would be necessary in an area to build new road or to broaden and or expand an already existing road, it is useful to analyze all possible alternative types of traffic solutions and possibilities and to take the existing infrastructure into consideration within the search of a final solution. Even in cases where the roads have sufficient capacity, it is prudent and advisable to consider other transport options for environmental reasons. Car shuttle services could be a potential solution to big cities for larger distances. The city of Belgrade as an example could use a rail connection with a car transport between "Topcider" and "Novi Beograd" or might even lead to "Karaburma" to ease congestion in the city center and also shorten the travel time through the city. In addition of the positive effects are possible to the environment because exhaust emission and traffic noise are reduced.

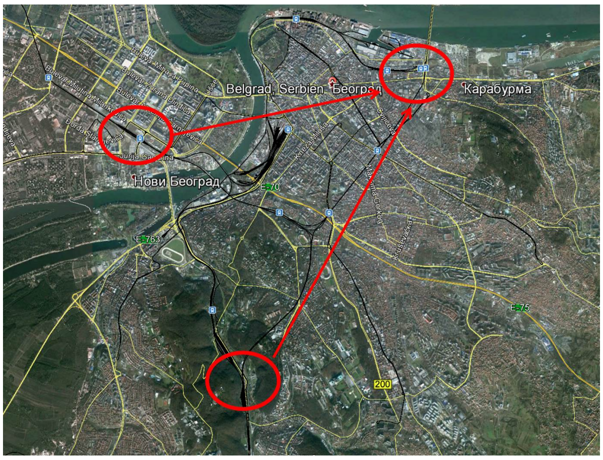


Fig.4: possible connection for car shuttle service (source: Google-Earth)

For a decision on the introduction of a car-train system many different potential analyzes have to be carried out. Primarily, the existing infrastructure of the railway is to be analyzed if potential routes that are eligible for car-train operation are given. After finding and defining the potential routes with respect of space and track systems as well as the length of the route between the potential car-train stations, the traffic analysis has to follow. It will show whether the new car transport option could be integrated successfully into the overall transport network. This test is based on the current traffic numbers, congestion analysis, waiting in traffic, possible bypasses the congestion endangered points or nodes and escape traffic. In the next step, the transport developments should - forecasts are analyzed to determine whether a car-train or a road version with extension of the road space is the better option for the future.

In this evaluation of the variants other already mentioned factors have to be co-analyzed for the assessment. This includes the environmental side of the two variants as well as the profitability and future significance in relation of the road and rail transport. With an existing rail infrastructure a car shuttle service is relatively inexpensive compared to a road renovation and expansion.

Car transport is particularly interesting to big cities with existing rail infrastructure and little free areas and spaces for street extension (such as Belgrade). In these cases, a road extension is always rather problematic and an ease of congestion by offering car shuttle service on the rail represents the best alternative.

Often industrial tracks with existing unloading ramps which are not in use anymore offer the opportunity to create a car handling system with relatively little effort.

7. DECISION

The decision for car shuttle service has to be taken on the basis of an accurate analysis and evaluation of traffic and economic conditions as well as environmental reason. Necessity and life potential (profitability) of the car handling system need to be scrutinized and carefully examined before an the decision for the creation of the system can be made. A relevant addition to the construction costs are operating costs. The revenue must cover the operation and maintenance.

8. SUMMARY AND RECOMMENDATIONS

Car train or transport of vehicles by train has been used for decades. In various versions they showed up in the past as both viable and non-viable. Despite many positive aspects and benefits in particular for the environmental protection, these traffic variations are integrated poorly into traffic. Both road construction and vehicle development have had a influence to this development. Both allow the achievement of driving at higher speed including high travel comfort which makes competition for car handling systems harder and more difficult. Nevertheless, there are still places which justify the use of these systems. Places like nature conservation parks are especially suitable. Urban areas are where the strain through traffic is very high and an alternative is required are another example. The important factors for the acceptance of these systems by car driving individuals are the loading processes (complexity and duration), speed (duration) and price. The targeted use of these systems and possible network expansion and further development and optimization of the loading processes could become a kind of combined public MIV (motorized individual traffic). The car shuttle trains in Switzerland show that these systems are functioning and development potential particularly in cooperation with politics is certainly there.

REFERENCES

[1] BLS Schweiz / Homepage
[2] Deutsche Bahn AG / Homepage

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

MODELING AND DESIGN FACILITIES FOR DEALING WITH DANGEROUS GOODS ON RAILWAY

Slavko VESKOVIĆ [1]
Goran MAKSIĆ [2]
Marko VASILJEVIĆ [3]
Gordan STOJIĆ [4]
Snježana RAJILIĆ [5]

***Abstract** – The aim of this research is implementation of decision making methods and risk analysis in the process of planning of layout and working technology in railways. In the paper, these methods are applied in layout planning for dangerous goods handling facilities. We proposed methodology for determination of criteria and their weights relevant for adequate selection and ranking of alternative solutions. Three alternatives and their simulation models with technologies for dangerous goods handling at private sidings are developed. Delphi method is used for defining relative weights of criteria and AHP method is used for ranking of alternatives. The final result is the selection of optimal alternative in the sense of defining necessary capacities and optimal layout and working technology.*

Keywords – risk analysis, planning, railway facilities, dangerous goods, decision.

1. INTRODUCTION

A number of substances used in everyday life, categorized as dangerous goods are increasing. Their transport is inevitable and in the transportation process, handling points as initial-end points are of great importance. As regulations in the field of ecology and environmental security are becoming more stringent, the layout and technology planning of handling points becomes more up-to-date.

Contemporary trends are to focus dangerous goods transport on railway. In Europe, 8% of the total freight transported are dangerous goods, and about 25 % are transported by railways[1]. In order for railways to successfully deal with this, certain conditions are required - safety and transportation procedures for reducing risks of accidents during the transport, and adequate track capacity.

This problem has been approached differently. The comparison of transport means for dangerous goods is given in the paper [1]. In the papers [2] the accent is put on routing and scheduling problems in transport network. Risk accidents analysis of technologies for dangerous goods handling in marshalling yards is given in papers [3].

The subject of this paper is modelling of layout and working technology of handling points for manipulation with dangerous goods in railways.

2. METODOLOGY

Planning of railway facilities for dangerous goods is based on an integrated decision and risk methodology for selecting the most suitable layout and working technology alternative. The general integration process includes steps as stated below:
Initial step forms admissible set of layout and technology alternatives.
Step 1 defines set of criteria for decision making.
Step 2 identifies the initial weights of relevant criteria.
Step 3 performs AHP as one of technique for Multi Criteria Decision Making (MCDM).
Step 4 forms rank list of alternatives.
Final step selects the most suitable alternative.

[1] Inland transport of dangerous goods, Institute for European Environmental Policy, 2011

[1] Slavko VESKOVIĆ, Faculty of traffic and transportation, University of Belgrade, e-mail: veskos@sf.bg.ac.rs
[2] Goran MAKSIĆ, Serbian Railways, e-mail: goran.maksic@srbrail.rs
[3] Marko VASILJEVIĆ, Faculty of traffic, University of East Sarajevo, e-mail: drmarkovasiljevic@google.com
[4] Gordan STOJIĆ, Faculty of technical science, University of Novi Sad, e-mail: gordan_st@yahoo.com
[5] Snježana RAJILIĆ Municipal Novi Grad, e-mail: snjayana_rajilic@yahoo.com

2.1. Layout and technology alternatives

Designing of multiple alternatives of private sidings is necessary in order to perceive different technical-technological sides of the problem and perform their comparison. Alternatives' generation is performed by designer's creativity. For this reason, admissible set of layout and technology alternatives is initially formed in order to select an optimal alternative in the following steps. The simulation modelling is recommended for better comparison of the admissible alternatives. Simulation models give opportunity to show certain system behaviour in real conditions relatively easily and enable comparison of different system solutions. Such analysis is easy to perform changing conditions as system surrounding, service rate or arrival rate.

2.2. Relevant criteria

There is a great number of criteria that can be studied regarding selecting or ranking alternatives. For the purpose of defining the relevant criteria hierarchical structure is established, with criterion groups on top level and criteria at lower level. Hierarchical criterion structure used in this paper for layout and technology planning of handling points with dangerous goods consist of 5 criterion groups and 14 criteria (Table 1. - detailed are given in [4]).

Risk management in hazardous goods transport comprises a group of preventive measures, the state of preparedness to react, reactions to accidents and all this in order to decrease the possibility of an accident and possible consequences that can be potential ecological catastrophes.

In scientific literature, there are different opinions on what risk is actually and how it can be quantified [5]. Some authors think that risk is multidimensional and that it relates to situations that can be followed by a certain undesired event. While quantifying risk of dangerous goods influence on people, analysts are focused on one or two factors - accident probability and number of people that are affected by dangerous goods in the case of an accident. Two factors combination product and can be considered as expected accident consequence. In dangerous goods transport, risk is defined as expected accident consequence connected with two factors (p_i - accident probability and expected consequence C_{ij}). So, the risk *TR* on the private sidings (*P*), with the sidings segments (i) for dangerous goods (j) is defined as the sum of partial risks per siding segments (4).

$$TR(P) = \sum p_i \cdot C_{ij,} \; (\mathrm{i} \in \mathrm{P}) \qquad (1)$$

The accident probability (p_i) is calculated as the product of shunting accident rate (per shunting movement) and wagons handling performance. This performance is in function of number of movements and number of wagons in shunting composition. Values of shunting accident rate are usually determined on the basis of accidents surveys from the previous period. The expected consequence (C_{ij}) is calculated from the exact number of employees and facilities within a buffer distance.

Tab. 1. Hierarchical structure of relevant criteria

Criterion group level	Criterion level	Expression
Transportation criteria	Technological functionality	Numerical units
	Utilization of certain facilities	
	Possibility of functioning in the case of an accident	Ling. description
Cost criteria	Infrastructure investments	Monetary units
	Exploitation costs	
	Infrastructure maintenance costs	
Spatial criteria	Handling point location in regard to residential zones	Ling. description
	Handling point location in regard to protected natural zones	
	Handling point location in regard to big economic entities	
Environment criteria	Ground pollution	Ling. description
	Influence on air pollution	
	Noise level	
	Vibration level	
Safety criterion	Risk of accidents	Numerical units

Due to the great number of the criteria, they should be grouped into influence groups according to what they represent. A great problem is criterion quantification within the groups according to possibilities of numeric defining. Certain criteria can be expressed in numbers which is the most favourable way for multi criteria decision making. However, for some criteria it is not possible to be expressed in numbers. Assessment of these criteria is possible on the basis of subjective factors expressed by linguistic descriptions: absolutely important, important, necessary, usual, unimportant and undesirable

2.3. Initial weights of relevant criteria

One of the main characteristics of multi criteria decision making is that the criteria may not have equal importance. Although subjectivity is expressed in the process of determining the relative weight of criteria there is a need for standardization. For the purpose of this paper, a Delphi method [6] is used to identify initial weights of relevant criteria. Procedure for determining the initial weight was carried out in three phases according to defined hierarchical criterion structure:

1. Determining the relative weight of every group of criteria (g_k, $k=1..5$)
2. Determining the relative weight of every relevant criterion (c_i, $i=1..14$).
3. Corrections of relative weight of criterion with its group weight (w^i_i, $i=1..14$).

The survey covered traffic and civil engineers, spatial planners and environmental experts. Two models were used in this process: *Expert for a field* and *All experts for all fields*. The case Expert for a field is simpler and experts assess criteria from their expert fields. Another model is more complex because the group of experts is heterogeneous. Here the determining of the criteria values is performed taking into the consideration conflicted interests, and this more closely corresponds to real-life conditions.

Determining the relative weights of criteria is very important for the final decision making process result. In this paper, initial values of criteria weights will be corrected by eigenvalues of the criteria resulted from the multi criteria decision making by AHP method.

3. CASE STUDY

3.1. Application on private sidings for dangerous goods

This paper considers the possibility of private sidings construction for the needs of “Batteries Factory Sombor”. Main scope of work of this factory is production of starter batteries for passenger and freight vehicles. The factory needs certain amounts of raw materials in order to realize continuous production. It is, primarily, sulfuric acid, raw refined lead, lead-calcium-aluminium alloy, liquefied petroleum gas (LPG), coke polypropylene boxes and separators. Bearing in mind daily amounts of raw materials that are brought to the factory and number of single output batteries, certain capacity calculations have been made.

3.2. Layout and technology alternatives

This paper considers three alternatives of private sidings (Fig. 1). In the description of alternatives, emphasis will be on the technical characteristics, technological process and the position of facilities to handle dangerous goods.

In the first alternative, private sidings directly comes to the handling points in the factory area. Other two alternatives consider that the private sidings are located directly by the railroad. Because of that, additional pipelines are necessary for liquefied petroleum gas transport from the track to factory facilities, as well as lorries with reloading mechanization that would perform reload process from the wagons and transport to factory facilities. This isolation reduces the risk of accidents but it affects the shunting duration

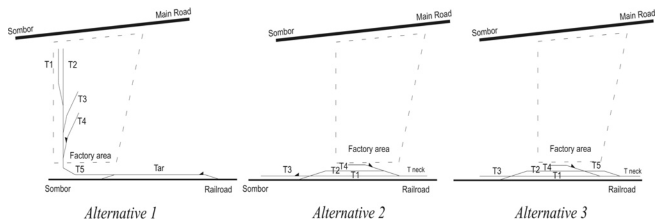


Fig.1. Proposed alternatives

Technology of private sidings servicing is modelled by the Queuing Theory. The model contains several simple consecutive servicing systems. In these simple systems shunting composition is considered as client, and consecutive servers are Sombor station, railroad and private sidings with handling points. Servicing durations are shown in the form of variable distributions obtained from statistical surveys (Tab.2).

Tab. 2. Exponentially distributed shunting durations

	Alt. 1	*Alt. 2*	*Alt. 3*
Server	λ	λ	λ
station (departure)	0.09	0.09	0.09
railroad	0.04	0.04	*0.04*
T_{ar} (arrival)	*0.06*	*0.1*	*0.1*
T_1	*0.2*	*0.25*	*0.25*
T_2	*0.25*	*0.17*	*0.17*
T_3	*0.33*	*0.33*	*0.33*
T_4	*0.33*	*0.14*	*0.33*
T_5	*0.2*	*0.25*	*0.14*
T_{ar} *(return)*	*0.2*	*0.2*	*0.2*
station (arrival)	*0.11*	*0.11*	*0.11*

Simulation models are performed in Simevents program, MATLAB 7.6.0 (R2008a) subprogram. From the simulation outputs we extract arithmetical mean ($\overline{X(n)}$) of private sidings occupations and total delivery durations as key technological indicators (Table 3). The usual way to assess the precision of $\overline{X(n)}$ is to construct a confidence interval for μ based on sufficient large number of independent experiments (n) [7]. For this reason we create 95 percent confidence intervals based on 80 observations (n=80). Also, Table 3 shows total number of wagons handling (WHP) with dangerous goods for alternatives 1. This performance directly influence on risk of accident during the switching at private siding*s*

Figure 2 presents arithmetical means of total delivery durations obeying the Low of large numbers. For performance of more then 40 observations it may be deducted that $\overline{X}(n)$ is not a random variable anymore, but it becomes arbitrary close to mathematical expectation μ

Tab. 3. Simulation model outputs

Server purposes		Alternative 1	
		$\overline{X}(n)$	Confidence interval
Arrival track	T_{ar}	17.9	17.9 ± 3.1
Track for *Habis* wagons	T_2	4.3	4.3 ± 1.0
Track for *Eas* wagons	T_1	4.4	4.4 ± 0.8
Track for tank with sulf. acid	T_3	2.7	2.7 ± 0.5
Track for tank with LPG	T_4	3.4	3.4 ± 1.1
Total duration		114.6	114.6 ± 8.6
WHP		30	

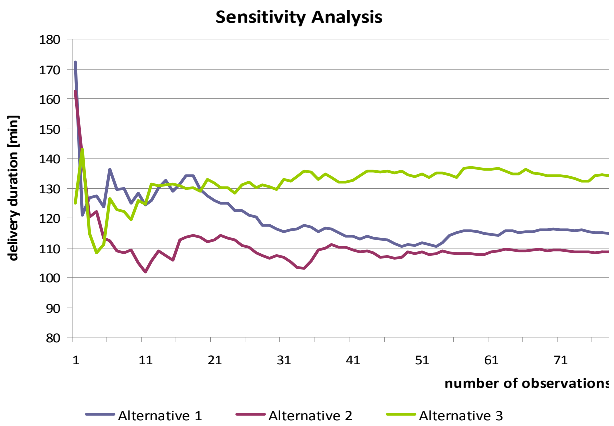


Fig.2. Expectation of total delivery durations

3.3. Evaluation of private sidings alternatives

In this methodology, pairwise comparison matrix obtained using the transformation of linguistic descriptions in numeric values has a central place. For evaluation of private sidings alternatives we form pairwise comparison matrix of dimension 14x14 for criteria in higher level and 14 matrix of dimension 3x3 for alternatives in lower level for each criterion.The final weights of the alternatives are evaluated as composite weights $U_j = \sum w_i^{\,f} E_j^{\,i}$. The best alternative is the one with *max* U_j.

Pairwise comparison matrix of alternatives:

for 1st criterion for 14th criterion

	A_1	A_2	A_3		A_1	A_2	A_3
A_1	1	0.5	0.33	A_1			
A_2	2	1	0.5	A_2			
A_3	3	2	1	A_3			

Vector priority for alternatives:

	U_j	rank
A_1	0.410	1
A_2	0.305	2
A_3	0.286	3

4. CONCLUSION

This paper contributes to the transport of dangerous goods through the formulation of a methodology for the ranking of layout and working technology for handling points with dangerous goods. In this methodology defining the relevant criteria and their weights has important place. Risk of accidents is indicated as the most important criterion, followed by criteria from the group of environmental (ground and air pollution). Cost criteria, especially maintenance and exploitation costs, are determined for the least relevant factors. In order to make realistic weight determination, Combination of Delphi and AHP methods is used in order to realistically determinate criteria weights. The procedure of multi decision making is performed using the AHP method.

The proposed methodology is used to evaluate alternatives in the case of private sidings with sulfuric acid and liquid petroleum gas handling points for the Battery Factory Sombor. For this purpose three alternatives with their simulation models were designed. Applying the methodology, it is found that the alternative with private sidings inside the factory area is the most suitable. The final result is the selection of optimal alternative in the sense of defining necessary capacities and optimal layout and working technology.

ACKNOWLEDGEMENT

This paper is supported by Ministry of Science and Technological Development of the Republic of Serbia (no. project 36012).

REFERENCES

[1] Rongrong, L., Yee, L.: *Multi-objective route planning for dangerous goods using compromise programming,* Journal of Geographical Systems, 13(2011)3, 249-271.

[2] Erkut, E., Gzara, F.: *Solving the hazmat transport network design problem*, Computers and Operations Research, 35(2008)7, 2234-2247.

[3] Bagheri, M., Saccomanno, F., Fu, L.: *Effective placement of dangerous goods cars in rail yard marshaling operation*, Canadian Journal of Civil Engineering, 37(2010)5, 753-762.

[4] Maksić, G., et al.: *Choice of infuential parameters of manipulation spot for the purpose of handling dangerous materials,* Ecologica, 16(2009), 249-255.

[5] Cozzani, V., et al.: *Hazmat transport: A methodological framework for the risk analysis of marshalling yards,* Journal of Hazardous Materials, 147 (2007), 412-423.

[6] Linstone, H., Turoff, M.: *Delphi Method: Techniques and Applications,* Addison-Wesley, Reading (Massachusetts), 1975.

[7] Law, A.: *Simulation Modeling and Analysis,* McGraw-Hill Inc, New York, 2007.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

RAILWAY TRAFFIC IN SUSTAINABLE ENVIRONMENTAL DEVELOPMENT AND ENERGY EFFICIENCY

Predrag PETROVIĆ [1]
Marija PETROVIĆ [1]
Slobodan VUKMIROVIĆ [1]
Živojin PETROVIĆ [2]

***Abstract** – Increase the frequency of all types of traffic, causing an increase in emissions of air pollutants and impacts on global climate change and warming the Earth. The United Nations and the European Union is taking a series of legislative measures aimed at reducing emissions of greenhouse gases. Regarding rail transport, it is in terms of air pollution and energy efficiency and rational when it comes to diesel and electrified railway traction. In this paper, we give some guidelines on sustainable environmental development, given a short overview of regulations to reduce the impact of greenhouse gas emissions, as well as guidelines for the rational use of energy in transport, methods, processes and procedures for risk management and impacts due to climate change. Such an approach to the analysis of strategies and policies for sustainable development and energy efficiency is Execute by the Community of European Railways (CER) and the International Union of Railways (UIC).*

Keywords – Railways, Environment, Energy Efficiency, Risk Management, Climate.

1. INTRODUCTION

Rail transport is one of the most energy efficient and environmentally suitable ways to transport people and transport of goods, with the real possibility of further reducing the impact on air pollution and environmental accidents as possible. Electrically powered locomotives are no direct air pollution, a new diesel engines and their systems for the treatment of exhaust gases significantly reduce their negative impact, which is the ecological aspect is very important for the initiation of the negative consequences of the appearance of the greenhouse effect and thus environmental pollution and labor environment.

When it comes to the energy system, the state of Serbia, must in the future, to provide conditions for open, efficient, sustainable and secure energy market, which would establish a business climate conducive to the intensification of international trade. To achieve these conditions, it is the fulfillment of numerous factors, some of which are very important, as they increase energy capacity, higher production efficiency, cost-effective energy transfer, ie. with minimal losses, rational consumption, greater orientation to rail transport and others.

Improving energy efficiency, increasing competition, can actually reduce the overall need for investment in energy infrastructure and fuel costs, while striving to produce electricity from alternative renewable sources, as well as the substitution of fossil fuels.

2. EUROPEAN POLICY AND LEGISLATIVE MEASURES IN THE TRANSPORT

Far back as in 1990. adopted a draft plan of the overall consequences of successive reduction of greenhouse gases, and to about 20%, and in the case of having favorable circumstances, this reduction can be expected in about 30%, by 2020. and even 50%, in 2050.

[1] Predrag PETROVIĆ, Marija PETROVIĆ, Slobodan VUKMIROVIĆ, Institute „Kirilo Savić“, Vojvode Stepe 51, 11000 Belgrade, Serbia, e-mail: mpm@eunet.rs, predrag.petrovic@iks.rs
[2] Živojin PETROVIĆ, Faculty of Mechanical Engineering, Belgrade, Serbia, e-mail: zpetrovic@yahoo.com

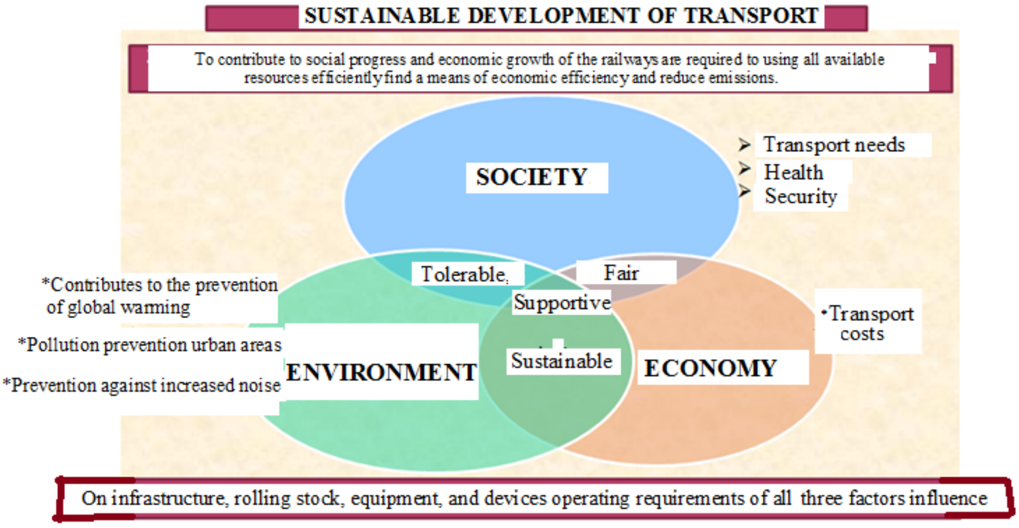


Fig.1. The effect of some factors on the sustainable development of railway transport

Surveys conducted in the EU in the field of nature conservation and environmental pollution have found that traffic directly cause about one quarter of the overall CO2 emissions, according to statistics from the period in 1990., And 2005th, only transport within the EU influenced the growth of CO2 emissions to 26%, of which more than 90% compared to road transport. Railways is the cause of only 0.6% of emissions from diesel consumption and less than 2%, by issuing plant to produce electricity. Some general factors that influence the sustainable development of railway transport, shown in Fig. 1.

One of the most important tasks in the field of sustainable development to protect the environment and achieve cost-effective energy efficiency, with a view to 2030 extention cable. Energy consumption in rail transport by 30%, compared to the baseline in 1990., A vision that by 2050., this value is halved. The function of the energy efficiency and the achievement of the objectives of the EU, the 2020th, the use of so-called "smart grid" will significantly contribute to reducing carbon dioxide emissions and reduce energy consumption, as well as the introduction of energy efficient technologies in the production of energy from renewable sources by 20%.

3. SMART GRIDS FUTURE STEPS

As mentioned, today's world is increasingly propagated so. intelligent products, or so. "Smart" devices that are used in many industries. All of this will be feasible by introducing intelligent power grid (Smart Grid), which is the so-called. energy future, which will households, industry, transport agents and other users to be connected to each other, so that the electricity spending as needed, with switched on and off.

Such possibilities become more interesting when one takes into account the combination of individual installations, components and devices, such as smartmeter, flexible electricity production in different types of plant automation and control home appliances. Although these are indications of the future, the EU is working intensively on the development and implementation of an integrated power grid (Smart Grid), which will represent the future of the network in many areas and in railway transport.

Intelligent electricity networks are better suited to compensate for fluctuations in power generation, particularly renewable energy. Such networks have special sensors and other communication systems to identify errors in the system and implement appropriate corrective measures. Smart grids will enable private users and companies to sell excess electricity (from household solar and wind plants, electric vehicles and energy and thermal systems), diverted to the public network.

4. MANAGEMENT RAILWAY SYSTEM IN ENVIRONMENTAL

Transport sector is one of the pillars of modern economy, although that, to a large extent influence the sustainable development of the environment. Potential role of the railway sector in terms of improving energy efficiency and reducing greenhouse gas emissions from fossil fuel and the use of alternative fuels with continuous improvement of efficiency of working capacity, comfort, and overall quality of transport services. To reinforce this position, the railway companies were forced to as part of its business conduct ambitious environmental policy with a special program of sustainable development, which implies a constant search for adequate solutions to issues that arise in this area.

One of the methodologies implemented by the railroad company's environmental certification in accordance with European regulations, which should allow the creation of environmentally friendly products transportation services, but also economically viable, with the smallest possible cost of raw materials and energy. Effects of acquisitions can control the flow of costs in the short term, but a growing wave of price, but indicates that only greater energy efficiency can bring long-term success. Some companies according to the protocol developed by ISO EN 14064 certification system, grading six gradations of CO2 in the process of making the product, in order to oblige and encourage all companies in the supply chain environmental management in their overall operations.

Energy management must have a clear policy, strategy and plan of concrete actions to improve the established time limits, numerical and practical goals. Special attention must be given to the rational use of energy, increase business productivity, purchasing power in terms of economic cost, investing in energy-efficient trains, stations and facilities, the use of energy from renewable sources and constantly monitoring the consumption of energy used.

The program for energy management are included in the standards ISO 9001 quality management and ISO 14001 accreditation for environmental management.

One aspect of energy management on the railway, is shown in Fig. 2.

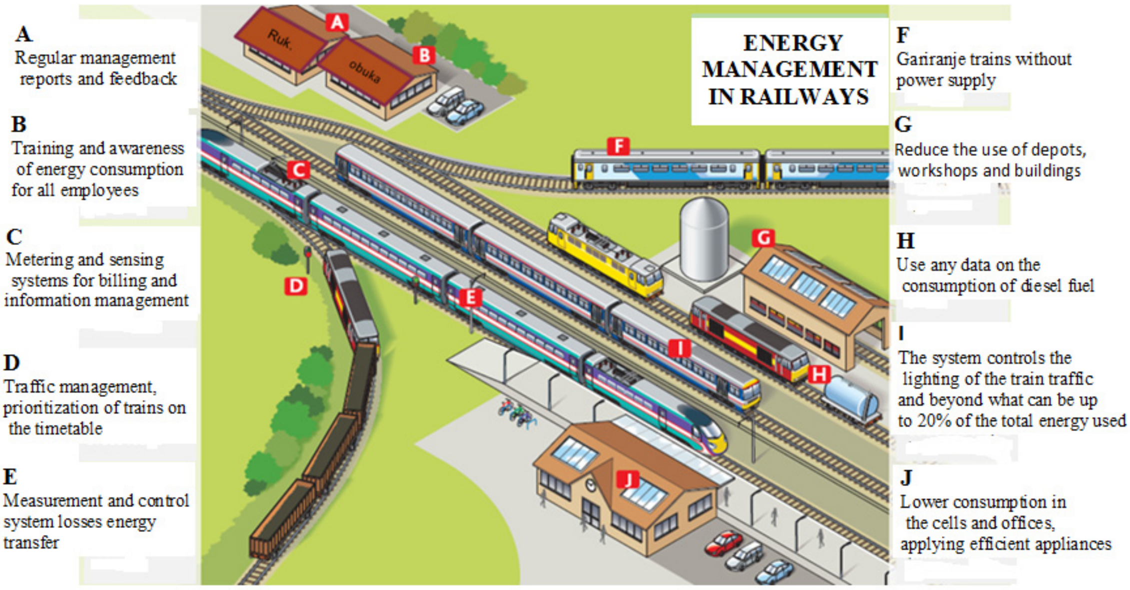


Fig. 2. Energy Management in Railways

This allows the recording of documents, in terms of: records of energy consumption, maintenance manuals, operating manuals, operating procedures and training manuals, audit operations, check management arrangements, the review process of policies, implementation of projects to encourage regular and formal review program effectiveness formed and others.

Power management on the railway is a systemic problem that requires regular reports and management information, training and awareness of energy consumption for all employees, metering and sensing systems for billing and information management, organizational measures to achieve energy savings in regular operation, measurement and management losses in the system of power transmission etc.

The so-called. smart and efficient energy solutions railways, means finding the right solutions for the measurement and analysis of energy consumption in railway systems through a common methodology for simulation comparison and prioritization, the "cost-benefit" analysis of the efficiency and also the necessary tools to support decision making in the market conditions. Search and formation energy database has the following objectives: an analysis in terms of life cycle cost of services, cost of energy, the ranking of the main technological performance for strategic planning, procurement of new vehicles, the modernization of the existing fleet and other.

All the factors involved in the use of energy are part of operational control, the optimization limits for reliable and energy-efficient operation. A significant contribution to the collection and analysis of data metering and control of all aspects of the business, achieved only in areas where there is no impact on the competitiveness of transport services, the contradictions between the achieved energy savings and time inefficiencies. Control and analysis of energy consumption affects the normalization of energy sorting at the source according to sections, regions, number of trains, to the driver in order to determine performance and efficiency.

Electricity for traction, is basically used to accelerate the train up to a certain speed, overcoming the resistance movement, supply management and supply of electricity for lighting, heating, cooling and ventilation wagons and the like. Technical solutions indicate that in addition to the investment in a modern fleet, the savings can be through the optimization of movement ("smart drive"), in order to efficiently use the degrees of handling and braking, with a measure of active traffic management and efficient layout of traction units.

Electric energy for cells, workshops, warehouses, stores and other business premises, must not be neglected, because these costs represent up to 30% of total electricity costs. Some aspects of energy saving rail traffic, according to field of application and applied technology can be:

1) Management (ecological "smart"-driving, managing and determining the capacity of trains).
2) Infrastructure (reversible substations for power transmission, power management in real-time asymmetric system, 2X1, 5 DC traction system, sub-parallel, reduced line redundancy, increase of voltage at 4kV, railway units to save energy).
3) Components of the vehicle (unit for depositing energy in vehicles, the reuse of heat loss).
4) Gear towing vehicle (super conductive transformers and inductors for towing, medium frequency distribution of energy, innovative hybrid diesel-powered).
5) Optimisation (new control technologies to reduce energy converters in inertial motion, active filtering technology to reduce losses of passive filter (reactor), the re-use of energy efficiency converters, control mean value of voltage).

Modern innovations for rationalization of electricity is the possibility of using technology to deposit on the vehicle, which in addition to its modularity and system complexity caused by multiple risk parameters related to sizing the influencing factors for energy savings, all of which are characteristic: size, weight and the ability of the system to deposit energy control concept, the necessary power supply vehicles, power and control of the diesel drive, driving systemic loss of power, vehicle information, schedule, profile stripes, etc..

Operating mode for energy savings in the case of diesel traction, based on equipment that has a range of power diesel engine in the optimum mode of deposition of energy, which can provide additional power in the absence of the required power at a time when there is a difficulty in the mining developments.

5. CONCLUSION

The aim of this paper is to initiate a future concrete cooperation between the railways and the Power Industry of Serbia aimed at a framework of rational energy use, protection and conservation of the environment, promotion and stimulation of all types of clean technologies in accordance with the fundamental principles of state policy. Serbian Railways should be included in the project of intelligent electricity grids, in order to efficiently balance the supply and demand of energy. To off-load periods of greatest demand and reduce wastage of electricity that occurs in long transmission networks.

REFERENCES

[1] “Railways and Environment, Building on the Railways, Environmental strengths”, UIC, CER, Brussel, 2009.

[2] „Rail Transport and Environment, Facts and Figures”, UIC, CER, Brussel, 2008.

[3] Mads Bergendorf, „Rail Energy-Intermidia Results“, ECO Rails Workshop, Brussels, 2010.

[4] Enno Wiebe, „UIC/UNIFE Technical Recommendations”, 11th UIC Sustainabillity Conference, Madrid, 2010.

[5] “Process, Power, People”, Energy Efficiency for Railway Managers, UIC, Paris, 2008.

[6] Consultation on the Transposition of Directive 2008/50 of the EU Parliament and of the Councile of 2008 on ambient air Quality and Cleaner air for Europe, 2009, DEFRA, London,

[7] Petrovic P., Vukmirović S., Jevtic M.: "The Importance of Interoperability of Railway systems in Serbia of the Trans-bonuses", Scientific-expert Conference on Railways, "XIV RAILCON '10", Niš, p. 239-242.

[8] Petrovic P., "Environment Serbia: a Review of the situation, Demography, Development of policy, Planning, education, Finance and Implementation," (Symposium "Research and Design for Economy-IIPP", University of Belgrade, 2007.

[9] Directiva 2009/29, Official Journal L 140, 05/06/2009 P. 0063 – 0087.

[10] Directiva 2009/31, Official Journal L 140, 05/06/2009 P. 0114 – 0135.

[11] Petrovic P., "Trends in Emission Control of Diesel Engines in terms of Global Environmental Pollution" (The Scientific Journal "Ecologica", No.13, 2007.. Belgrade, Faculty of "Futura", p.169-176).

[12] Petrovic P., "International Conference of Environment and Sustainable Development" (The Scientific Journal "Research and design for Economy-IIPP, University of Belgrade, No. 17-2007, V, p. 57

[13] Petrovic P., Popovic P., Lučanin V.: "Interoperability as a Strategy of Operational Excellence in the International Competitiveness of Rail Transport Serbia ", (12-th International Conference" Quality and reliability ICDQM-2009 ", Belgrade, Serbia, str.703-711th

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

SELECTION OF RAILWAY LEVEL CROSSINGS FOR INVESTING IN SECURITY EQUIPMENT USING HYBRID DEMATEL-MARIC MODEL

Dragan PAMUČAR [1]
Ljubislav VASIN [2]
Vesko LUKOVAC [3]

Abstract *– According to the European Railway Agency in the European Union every year on railway level crossings (RLC) occurs over 1200 traffic accident in which life loses more than 400 people. In addition to the tunnel and specific locations that are identified as black spots on the roads, RLC have been identified as potential weak points in road infrastructure that significantly jeopardize traffic safety. In Serbia exists about 2350 RLC, one of which is part the secured by systems of active and passive safety (traffic signs, light signals, sound signals, barriers, etc..). Insurance RLC is a material expenditure. The RLC selection process for installation of security equipment accompanied by a greater or lesser degree of criteria vagueness that are necessary for making the relevant decisions. For exploitation these uncertainties and vagueness in this paper was used fuzzy logic. This paper presents the application of a new method of multi-criteria decision-making (Multi-Attributive Real-Ideal Comparative Analysis - MARICA), which represents support in the selection process for RLC to invest in safety equipment. Identified are eight criteria that influence the investment decision. MARICA method was tested on the example of choice of eight RLC for investing in safety equipment.*

Keywords – Railway level crossings, Railway accidents, Multicriteria decision making, MARICA, DEMATEL.

1. INTRODUCTION

Railway level crossings represent the intersections of road and rail transport, and potentially are dangerous points for road users. In general terms level crossings may be provided with automatic or mechanical insurance. In addition, RLC may be and unsecured, where ramps for drivers do not exist and where they placed only traffic signs and other equipment. Ensuring a level crossing with automatic insurance (AO) requires a great investment because the devices to ensure the RLC are expensive and because there are a large number of RLC who are unsecured.

At the RLC a large number of accidents that accompany major material damage and loss of lifes happens. It is estimated that in road accidents an average of 1,308 people lose their lives daily in the world [5]. Of the approximately 54 million people who die each year in the world, the number of people killed in road accidents amounted to 1.17 million (2.17%).

According to the European Railway Agency, of the total number fatalities in railway accidents, 27% accounts at level crossings [5]. Traffic accidents at railway crossings are mostly consequences of improper and inattentive behaviour of participants in road traffic.

According to the statistics and forecasts of the EU [3], the volume of rail traffic in the next 30 years will be doubled, which is a direct indicator of the expected increase in emergencies at level crossings on all lines, including lines in Serbia. How the volume of traffic on the railways will increase, with a high degree of probability it can be concluded that the number of accidents at RLC will increase. In this context it will be necessary and to develop a plan of investing in RLC insurance in order to raise the level of traffic safety and accident reduction. Insurance RLC with automatic security equipment (barriers) is an investment that requires the allocation of significant funds while making decisions about investment management has a big responsibility, as approved funds must give proper effect. It is therefore very important that management has adequate tools to facilitate the process of selecting RLC and making investment decisions.

In this paper the application of MARICA method for making optimal investment decision in order to improve safety at RLC is presented. It starts from the premise that

[1] Assistant profesor, PhD Dragan Pamučar, dipl. eng, Military academy, Belgrade, dpamucar@gmail.com
[2] Associate profesor, PhD Ljubislav Vasin, dipl. eng, Military academy, Belgrade, ljvasin@gmail.com
[3] Assistant, Mag. Vesko Lukovac, dipl. eng, Military academy, Belgrade, lukovacvesko@yahoo.com

the observed RLCNO at a time when there are resources for a limited number of RLC on which to install new safety equipment for AO.

This paper presents a hybrid model of multi-criteria decision-making in which is implemented fuzzy DEMATEL method [2,4,6] and a new method of multi-criteria decision-making methods MARICA, which was developed at the Center for Logistics Research of Defense University in Belgrade. A modified fuzzy DEMATEL method was used in the evaluation process and criteria for determining weight coefficients. After determining the weight criteria, using the method MARICA, the value of criterion function are calculated. After determining criterion function the ranking of alternatives and the selection of the optimal railway level crossings for investing in safety equipment is peformed.

2. SETTING OF HYBRID DEMATEL-MARICA MODEL

Problem is formally presented by choosing one of the m options (alternatives) A_i,i =1,2….m, which we evaluate and compare among themselves on the basis of n criteria (X_j,j =1,2….n) whose values are known to us. Alternatives vectors are shown with x_{ij}, where is x_{ij} value of i-th alternative by j-th criteria. Because the criteria in varying degrees impact on final grade of alternatives, to each criterion we ascribe weighting coefficient $w_j, j=1,2,...,n$ (where is $\sum_{j=1}^{n} w_j = 1$) which reflects its relative importance in the evaluation of alternatives. Weighting coefficients in this paper were obtained by applying fuzzy DEMATEL method. In the process of determining the weight coefficients of criteria most commonly more experts are included. Due to this, in the following section the process of implementing DEMATEL method in groups decision-making process is explained.

In the first step of fuzzy DEMATEL method the expert ratings is collected and calculated the average matrix $\tilde{Z}$. For comparison of criteria pair experts use fuzzy scale in which are linguistic expressions represented by triangular fuzzy numbers $\tilde{z}_{ij}^{e} = \left(z_{ij,e}^{(l)}, z_{ij,e}^{(m)}, z_{ij,e}^{(r)}\right), e=1,2,...,m$, where e represents the label an expert, and m represents the total number of experts. By aggregation of expert opinions the final matrix $\tilde{Z} = \left[\tilde{z}_{ij}\right]$ is obtained. The elements of the matrix $\tilde{Z}$ are obtained by using the expression (1), (2) and (3)

$$z_{ij,e}^{(l)} = \min_{M}\left\{z_{ij,e}^{(l)}\right\},\ M = \{1,2,...,e,...,m\} \tag{1}$$

$$z_{ij,e}^{(m)} = \frac{1}{m}\sum_{k=1}^{m} z_{ij,k}^{(m)} \tag{2}$$

$$z_{ij,e}^{(r)} = \max_{M}\left\{z_{ij,e}^{(r)}\right\},\ M = \{1,2,...,e,...,m\} \tag{3}$$

where $z_{ij,e}^{(l)}$, $z_{ij,e}^{(m)}$ i $z_{ij,e}^{(r)}$ represent the preference of the e^{th} expert, M represents a set of experts who participate in the research, e represents the label an expert, and m represents the total number of experts.

After calculation of matrix elements $\tilde{Z}$, in the next step, elements of the normalized initial direct-relation matrix $\tilde{D} = \left[\tilde{d}_{ij}\right]$ are calculated, where every element of matrix $\tilde{D}$ belongs to the interval [0,1]. Calculation of matrix elements $\tilde{D}$ (4) is performed by using the expression (5) and (6).

$$\tilde{D} = \begin{bmatrix} \tilde{d}_{11} & \tilde{d}_{12} & ... & \tilde{d}_{1n} \\ \tilde{d}_{21} & \tilde{d}_{22} & ... & \tilde{d}_{2n} \\ ... & ... & ... & ... \\ \tilde{d}_{n1} & \tilde{d}_{n2} & ... & \tilde{d}_{nn} \end{bmatrix} \tag{4}$$

The elements of the matrix $\tilde{D}$ is obtained by summing the elements of the matrix $\tilde{Z}$ by rows. After that, by applying expression (6), among the summarized elements the maximum element $\tilde{R}$ are indentified. With simple normalization, expression (5), each element of the matrix $\tilde{Z}$ is divided by the value which we get by applying the expression (6).

$$\tilde{d}_{ij} = \frac{\tilde{z}_{ij}}{\tilde{R}} = \left(\frac{z_{ij}^{(l)}}{r^{(l)}}, \frac{z_{ij}^{(m)}}{r^{(m)}}, \frac{z_{ij}^{(r)}}{r^{(r)}}\right) \tag{5}$$

$$\tilde{R} = \max\left(\sum_{j=1}^{n} \tilde{z}_{ij}\right) = \left(r^{(l)}, r^{(m)}, r^{(r)}\right) \tag{6}$$

where n represents the total number of criteria.

In the next step, the elements of the total relation matrix $\tilde{T}$ are calculated. The total-influence matrix $\tilde{T}$ is calculated by applying equation (7), where I represent identity matrix.

$$\tilde{T} = \lim_{w\to\infty}\left(\tilde{D} + \tilde{D}^2 + ... + \tilde{D}^w\right) = \tilde{D}\left(I - \tilde{D}\right)^{-1} \tag{7}$$

In the final step of DEMATEL method, elements of the matrix $\tilde{T}$ are summed by rows and columns, bz the expressions (8) and (9).

$$\tilde{D}_i = \sum_{i=1}^{n} \tilde{t}_{ij},\ i = 1,2,...,n \tag{8}$$

$$\tilde{R}_i = \sum_{j=1}^{n} \tilde{t}_{ij},\ j = 1,2,...,n \tag{9}$$

where n represents the number of criteria.

Based on the values obtained by the expressions (8) and (9) the weight coefficients of criteria are calculated. The weight coefficients of criteria are determined using expressions (10) and (11)

$$\widetilde{W}_i = \left[\left(\widetilde{G}_i + \widetilde{R}_i \right)^2 + \left(\widetilde{G}_i - \widetilde{R}_i \right)^2 \right]^{1/2} \quad (10)$$

$$\widetilde{w}_i = \frac{\widetilde{W}_i}{\sum_{i=1}^{n} \widetilde{W}_i} \quad (11)$$

where $\widetilde{w}_i$ represents the final weights of criteria which are used in the process evaluation of alternatives [4].

By determining the weight coefficients of criteria conditions for representing mathematical formulation of MARICA method are created. A basic setting of MARICA method reflected in determining the gap between the ideal and the empirical ponders. By summing the gap for each criteria of observed alternative the total gap for each alternative is determined. At the end, the ranking of alternatives is carried out; where for the best ranked alternative the one which has the lowest value of the total gap is chosen. The alternative with the lowest total gap represents an alternative that for the highest number of criteria had values that were closest to the ideal ponders (ideal values of criteria). MARICA method is implemented through six steps:

Step 1. The definition of the initial decision matrix (X). In the initial decision matrix the values of criteria (x_{ij}, $i = 1,2,...n; j = 1,2,...m$) for each of the considered alternatives are determined.

The elements of the matrix X are obtained on the basis of personal preferences of decision maker or aggregation of expert decisions.

Step 2. Determination of preferences according to alternatives P_{A_i} choice. It is assumed that the decision maker (DM) does not take into account the probability of some alternatives selection, i.e. there are no preferences according alternative choices. Then he can observe alternatives such way that each takes place with equal probability.

$$P_{A_i} = \frac{1}{m}; \; \sum_{i=1}^{m} P_{A_i} = 1, \; i = 1,2,...,m \quad (12)$$

where m is the total number of alternatives that are chosen from.

In the analysis of decision-making with the a priori probabilities we assume that DM is neutral in relation to risk. In this case, all preferences according choice of the individual alternatives are equal i.e.

$$P_{A_1} = P_{A_2} = ... = P_{A_m} \quad (13)$$

Step 3. The calculation of matrix elements of theoretical ponders (T_p). The matrix of theoretical ponders (T_p), size n x 1 (n represents the total number of criteria) is defined. The elements of the matrix are calculated as the product of preference of choice alternatives P_{A_i} and the criteria weight coefficients (w_n).

$$T_p = P_{A_i} \begin{matrix} w_1 & w_2 & ... & w_n \\ \left[P_{A_i} \bullet w_1 \right. & P_{A_i} \bullet w_2 & ... & \left. P_{A_i} \bullet w_n \right] \end{matrix} \quad (14)$$

where n represents the total number of criteria and t_{pi} represents the theoretical ponder.

Step 4. Determination of the actual ponders (T_r) matrix elements.

$$T_r = \begin{matrix} \\ A_1 \\ A_2 \\ ... \\ A_m \end{matrix} \begin{matrix} \begin{matrix} C_1 & C_2 & ... & C_n \end{matrix} \\ \begin{bmatrix} t_{r11} & t_{r12} & ... & t_{r1n} \\ t_{r21} & t_{r22} & & t_{r2n} \\ ... & ... & ... & ... \\ t_{rm1} & t_{rm2} & ... & t_{rmn} \end{bmatrix} \end{matrix} \quad (15)$$

where n represents the total number of criteria and m represents the total number of alternatives.

Calculation of actual ponders (T_r) matrix elements is done by multiplying the matrix elements of theoretical ponders (T_p) and the elements of initial decision matrix (X) according to the expression:

- For criteria of „benefit“ type (higher value of criteria is preferable)

$$t_{rij} = t_{pij} \bullet \left(\frac{x_{ij} - x_i^-}{x_i^+ - x_i^-} \right) \quad (16)$$

- For criteria of „cost“ type (lower value of criteria is preferable)

$$t_{rij} = t_{pij} \bullet \left(\frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \right) \quad (17)$$

Step 5. Calculation of the total gap matrix (G). The elements of the matrix are obtained as the difference (gap) between the theoretical (t_{pij}) and actual ponders (t_{rij}).

Step 6. The calculation of the final values of criterion functions (Q_i) by alternatives. Values of criterion functions are obtained by summing the gap (g_{ij}) by alternatives (summing the elements of the matrix (G) by columns):

$$Q_i = \sum_{j=1}^{n} g_{ij}, \; i = 1,2,...,m \quad (19)$$

3. APPLICATION OF DEMATEL-MARICA MODEL

The testing described DEMATEL-MARICA model was performed on example of prioritizing eight illustrative railway crossings. The eight criteria for the selection and evaluation of railway crossings were defined [3]:

$$G = T_p - T_r = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & \cdots & g_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ g_{m1} & g_{m2} & \cdots & g_{mn} \end{bmatrix} = \begin{bmatrix} t_{p11} - t_{r11} & t_{p12} - t_{r12} & \cdots & t_{p1n} - t_{r1n} \\ t_{p21} - t_{r21} & t_{p22} - t_{r22} & \cdots & t_{p2n} - t_{r2n} \\ \cdots & \cdots & \cdots & \cdots \\ t_{pm1} - t_{rm1} & t_{pm2} - t_{rm2} & \cdots & t_{pmn} - t_{rmn} \end{bmatrix} \quad (18)$$

K_1- The frequency of rail transport on the observed railway crossing (w=0.12);

K_2- The frequency of road transport on the observed railway crossing (w=0.19);

K_3- Number of tracks on the observed railway crossing (w=0.11);

K_4- The maximum permitted speed of trains on the chainage of level crossing (w=0.08);

K_5- The angle of intersection of the railroad and road (w=0.15);

K_6- The number of emergency events on the observed railway crossing in the past year (w=0.12);

K_7- Visibility of observed railroad crossing from the aspect of road transport (w=0.14);

K_8- The investment value of the activity in function of railroad crossing width (w=0.09).

For the evaluation of qualitative criteria (K_5, K_7 and K_8) fuzzy Likert scale was used [1]:

Table 1. Fuzzy Likert scale

R.b.	Linguistic terms	Fuzzy numbers
1.	Very good (VG)	(4.5,5,5)
2.	Good (G)	(3.5,4,4.5)
3.	Fair (F)	(2.5,3,3.5)
4.	Poor (P)	(1.5,2,2.5)
5.	Very poor (VP)	(1,1,1)

Table 2 shows the eight railway level crossings at which the presented model is tested.

Table 2. The evaluation of railway level crossings

Alter.	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*
PPP 1	24	165	2	40	G	3	P	G
PPP 2	56	212	2	50	P	5	P	F
PPP 3	41	71	2	60	G	7	P	VG
PPP 4	36	168	1	50	F	5	VG	G
PPP 5	25	153	2	40	P	3	P	VG
PPP 5	12	220	2	50	P	5	P	F
PPP 6	28	137	4	60	F	6	F	VG
PPP 7	35	112	2	60	G	4	F	P
PPP 8	24	165	2	40	G	3	P	G

*PPP- Railway level crossings

Values of criteria functions (Q_i) by alternatives (Table 3) are obtained by summing the gap (g_{ij}) by alternatives, ie summing the elements of the matrix (G) by columns, the expression (19).

By using the expression (20) defuzzification of fuzzy numbers was performed.

$$defuzzy\ A = \left[\left(a^{(r)} - a^{(l)}\right) + \left(a^{(m)} - a^{(l)}\right)\right] \cdot 3^{-1} + a^{(l)} \quad (19)$$

where $a^{(l)}$ and $a^{(r)}$ respectively represent the left and right distribution of confidence interval triangular fuzzy number, $a^{(m)}$ represents the value in which a triangular function reaches its maximum value.

Tab. 3. Rank alternative by the method MARICA

Alternative	*Q*	Rank
PPP 1	0.0851	7
PPP 2	0.0629	3
PPP 3	0.0668	5
PPP 4	0.0614	2
PPP 5	0.1029	8
PPP 5	0.0729	6
PPP 6	0.0590	1
PPP 7	0.0635	4

It is desirable to have an alternative with the lowest value of the total gap. So, the highest-ranked alternative is the one that has the lowest value of the total gap i.e. alternative 7.

4. CONCLUSION

Through this paper the application of a hybrid DEMATEL - MARICA model is shown in making an investment decision on the selection of railway level crossings for installation the safety equipment. DEMATEL method is applied in part for determining weight coefficients. and a new multicriteria method – MARICA method in part of the alternatives evaluation. Application of the method has been elaborated through the steps and shown on the illustrative example.

Beside to the shown application in the selection of railway level crossings, MARICA method can be used to solve other problems of multi-criteria decision making. The main recommendations for further use of this method is: a simple mathematical form, the stability of solutions and the ability to combine with other methods, especially in the part relating to the determination of weight criteria.

REFERENCES

[1] Anandarao, S., Martland, C.D., *Level crossing safety on east Japan company: application of probabilistic risk assessment techniques*, Transportation 25 (3), 265–286, 1998.

[2] Buyukozkan, G., Cifci, G., *A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers*, Expert Systems with Applications, 39, 3000–3011, 2011.

[3] Ćirović,G., Pamučar, D., *Decision support model for prioritizing railway level crossings for safety improvements: Application of the adaptive neuro-fuzzy system*, Expert Systems with Applications, 40,6, 2208-2223, 2013.

[4] Dalalah, D., Hayajneh, M., Batieha, F., *A fuzzy multi-criteria decision making model for supplier selection*, Expert Systems with Applications, 38, 8384–8391, 2011.

[5] European Railway Agnecy, Railway safety performance in the European Union, 2011.

[6] Wang, Y.L., Tzeng, G.H., *Brand marketing for creating brand value based on a MCDM model combining DEMATEL with ANP and VIKOR methods*, Expert Systems with Applications 39, 5600–5615, 2012.

ON VALIDITY OF INTRODUCING THE ENERGY METERS ON ELECTRIC TRACTION UNITS

Slobodan ROSIĆ [1]
Dragutin KOSTIĆ [2]

Abstract *– In the new conditions in railway sector in Europe, energy efficiency is very important, both for reduction in CO_2 emmision, and for economical effectivness of railway operators. Mandatory instalation of devices for measuring electrical energy consumption can significantly contribute to this cause. Having in mind the relativly small costs of this obligation, and great possibilities for savings, introduction of this measure is completely justified. In addition, mandatory introduction of measuring devices will enable the fairer treatment of operators, and improve the competitivness of railway sector.*

Keywords – Energy metering, traction units, normative framework.

1. INTRODUCTION

Devices for measuring electricity consumption on railway vehicles are not a new technology, but they didn't have any significance for railway system so far. Although the metering consumption on the vehicle does not save any energy by itself, it is required for efficient managment of those procceses.

In current conditions in European railway sector there are three main areas where this is important:

- reduced electrical energy consumption,
- adeqaute and fair billing of consumed energy to each operator,
- possibility to choose the most favourable electrical energy supplier.

These three areas are very significant in railway operators buiseness, and the first one is also important for the entire society, because of the need to reduce the CO_2 emmision.

It is also required that the railway services market be regulated in a way that adequately valorizes energy efficient operators, and leaves them with the possibility to choose the most favourable energy supplier. In order for this to be possible, it is important to have the ability to accuratly measure the energy consumed in transporting as well as billing of metered consumption.

2. NORMATIVE FRAMEWORK FOR DEVICES FOR MEASURING THE ELECTRICITY CONSUMPTION ON RAILWAY VEHICLES, AND THEIR USE ON EUROPEAN RAILWAYS

Until the development of common european regulative for railway sector, devices for measuring the electricity consumption were not standardized in any of the european countries. Basis for enacting the common norms for these devices was created when European Union adopted a directive 2001/16/EC about interoperability of railway systems. Common technical specifications of interoperability (TSI) were based on the directive, and common norms for devices for measuring eletricity consumption were defined within them for the first time.

These devices are defined in two TSIs: “TSI for locomotives and passenger railway vehicles” and “TSI for infrastructure”. Both TSIs refer to the coresponding EN norms that explain the detailed demands and standards for these devices and their components. EN 50463-1 to 5 series of standards named “application on railway – measuring energy on train” were enacted for them. This system is defined to serve for managing energy consumption as well as serving for energy billing in EN 50463 (general part). Functional chart of the system is given on figure 1. Device for measuring energy consumption on platform vehicles is not mandatory according to the currents TSIs, unless it is used for billing the consumed energy.

[1] Slobodan ROSIĆ, BSc, JP Železnice Srbije, Nemanjina 6, 11000 Beograd, srosic@sbb.rs
[2] Dragutin KOSTIC, PhDEE, Faculty of Traffic and Transport Eng. University of Belgrade, 11000 Beograd, Vojvode Stepe 305, d.kostic@sf.bg.ac.rs

Use of this device in certain countries is defined by national regulations that the infrastructure manager must publish in his Network statement. Current situation about billing the energy consumption is as follows:

Out of 26 member states of EU (2 dont have any railway) and 5 candidate states (Serbia, BiH, Montenegro, Macedonia and Albania), device for measuring energy consumption board is only mandatory in Hungary. This device is mandatory in Belgium if the operator is not buying electricity from the railway infrastructure manager (Infrabel), but from companies on the electrical energy market. In all the other countries, the use of these devices is not mandatory, but it is possible in the most of the countries in western Europe and Scandianvia [1].

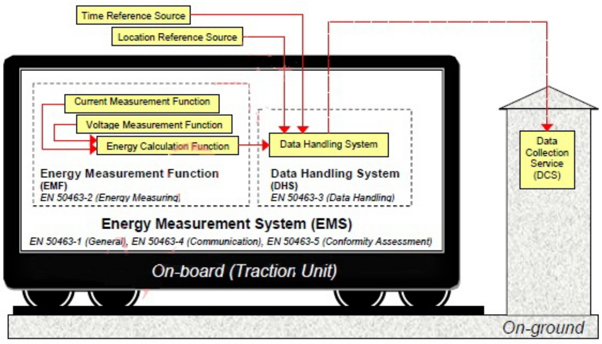


Fig.1. Functional chart of measuring system

Untill now, there was no unanimous attitude about mandatory installment. While the SNCF (French national railways) considered that those devices have no major significance, and that no significant effects can be expected from them, DB (German federal railways) had completly opposite attitude and decided that within few years, all their vehicles must be equiped with them. European commision, general directorate for transport (DB Move) currently has the attitude that the next revision of TSI should declare devices for measuring energy consumption on railway platform vehicles mandatory [2][3].

3. ANALYSIS OF JUSTIFICATION OF MANDATORY INSTALATION OF ENERGY METERS ON SERBIAN RAILWAY NETWORK

Analysis of justification of mandatory instalation of energy meters on traction units would include several steps:

3.1. Evaluation of possible effects on energy consumption for all considered types of the traffic

Railway traffic in Serbia can be divided into three categories: Passenger local, Passenger distant, and Cargo. Table 1 shows evaluation of effects of considered measures for reduction in electrical energy consumption expressed in precentage of reduction in electrical energy consumption that is expected when applying those measures, based on research on other European railways [4][5][6].

Tab. 1. Evaluation of measures for reduction of electrical energy consumption

No		Passenger local	Passenger long-distant	Cargo
1.	Reduction in weight	15 %	10 %	2 %
2.	Reduction of resistance	-	-	1 %
3.	Efficiency of propulsion	2 %	2 %	1 %
4.	Recuperation and storage of energy	15 %	10 %	15 %
5.	Optimization of heating and airconditioning	2 %	2 %	-
6.	Auxiliaries consumption (out of traffic)	4 %	2 %	-
7.	Energy efficient driving and traffic regulations	7 %	5 %	5 %
8.	Optimization of the timetable	2 %	1 %	1 %

3.2. Evaluation of significance of introducing the energy metering on traction units for realization of each of these measures

In order for some of the measures for reduction of electrical energy consumption to be effective, it is necessary to have accurate measurement of the electrical energy consumption, while for others, it is less important. Since Serbian railways are currently extremly energeticaly inefficient, it is clear that the operators will invest in some of these measures only if they are able to valorize them through reduction in costs of electrical energy.

Otherwise they will, regardless of their own efficiency, share the inefficiency of the existing operator, and they wont be interested in investments. On the other hand, for some of the measures, it is not of significant importance. For measures where the significance of measuring devices is great, we consider that 100% of the possible savings is related to the use of the devices, for those where the significance is moderate, it is 50%, and for those where significance is minor, we consider it to be 10%. Evaluation of significance is given in Table 2.

Tab. 2. Evaluation of significance of energy meters on individual measures

No		Evaluation of significance
1.	Reduction in weight	Minor (10 %)
2.	Reduction of resistance	Moderate (50 %)
3.	Efficiency of propulsion	Moderate (50 %)
4.	Recuperation and storage of energy	Great (100 %)
5.	Optimization of heating and airconditioning	Great (100 %)
6.	Auxiliaries consumption (out of traffic)	Minor (10 %)
7.	Energy efficient driving and traffic regulations	Great (100 %)
8.	Optimization of the timetable	Moderate (50 %)

3.3. Determining the possible reduction in electrical energy consumption

Based on the previous two tables, it can be estimated that measuring devices can effect the reduction in electrical energy consumption on Serbian Railways for 27,9% in local passenger traffic, 20,7% in distant passenger traffic, and 21,7% in cargo traffic. According to statistical data, electrical energy consumption on railway per type of transport was: local passenger traffic 14% distant passenger traffic 25%, cargo traffic 61% [7].

Based on this, we can estimate that mandatory instalation of devices for measuring energy consumption on board can affect the reduction in electrical energy consumption for all types of traffic on Serbian Railway network for about 22% for new vehicles and about 20,9% for existing vehicles (measures 1. and 3. cannot be applied to existing vehicles).

3.4. Comparing the achieved savings to the costs of introducing these devices

According to statistical dana for 2012, 143 002 155 KW/h of electrical energy was spent on the Serbian Railways netwok - about 5 737 572 euros, which means that the cost per one tractive unit of active rolling stock is 37 256 euros [7]. Savings in electrical energy consumption of 20,9% would total to 7787 euros per year. On the other hand, according to the DB study, cost of installing the measuring devices during the regular repairs on tractive vehicles are about 2 000 euros [3]. So the value of the reduced consumption of eletrical energy is surpassing the instalation costs by far in the first year.

4. CONCLUSION

Classical integrated railway companies measured their electrical consumption at the power station, cumulatively, and they didn't need to measure the consumption of every single train or vehicle.

Significant changes in European railway system in the past few decades influenced a change in this situation. One of the main goals of this reform was increasing the efficiency of the sector by reducing the costs and introducing competition. Efficiency in energy consumption has an important role in reaching this goal. Therefore it is neccesary for railway operators to be able to manage their energy efficiency. The first step of the process of management of energy efficiency is accurately measuring of the energy consumption.

ACKNOWLEDGEMENT

The paper is done within a framework of a project TR36047 supported of the Ministry of Science and Technological Development.

REFERENCES

[1] www.rne.eu/**network-statement**
[2] *Documents of Energy and Metering day*, Wiena 3rd Feb.2011.
[3] DB AG (2000): TEMA project
[4] EIM (2010): EIM Position Paper on Energy Meters on Electric trains
[5] Treige, P.; J. Olde (2000): *Energiemessung auf elektrischen Triebfahrzeugen bei der Deutschen Bahn*. Elektrische Bahnen 8/2000, p. 300.
[6] Bryan Donnelly, ATOC (2010): *Refurbishment of Rolling Stock*. Workshop Railenergy Final Conference 2010, Brussels
[7] Gunselmann W. (2005): *Technologies for Increased Energy Efficiency in Railway Systems*, EPE Dresden 2005 , pp. 1-10
[8] AD „Železnice Srbije“: Statistika za 2012. Želnid, Beograd 2013.

A COMPARISION OF DRIVER BEHAVIOR AT RAILWAY CROSSING WITH PASSIVE AND ACTIVE PROTECTION SYSTEMS

Sandra KASALICA [1]
Goran TRIČKOVIĆ [2]
Dušan JEREMIĆ [3]
Marko BURSAĆ [4]

Abstract –An observational study was conducted which compared the behaviour of drivers at a railway crossing as train approached. The effectiveness of a passive protection system was compared with one incorporating flashers and barrier gates for a particular crossing. The addition of the gates significantly reduced the percentage of drivers crossing in front of trains from 57% to 15.5%. Plots of crossing probabilities showed them reduced as time until train arrival and the distance of the train from the crossing decreased.

Keywords – Driver behaviour, Railway crossing safety, Railway crossing protection, Half-gates.

1. INTRODUCTION

On the territory of the Republic of Serbia total length of railway network is about 4,000 km, out of which 276 km are multiple tracks and 934 km are electrified. There are 2,138 railway crossings in total. All these crossings have various warning devices Serbian railway crossing inventory database (2007-2011) [1].

According to Statistics on accidents at Serbian Railways (Serbian Rail Administration, 2011) [2], the number of deaths and severe injuries at crossings is increasing every year, with a considerable material damage. For Serbian Railways it is very important to estimate safety in order to indentify high risk locations, as well as to develop an engineering treatment and estimate its impact.

There are generally three different types of measures which can be used to make crossing safer: 1) crossing closure or grade separation, 2) improving crossing geometry, and 3) upgrading traffic control devices. Active protection system that has been implemented by us are half-gate. As a complement to this system on two crossings with half-gates video enforcement system has been added. However, unsafe driver behavior is largely intact, and at railway crossings with active signaling. According to statistics [2], 21% of people killed on railway crossings with active protection systems.

In [3] was conducted a small observational study of driver behavior as trains approached at rural crossing in the south part of Serbia, in a populated area of Čapljinac near the city of Niš, for which the authors were aware that in the near future to provide an automatic device railway crossing with half-gate.

2. METHODS

Observational setting

Observed railway crossing Čapljinac is secured by active protection system which includes half-gates, flashing lights and sound warning devices (hereinafter active protection), in comparison to previous warning device which was St. Andrews cross and Stop sign (hereinafter passive protection). Approaching train on certain fixed distance activates protective system. There were no other significant changes except road surface on crossing was paved again.

The settlement is rural and the road is of a local character. Railway crossing has two of four sight triangles. The average daily traffic (ADT) is about 500 road vehicles. The approaching speed of road vehicles is limited to 30 km/h. Other details about this crossing are the same as in previous study.

The railway is a trunk single-track railway, a part of the international Corridor 10. The traffic on the railway is mixed, passenger and freight. The realised number of trains is around 20 trains daily. The permitted speed on

[1] Sandra KASALICA, Ph. D, Railway College of Vocational Studies, sandra.kasalica@gmail.com
[2] Goran TRIČKOVIĆ, Spec. App. Eng. Traffic, Railway College of Vocational Studies, tricko86@gmail.com
[3] Dušan JEREMIĆ, M Sc, Railway College of Vocational Studies, dusan.jeremic@vzs.edu.rs
[4] Marko BURSAĆ, B Sc, Railway College of Vocational Studies, marko.bursac@vzs.edu.rs

the railway is 100 km/h, and measured speed over crossing is between 23 and 92 km/h, while on passive device study is from 30 to 95 km/h.

Subjects

Drivers of vehicles who arrived at the crossing after the flashers and gates are activated, but before train arrival constituted the subjects in the study. The observation lasted for one week during spring. It was conducted in different periods of the day only during daylight hours. The period of the day during which the observation was made depended primarily on the frequency of rail traffic. The weather conditions were good, with good visibility.

Procedure

For the purpose of observing and recording the behaviour of road traffic participants at the chosen railway crossing, two researchers were involved simultaneously. Two researchers were located in a small official railway warehouse and they recorded the road traffic from that building, using two installed video cameras. They were not visible by the traffic participants and neither did they affect their behaviour. Procedure was much simpler than in previous study.

When approaching train activates warning system, researchers started recording railway crossing regardless if road vehicle is present or not. Recordings were later analysed.

For each particular train arrival, video recordings were analysed and following data was processed: (1) whether the driver stopped in front of approaching train or continued driving, (2) the elapsed time (in seconds from signal onset) until a vehicle arrived at the crossing, (3) the moment when the road vehicle crossed the crossing, (4) the driver's behaviour before crossing, whether they stopped, decelerated or passed the crossing without deceleration, (5) the moment of the train arrival and (6) the moment when crossing device was turned off. Based on the collected data, database was constructed for further research. During the period from warning device upgrade until this study was conducted no accidents data was recorded.

At the outset of the study several hypotheses were entertained concerning the differences that might be observed between drivers approaching the two types of protection systems, passive and active.

The first hypothesis was that fewer drivers would elect to cross in front of the trains now that half-barrier gates were present. Second hypothesis was about drivers who crossed in front of approaching train. Hypothesis was that most of the drivers will cross on warning lights without stopping or slowing down.

3. RESULTS

During the observation period, 58 cases of approaching vehicles were recorded at the observed railway crossing. The period of day when vehicles appeared was from 7:30 to 18 h. This time distribution is not much different than one conducted in previous study (passive device). Driver visibility depending on the weather conditions was not changed considerably compared to weather conditions in previous study.

Variables analysed in active protection study were: train speed, train distance from crossing, time until train arrived, time between device activation and train arrival and existence of sight triangle for approaching vehicle. Analysis was conducted based on exact variable values for each vehicle arrival on crossing in front of approaching train. Variables analysed in passive protection study [3] were: train speed, train distance from crossing, remaining time until train arrived and existence of sight triangle for approaching road vehicle.

It is assumed that different types of violation are influenced by different variables. Therefore, the total number of violations observed was divided into three categories [4]. The first category of violations was defined as occurring between the onset of the flashing light signals and two seconds after the gate arms started to descend. The second classification of violations was defined as violations occurring after the gate arm had been in motion for two seconds until the gate arms were in their horizontal position, or occurring after the gate arms were completely horizontal and before the train arrived. The last violations classification occurred after the train departed but before the gates were completely raised, which was not considered because it does not pose a threat as the first two categories.

3.1 Crossing behaviour

Nine out of 58 drivers (15.5%). crossed the tracks despite active device When passive device was present, percentage of drivers who crossed in front of approaching train was significantly higher (35 of 61 or 57%). According to z-test there are statistically significant differences in behaviour of these two groups of drivers, those who crossed in front of the train at active and passive protection ($p = 0.000$).

From 9 drivers which crossed in front of approaching train, 8 drivers crossed on flashing light warning and one drove around half-gates.

From 9 drivers which crossed in study with active protection, two drivers or 22% stopped their car before crossing over. In study with passive protection 10 of 35 (29%) showed such behaviour. The resulting z-test shows that differences in old and new conditions are not significant ($p = 0.339$).

Similarly, 2 of 9 (22%) drivers in study with active protection slowed down before crossing, while 17 of 35 (48%) drivers slowed down before crossing in study with passive protection. ($p = 0.0835$).

The remaining group of crossing drivers neither stopped nor slowed down before crossing. In conditions with new protection 5 of 9 (55.5%) drivers showed this kind of behaviour. In study with passive protection device this classification is 8 from 35 (23%). Differences in proportion suggest existence of significant differences between observed events in old and new conditions ($p = 0.032$).

The analysed safety margin, which is the time interval from the moment a road user has left the crossing area to the moment a train arrives at the crossing area, ranges from 6 to 79s.

Safety margin in passive protection conditions was from 10 to 86s. Average safety margin for these two groups is 32.7s for passive and 54.6s for active protection. Safety margin shows significant differences in these two cases ($p = 0.004$).

Drivers who did not cross in front of approaching train were waiting in different time intervals. Among 49 drivers waiting in active protection conditions, waiting time interval was between 2 and 126s. Average waiting time in active protection conditions is 33.6s. Average waiting time in passive protection conditions is 19.7s. Average waiting time in both cases is statistically significantly different ($p = 0.000$). This waiting time difference is certainly consequence of different protection system in old and new circumstances.

Tab.1. Summary of differences in driver behaviour

Behaviour	Passive protection	Active protection	Difference probability
Stop and wait	26 of 61 (43%)	49 of 58 (84.5%)	$p = 0.000$ *
Cross desprite warning	35 of 61 (57%)	9 of 58 (15.5%)	$p = 0.000$ *
Stop before proceeding	10 of 35 (29%)	2 of 9 (22%)	$p = 0.339$
Slow before proceeding	17 of 35 (48%)	2 of 9 (22%)	$p = 0.0835$
Did not stop or slow	8 of 35 (23%)	5 of 9 (55.5%)	$p = 0.032$ *
Mean waiting times	19.7 s	33.6 s	$p = 0.000$ *
Mean crossing safety margin	32.7 s	54.6 s	$p = 0.004$ *

As railway crossing in this study has two of four sight triangles, behaviour of drivers with good and bad sight of approaching train was further analysed. In total, 27 drivers (46.5%) from 58 had good sight of approaching train. From 27 drivers 7 crossed (26%) and 20 drivers stopped and waited until train passed. Remaining 31 drivers had bad sight of approaching train, from which 2 crossed (6.5%), and remaining 29 waited (93.5 %). Warning time is time between device activation and train arrival on crossing, and it is between 44 and 95s. In case of one slower train that time was 141s. Average warning time in this sample was 71 seconds.

If t_1 is a moment of crossing device activation and t_2 moment of road vehicle arrival on crossing, difference between them, $t_2 - t_1$ is from 3 to 80s. This time will be discussed in crossing probability function.

Technical irregularities on crossing were observed in two cases. In one case railway crossing was not secured while in other device was activated although train arrival wasn't recorded. Data from first case was included, but data from second was disregarded because train parameters were missing.

See Tab.1 for an overview of the differences in driver behaviour observed between conditions.

3.2 Probability of crossing

The probability of drivers crossing in front of the approaching trains was determined for the two protection systems. Probability of crossing was plotted as a function of train location (distance of train from the crossing at the time the vehicle arrived) in Fig.1.

The time available to cross (a combination of train speed and location upon arrival) may be seen in terms of its impact on crossing decision in Fig.2. Finally, the speed of train relative to the probability of crossing may be seen in Fig.3.

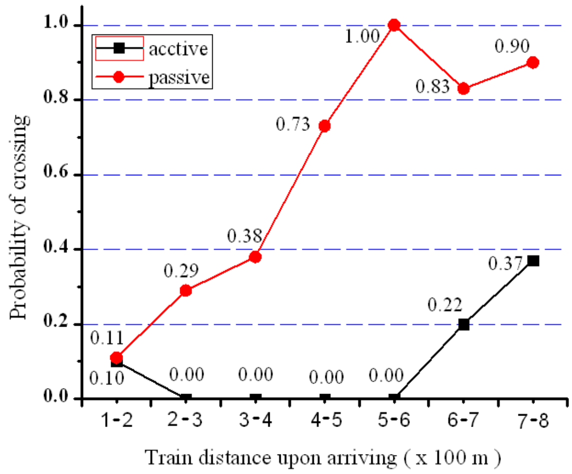


Fig. 1.Probability of crossing as a function of distance of the train from the crossing.

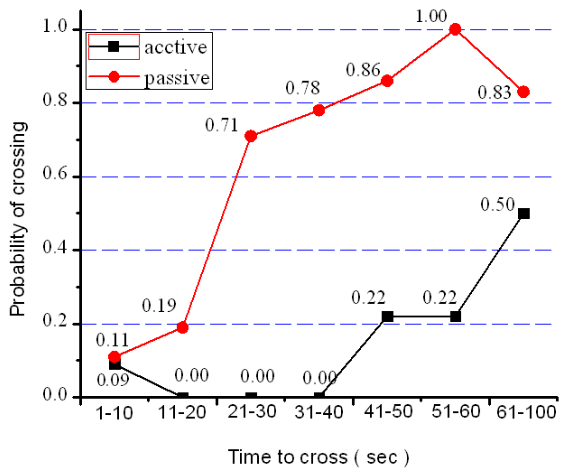


Fig. 2.Probability of crossing as a function of time available until train arrival.

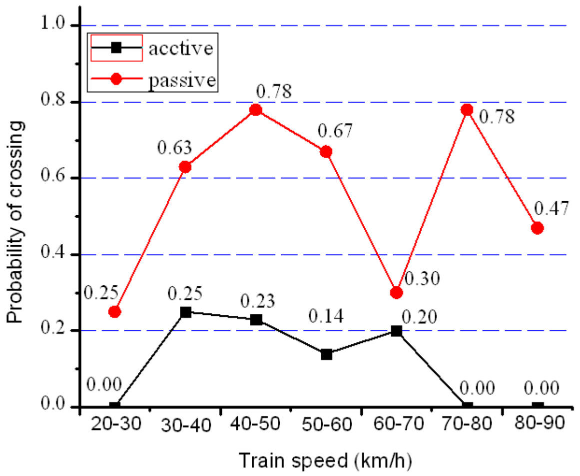


Fig. 3.Probability of crossing as a function of train speed.

4. DISCUSSION

It may be argued that upon arriving at the crossing drivers are making a decision as to whether or not to cross on the basis of their perception of the time available to them before the train arrives. Fig. 2. shows that drivers in both groups are more inclined to cross with longer times before train arrival. Note also that the decisions made by the drivers at the gated crossing are somewhat more cautious than those in the passive condition.

The judgment as to time until train arrival may be seen as potentially being affected by the distance of the train from the crossing and by the apparent speed of the train. Fig. 1. reveals that both groups are inclined to cross as expected, e.g. drivers are not inclined to cross when train is near the crossing. It can be determined, as above, that driver's decisions are more cautious in presence of active protection.

The apparent speed of the train should also affect the decision to cross since it affects the time available. The relationship between train speed and crossing probability shown on Fig. 3 does not show expected linear dependence of train speed and crossing probability ($y = -0.019x + 0.193$, $R^2 = 0.126$). It suggests that train speed estimate, particularly for those trains at some distance from the crossing, is a difficult one.

When drivers are assessing signalization, there is significant difference between drivers that stopped and those who crossed in front of approaching train, according to Analysis of Variance (ANOVA) test ($F = 15.60$, $p = 0.00189$). Effects of device working time on driver's decision to cross showed that drivers are more inclined to cross if device is working for a shorter time. It means that group of drivers which decided to cross done that while flashing lights were working.

The first hypothesis regarding the effects of upgraded protection system was clearly supported by the data. That is, the addition of half-gates appears to have substantially reduced the number of crossings made in front of oncoming trains. It was shown that active protection largely reduces percentage of drivers which cross in front of approaching train from 57% to 15.5%. It certanly explains why number of accidents is largely reduced on railway crossings with active protection system.

The second hypothesis is also backed up with data. It refers to fact that majority of drivers crossed exactly on flashing lights without stopping or slowing down. These results are consistent with study [5]. In that way drivers leave longer safety margin than in case of passive protection, p = 0.004.

5. CONCLUSION

This investigation does allow for some tentative conclusions. First the primary benefit of half-gates would seem to be that they reduce the number of crossings made in the presence of approaching trains compared to passive system. Furthermore, it was concluded that technical measurement, half-gates implemented on this site, was quite satisfactory regarding deterrence of drivers from irregular behavior. However, the crossing investigated was primarily used by persons who traversed it routinely and most likely had some knowledge of train speeds, sight restrictions, etc. Compliance to barrier gates would surely differ in other settings where, for example, traffic volume was higer and drivers were commonly influenced by the crossing decisions made by other drivers.

To understand the effect of this and other protection devices requires that they be investigated in many different contexts. Such research might then suggest those settings in which barrier gates might be most effective.

REFERENCES

[1] Serbian Rail Administration. The Serbian railway crossing inventory database (2007- 2011), Serbian Railways; in Serbian.

[2] Serbian Rail Administration. Statistics on accidents on Serbian railways 2011; in Serbian.

[3] Kasalica, S., Vukadinović, R., and Lučanin, V. (2012). "Study of drivers behaviour at a passive railway crossing." *Promet - Traffic Transp.,* 24 (3),193-201.

[4] Fitzpatrick, K., Carlson, P. and Bean, J. (1997). "Traffic violations at grade highway-railway grade crossings". Texas transportation institute, Research report 2987-1.

[5] Richards, S. H., and Heathington, K. W. (1989). " Driver Behavior at Rail-Highway Crossings". Report No. DTFH61-88-Z-00145. U.S. Department of Transportation, Federal Highway Administration. Washington, D.C.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

RANKING OF HEADWAYS PRIORITY IN RAILWAY TIMETABLE

Predrag JOVANOVIĆ [1]
Dragomir MANDIĆ [2]
Dragan IVANOVIĆ [3]

Abstract *- Timetable construction aims to traffic planning all trains on one track as well as the interaction between them. Aspiration of designers is to connect the start and end station of every train in the shortest possible time, which would make possible to provide a higher level of transport services. On the other hand, it is impossible to make a perfect schedule in which there will be no operation delays. The aim of this paper is to define the criteria through which will be possible to determine the priority of the headways in which time reserves should be implemented, in order to improve robustness of the timetable, in order to keep difference between designed and real-life traffic at minimum.*

Keywords – railway timetable, buffer times, robustness, delay.

1. INTRODUCTION

In designing the timetable, in order to increase the stability and robustness, the headways should be increased by adding time reserves into them. These reserves are called buffer times. Besides them, there are reserves in driving times and the time reserves implemented in time dwelling time, aiming to reduce the possibility of disruptions caused by the entry and exit of passengers.

The more time reserves timetable has it is more robust, i.e. there is less possibility of the disruption to occur during implementation.

In the process of creating timetable, sometimes it is not possible to provide a buffer in all headways, or it is not possible to provide the necessary value of buffer times. On the other hand, implementation of any extension of travel time, lower the quality of transport services. In this paper, we will define criteria for the selection and priority ranking of headways, in which time reserves should be implemented. The work itself will not consider necessary amounts of the buffers.

2. DEFINITION OF IMPORTANCE OF TIME RESERVES BETWEEN TWO TRAIN PATHS

In case when in the projected timetable time reserves should be added, in order to prevent the delay propagation between the two trains, and when total available amount of time reserves is limited, question arise between which trains add buffer time, i.e. which train path should be more "protected".

Intuitively, in the case of interaction between trains of different ranks, train with higher rank should be more protect. This may not be the unique criterion, because it will be impossible to make a decision when trains have the same rank. In addition, the importance of the “path protection” from delay propagation is dependent on other factors.

In determining, the place of buffer implementation should take into account the time reserves already implemented in the previous part of each path.

For precise determination of the buffer time importance, in case of passenger trains also should take into account the number of major railway nodes through which the trains passes, because in them is higher possibility of delays.

2.1 Criterion of higher rank protection

Rank of trains allows us to determine to which train priority should be given, whether in timetable designing, whether in traffic realization. However, the rank of trains is important from the point of managing train traffic in real-time. Dispatchers usually do not take into account the stability and robustness of the timetable.

When the interaction is such that in the meeting station first comes lower rank train, buffer time, larger than average, should protect the higher rank train, in

[1] Predrag JOVANOVIĆ, MSc, Faculty of Traffic and Transport Engineering, University of Belgrade, Vojvode Stepe 305, 11000 Beograd, p.jovanovic@sf.bg.ac.rs
[2] Dragomir MANDIĆ, PhD, Faculty of Traffic and Transport Engineering, University of Belgrade, Vojvode Stepe 305, 11000 Beograd, drama@sf.bg.ac.rs
[3] Dragan IVANOVIĆ, BSc, 11000 Beograd, dr.ivan73@gmail.com

order to disable transmission of delays. In this way, train rank influence the value of the buffer time. However, when there is more than one of these cases, and when the available time reserves are limited and less than the sum of all required buffer time, one must choose a path to protect. Exclusively based on train rank, such decision cannot be reached.

The only that this criterion allows, is the principle of "in depth" meeting the demands, i.e. priority to protect the path of the highest rank until it is possible, and if there is remaining resources, protection of the path of the next rank, etc..

2.2 Criterion of length of the remaining travel distance

When considering the length of the remaining travel distance of the train whose path buffer time should protect two basic, but logically opposing ideas arises. First, the larger remaining travel distance is, the greater the possibility that the train has delay in the final station, simply because there is more places where delays may occur. On the other hand, the longer the remaining part travel distance is, the greater are the opportunities for later implementation of time reserves, which could enable neutralization of occurred delays.

The most accurate would be to set up this problem as a Pareto-optimal problem and thus prioritize headways in which to allocate a buffer times in, but it significantly increases the complexity of the problem.

To simplify the problem, with a sufficient level of precision, the importance of certain headways for implementing buffer time between the train paths ***at the station S*** should determine by the "coefficient of modified rank", using train rank and remaining travel distance of a path that should protect:

$$\rho(r) = \frac{r_t}{\sum_{msr=S}^{MSR} l_{msr}} \left[1/km\right],$$

when ($N_V$mod2) ≠ 0, or

$$\rho(r) = \frac{r_t}{\sum_{msr=1}^{S-1} l_{msr}} \left[1/km\right], \qquad (1)$$

when ($N_V$mod2) = 0,

where:

- *MSR* - total number of inter-station distance on train travel distance, where is valid *MSR* = *NS* – *1*,
- *NS* - total number of stations at line or section,
- *S* - station for which the priority of time reserves allocation we consider,
- *msr* – distance between two stations,
- *ρ(r)* - coefficient of modified rank of train,
- r_t – rank of train whose path buffer time protects and
- $\sum_{msr=S}^{MSR} l_{msr}$ or $\sum_{msr=1}^{S-1} l_{msr}$ - the remaining travel distance, depending on the direction of train, where the trains operating in direction east-west and north-south are marked by even numbers.

Train rank, r_t, can take a value from one, which takes the lowest ranks, up to total number of different ranks of trains, which run through the observed station.

The higher the "coefficient of modified rank", higher will be the priority protect that train's path. As this coefficient decreases with the increase of the remaining travel distance, it is clear that in this way we favors the possibility that in the rest of travel distance more reserves can be added, as we assume that this process is iterative.

2.3 Criteria of previously allocated time reserves

On arrival of the train in a meeting-station only two cases could occur: the train runs on schedule or that the train is late. Logically, the case when the train is late will be less likely if the path of the train from the starting-station to meeting-station is protected with larger amount of time reserves. In other words, a higher priority should give to locating the buffer time in headways in which the train that came first in station has less time reserves, at the distance traveled.

It can be assumed that it is more accurate to take into account only the time reserves for each path from the last scheduled stop of the train, up to the station S, for which a priority allocation we determine. However, in this way would be favored paths of trains that have frequent planned stops, and usually those are trains of lower rank. That is why we rejected that and we observe all time reserves, from starting station to station S.

It is important to emphasize that in this case, we are always watching time reserves in path of the train that first comes to the meeting, because the buffer time protects another train against possible delay transmission. As travel distances for different trains do not have to be the same for all trains, shall not consider only the sum of all time reserves. The most practical would be to take into account the "density of time reserves allocation" with regard to the distance traveled, and "density of time reserves allocation" is possible to define in many different ways:

1. "density of allocation" time represents the ratio of total amount of time reserves up to station S and the distance that the train passes to that point:

$$\gamma_1(t_{res}) = \frac{\sum_{msr=1}^{S-1} t_{msr}^{res} + \sum_{s=2}^{S} t_s^{buff} + \sum_{s=2}^{S} t_s^{dw-buff}}{\sum_{msr=1}^{S-1} l_{msr}} \left[min./km\right]$$

$(N_V \bmod 2) \neq 0$, or

$$\gamma_1(t_{res}) = \frac{\sum_{msr=S}^{MSR} t_{msr}^{res} + \sum_{s=S}^{NS-1} t_s^{buff} + \sum_{s=S}^{NS-1} t_s^{dw-buff}}{\sum_{msr=S}^{MSR} l_{msr}} \left[min./km\right] \quad (2)$$

$(N_V \bmod 2) = 0$

where:

- $\gamma_1(t_{res})$ - density of time reserves allocation,
- $\sum_{msr=1}^{S-1} t_{msr}^{res}$ or $\sum_{msr=S}^{MSR} t_{msr}^{res}$ - sum of driving time reserves, on each inter-station distance,
- $\sum_{s=2}^{S} t_s^{buff}$ or $\sum_{s=S}^{NS-1} t_s^{buff}$ - the sum of the buffer time in all stations up to station S,
- $\sum_{s=2}^{S} t_s^{dw-buff}$ or $\sum_{s=S}^{NS-1} t_s^{dw-buff}$ - the sum of dwell-time reserves in times of practicing, in all stations up to station S and
- $\sum_{msr=1}^{S-1} l_{msr}$ or $\sum_{msr=S}^{MSR} l_{msr}$ - path length, from the first station up to station S.

Thus defined, the "density of time reserves allocation" represents the average amount of time reserves, by distance traveled.

Greater the density of time reserves allocation is, the train path is better protected from possible disturbances, at already passed part of the line.

2. "density of time reserves allocation" represents the ratio of the total amount of time reserves and minimum travel time from starting station up to station S:

$$\gamma_2(t_{res}) = \frac{\sum_{msr=1}^{S-1} t_{msr}^{res} + \sum_{s=2}^{S} t_s^{buff} + \sum_{s=2}^{S} t_s^{dw-buff}}{\sum_{msr=1}^{S-1} t_{msr}^{travel} + \sum_{s=2}^{S} t_s^{dwell}},$$

when $(N_V \bmod 2) \neq 0$, or

$$\gamma_2(t_{res}) = \frac{\sum_{msr=S}^{MSR} t_{msr}^{res} + \sum_{s=S}^{NS} t_s^{buff} + \sum_{s=S}^{NS} t_s^{dw-buff}}{\sum_{msr=S}^{MSR} t_{msr}^{travel} + \sum_{s=S}^{NS} t_s^{dwell}}, \quad (3)$$

when $(N_V \bmod 2) = 0$

where:

- $\sum_{msr=1}^{S-1} t_{msr}^{travel}$ or $\sum_{msr=S}^{MSR} t_{msr}^{travel}$ - sum of smallest driving times for each inter-station distance, from the first one to the one which station S belongs to and
- $\sum_{s=2}^{S} t_s^{dwell}$ or $\sum_{s=S}^{NS} t_s^{dwell}$ - sum of the planned dwell times, without buffer times, in all stations, from the first one up to station S.

3. "density of time reserves allocation" represents the ratio of the total amount of time reserves, and total, planned, travel time up to the station S:

$$\gamma_3(t_{res}) = \frac{\sum_{msr=1}^{S-1} t_{msr}^{res} + \sum_{s=2}^{S} t_s^{buff} + \sum_{s=2}^{S} t_s^{dw-buff}}{\sum_{msr=1}^{S-1} t_{msr}^{travel} + \sum_{s=2}^{S} t_s^{dwell} + \sum_{msr=1}^{S-1} t_{msr}^{res} + \sum_{s=2}^{S} t_s^{buff} + \sum_{s=2}^{S} t_s^{dw-buff}} [\%],$$

$(N_V \bmod 2) \neq 0$,

$$\gamma_3(t_{res}) = \frac{\sum_{msr=S}^{MSR} t_{msr}^{res} + \sum_{s=S}^{NS} t_s^{buff} + \sum_{s=S}^{NS} t_s^{dw-buff}}{\sum_{msr=S}^{MSR} t_{msr}^{travel} + \sum_{s=S}^{NS} t_s^{dwell} + \sum_{msr=S}^{MSR} t_{msr}^{res} + \sum_{s=S}^{NS} t_s^{buff} + \sum_{s=S}^{NS} t_s^{dw-buff}} [\%], \quad (4)$$

$(N_V \bmod 2) = 0$.

In this way, the "density of time reserves allocation" represents the percentage of all time reserves in the planned travel time of the train for station S, for which priority of headways protection is determined. "Density of time reserves allocation" determine for the train that first comes at meeting station.

2.4 Criterion of time reserves existence by the end of the path

The purpose of defining of all train paths in the timetable is to determine all events in advance and to define the appropriate times regarding train travel from first to the last station. Therefore, the primary objective of the real-time traffic realization is to provide that each train leave from the starting station at planned time and to arrive at the final station without delay. Considering this, the defining buffer time allocation can take into consideration the possibility that at the remaining part of the path some earlier occurred delays can be reduced or neutralized. Therefore, we introduce the "coefficient of remaining time reserves" which is defined as:

$$\delta(t_{res}) = \frac{\left[\sum_{msr=1}^{MSR} t_{msr}^{res} + \sum_{s=2}^{NS} t_s^{buff} + \sum_{s=2}^{NS} t_s^{dw-buff} - \left(\sum_{msr=1}^{S-1} t_{msr}^{res} + \sum_{s=2}^{S} t_s^{buff} + \sum_{s=2}^{S} t_s^{dw-buff}\right)\right]}{(NS - S) \cdot \sum_{s=S+1}^{NS} n_{sas}} [min/sast.]$$

$(N_V \bmod 2) \neq 0$,

$$\delta(t_{res}) = \frac{\left[\sum_{msr=1}^{MSR} t_{msr}^{res} + \sum_{s=2}^{NS} t_s^{buff} + \sum_{s=2}^{NS} t_s^{dw-buff} - \left(\sum_{msr=S}^{MSR} t_{msr}^{res} + \sum_{s=S}^{NS} t_s^{buff} + \sum_{s=S}^{NS} t_s^{dw-buff}\right)\right]}{(S-1)\cdot \sum_{s=1}^{S-1} n_{sas}} [min/sast.] \tag{5}$$

$(N_V \mathrm{mod} 2) = 0$,

where:

- $\sum_{s=S+1}^{NS} n_{sas}$ or $\sum_{s=1}^{S-1} n_{sas}$ - number of planned meeting after the station S. To avoid the possibility of division by zero, the arrival of the train in last station we will consider as a final meeting.

In addition, as this ratio decreasing, priority for path protection, by implementing buffer time at the station S, increases.

3. DETERMINATION OF RELATIVE WEIGHT OF CRITERIA FOR BUFFER TIME ALLOCATION

Although using each of these criteria for determining the priority for time reserve allocation in timetable could easy define which train path should protect, depending on the importance and location of the stations, the significance of the criteria will vary from case to case. Therefore, it is necessary to determine weight of each criterion, before their application.

First, it is necessary to compose the decision-making matrix, presenting criteria as columns, and the alternatives, i.e. headways themselves, as rows. Normalization is carried out by dividing each individual value by criteria with the sum of values for all alternatives by the observed criteria:

$$r_{ij} = \frac{a_{ij}}{\sum_{i=1} a_{ij}}. \tag{6}$$

After normalization, the entropy of information, for each criterion, is determined according to equation:

$$e_j = -k \cdot \sum_{i=1} r_{ij} \cdot \ln r_{ij} \tag{7}$$

where:

- e_j - entropy according to the criterion j,
- k - constant.

The constant k is equal to:

$$k = \frac{1}{\ln n}, \tag{8}$$

where n is the number of alternatives, which ensures that the value of e_j is taken from the interval [0, 1].

In the second step, the so-called the degree of divergence for each of the criteria, d_j, is determined as a:

$$d_j = 1 - e_j \tag{9}$$

The higher the degree of divergence of a criterion is the higher is the importance of the criterion.

The final relative criteria weights obtain by normalization of the values and the relative weight of the criteria are determined as a:

$$w_j = \frac{d_j}{\sum_j d_j}. \tag{10}$$

In this way, after determining the relative weights of the criteria and, after collecting the necessary data from the timetable, in order to determine the values of alternatives for each criterion, by using any of the methods of multi-criteria decision-making is possible to determine the critical headways. Those headways are with high priority and should increase them by implementation of buffer times. In that manner, timetable robustness increases as well.

4. CONCLUSION

Presented model provides several criteria that allow us to perform buffer time allocation. As application of only one of the proposed criterion does not necessarily give the optimal solution, they should all be included in the decision making process. This can be done using a multi-criteria analysis tools. Previously, of course, the relative importance of each criterion must be determined. As a result, the model provides a suggestion which path in which station to "protect" by buffer time, as possibility to minimize impact of potential delays on the schedule of other trains, which is a measure of the robustness of the planned timetable.

REFERENCES

[1] Andersson E., *Assessment of Robustness in Railway Traffic Timetable,* Licentiate Thesis, Linkoping University, Sweden, 2014.

[2] Pachl J., *Railway Operation and Control,* Mountlake Terrace WA, USA, 2002.

[3] Jian M., Zhi-Ping F., Li-Hua H., *A subjective and objective integrated approach to determine attribute weights*, European Journal of Operational Research, Vol. 112 Issue 2, 1999., pp. 397-404.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

APPLICATION OF OPENTRACK AT RAILWAY PROJECTS IN AUSTRIA

Andreas SCHÖBEL [1]

Abstract *– OpenTrack is an user-friendly railroad network simulation program developed at the Swiss Federal Institute of Technology's Institute for Transportation Planning and Systems (ETH IVT). It is a microscopic model that simulates rail system operations based on user defined train, infrastructure, and timetable databases. OpenTrack functions as a railroad laboratory, by, for example, allowing users to define incidents and take infrastructure out of service to evaluate alternative scenarios. The program uses a mixed discrete/continuous simulation process that calculates both the continuous solution of train motion equations and the discrete processes of signal box states and delay distributions. It generates a wide variety data that can be easily presented in many formats including graphs (e.g. time-space diagrams), tables, and images. OpenTrack's main uses have been to evaluate and test infrastructure plans and operating schedules to optimize network and timetable design. In this paper show cases from successful application in Austria will be described. One example deals with the upgrade of the local line from Neusiedl am See to Pamhagen (Hungarian border). Another example is the narrow gauge line from Jenbach to Mayrhofen in Tyrol.*

Keywords – Railway operation, microscopic simulation, design of railway infrastructure, development of integrated timetable, calculation of technical running time.

1. INTRODUCTION

OpenTrack is a microscopic synchronous railroad simulation model. It provides users with a great deal of flexibility for defining different dispatching logic as well as operational variables in a user-friendly manner.

OpenTrack was developed at the Swiss Federal Institute of Technology's Institute for Transportation Planning and Systems (ETH IVT). The project's goal was development of a user-friendly railroad simulation program that can run on different computer platforms and can answer many different questions about railway operations. Figure 1 illustrates the three main elements of OpenTrack: data input, simulation.

2. DATA FLOW DURING A SIMULATION PROJECT

OpenTrack administers input data in three modules: rolling stock (trains), infrastructure, and timetable. Users enter input information into these modules and OpenTrack stores it in a database structure. Once data has been entered into the program, it can be used in many different simulation projects. For example, once a certain locomotive type has been entered into the database, that locomotive can be used in any simulation performed with OpenTrack. Similarly, different segments of the infrastructure network can be entered separately into the database and then used individually to model operations on the particular segment or together to model larger networks.

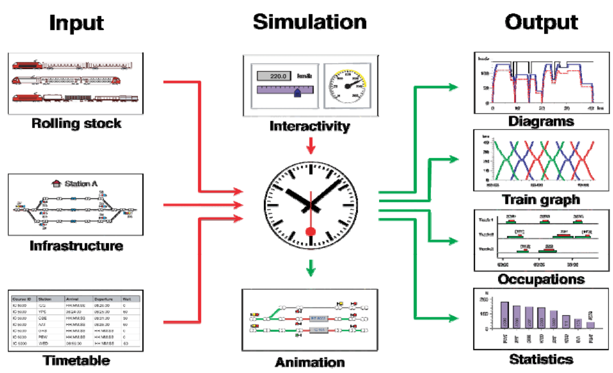


Fig.1. Data flow during a simulation project

Train data (locomotive and wagons) is entered into the OpenTrack database with easy to use forms displayed using pull down menus. Infrastructure data (e.g. track layout, signal type/location) is entered with a user-friendly graphical interface; quantitative infrastructure data (e.g. elevation) is added using input

[1] Andreas SCHÖBEL, OpenTrack Railway Technology GmbH, Kaasgrabengasse 19/8, A-1190 Wien, andreas.schoebel@opentrack.at

forms linked to the graphical elements. Following completion of the RailML data structure for rolling stock and infrastructure, OpenTrack will be modified to enable train and infrastructure data to be directly imported from RailML data files.

Timetable data is entered into the OpenTrack database using forms. These forms include shortcuts that enable data input to be completed efficiently. For example, users can designate hourly trains that follow the same station stopping pattern an hour later. Since OpenTrack uses the RailML structure for timetable data, timetable data can also be entered directly from various different program output files as well as database files.

One advantage of OpenTrack is that it enables users to adjust many variables that impact railroad operations. For example, users can simulate the impact of weather on traction by specifying the adhesion scenario (good, normal, bad). OpenTrack then estimates locomotive traction power using a percentage (also user-defined) of that calculated using the Curtius and Kniffler formula. While OpenTrack provides standard default values for all variables, having the ability to adjust variables makes the program quite useful.

In order to run a simulation using OpenTrack the user specifies the trains, infrastructure and timetable to be modeled along with a series of simulation parameters (e.g. animation formats) on a preferences window. During the simulation, OpenTrack attempts to meet the user-defined timetable on the specified infrastructure network based on the train characteristics. OpenTrack uses a mixed continuous/discrete simulation process that allows a time driven running of all the continuous and discrete processes (of both the vehicles and the safety systems) under the conditions of the integrated dispatching rules.

The continuous simulation is dynamic calculation of train movements based on Newton's motion formulas. For each time step, the maximum force between the locomotive's wheels and the tracks is calculated and then used to calculate acceleration. Next, the acceleration function is integrated to provide the train's speed function and is integrated a second time to provide the train's position function.

The discrete simulation process models operation of the safety systems; in other words, train movements are governed by the track network's signals. Therefore, parameters including occupied track sections, signal switching times, and restrictive signal states all influence the train performance. OpenTrack supports traditional multi-aspect signaling systems as well as new moving block train control systems (e.g. European Train Control System – ETCS signaling).

OpenTrack is a dynamic rail simulation program. As such, the simulated operation of trains depends on the state of the system at each step in the process as well as the original user-defined objective data (e.g. desired schedule).

A simple way of describing dynamic rail simulation is that the program decides what routes trains use while the program is running. For example, when building the network, users identify various different routes that trains can use between two points; OpenTrack decides, during the simulation, which route the train will use by assigning the train the highest priority route available. If the first priority is not available, OpenTrack will assign the train the second highest priority route and so on.

OpenTrack's dynamic nature allows users to assign certain attributes to specified times in the simulation. Thus, users can assign a delay to a particular train at a given station and time, rather than being limited to assigning a delay at the start and using it through the entire simulation. Similarly, users can define other types of incidents (e.g. infrastructure failures, rolling stock breakdowns) for particular times and places.

Finally, dynamic simulation enables users to run OpenTrack in a step-by-step process and monitor results at each step. Users can also specify exactly what results are displayed on the screen. Running OpenTrack in a step-by-step mode with real time data presented on screen helps users to identify problems and develop alternative solutions.

One of the major benefits of using an object oriented language is the great variety of data types, presentation formats, and specifications that are available to the user. During the OpenTrack simulation each train feeds a virtual tachograph (output database), which stores data such as acceleration, speed, and distance covered. Storing the data in this way allows users to perform various different evaluations after the simulation has been completed.

OpenTrack allows users to present output data in many different formats including various forms of graphs (e.g. time-space diagrams), tables, and images. Similarly, users can choose to model the entire network or selected parts, depending on their needs. Output can be used either to document a particular simulation scenario or as an interim product designed to help users identify input modifications for another model run.

3. SHOWCASE AT THE ZILLERTALBAHN

The Zillertalbahn operates the narrow gauge line from Jenbach to Mayrhofen. At Jenbach there is the connection to the network of Austrian Railways (ÖBB) where all regional, national and several international have a commercial stop. Figure 2 shows the graph for the topology of an upgraded design of the infrastructure to fulfill future requirements of service quality and density. Today there are already two double track sections in operation between Kaltenbach-Stumm and Aschau as well as between Zell am Ziller and Ramsau-Hippach. To offer an integrated timetable on a regular and symmetric basis another crossing opportunity between Aschau and Zell am Ziller is required where there is a plan to realize a new commercial stop close to a skiing center. For the calculation of the running time new electrical train units where assumed as well as an increase of the track speed limit towards 80 km/h where ever reasonable. This allows to shorten the running time from Jenbach to Mayrhofen from 55 to 45 minutes.

Fig.1. Infrastructure topology of the Zillertalbahn

Figure 3 shows the graphical timetable for the morning peak hours from 8 to 11 during winter season where additional services run to provide a 15 minutes interval. The blue lines represent the courses providing the 30 minutes interval during the entire day while the green lines indicate the additional services for the 15 minutes interval. By the application of OpenTrack it could be demonstrated that all services are able to arrive on time at their final destination. Therefore the proof of concept for the investment strategy for the next years could be provided by the results of the simulation of railway operation.

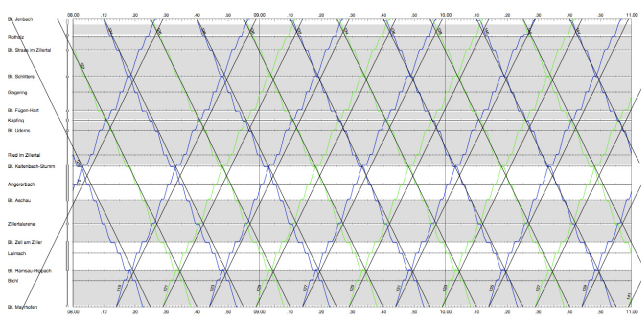


Fig.3. Integrated timetable

4. SHOWCASE AT THE NEUSIEDLERSEEBAHN

The NeusiedlerSeeBahn is responsible for the line from Neusiedl am See to Pamhagen. At Neusiedl am See the branch line from/to Eisenstadt is located. Pamhagen is the last station in Austria before the Hungarian border. From Neusiedl am See a line leads to Parndorf Ort where there is the connection to the Eastern line of Austrian Railways which is connecting Vienna and Budapest. People living at the villages located between Neusiedl am See and Pamhagen typically go for work to Vienna every single day of the week. Therefore the NSB is interested in offering shorter traveling times to Vienna. To achieve this goal some investments were done in the last years to increase the track speed. OpenTrack has been successfully used to evaluate the shortenings of running times for local trains and regional trains.

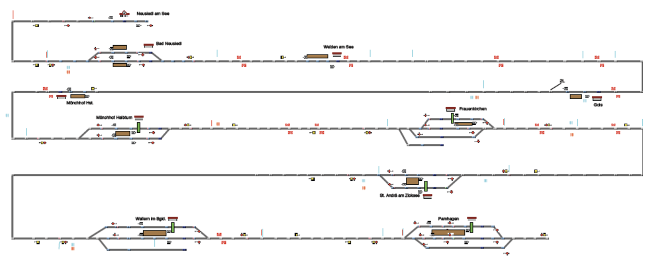


Fig.4. Infrastructure layout of the line from Neusiedl am See to Pamhagen

Figure 4 shows the topology of the line from Neusiedl am See to Pamhagen. Crossing opportunities are located at Bad Neusiedl, Mönchhof-Halbturn, Frauenkirchen, St. Andrä am Zicksee, Wallern and Pamhagen. The first step in the project was the check of the model with the existing timetable. This step allowed the exact calculation of running times reserves included in the existing timetable.

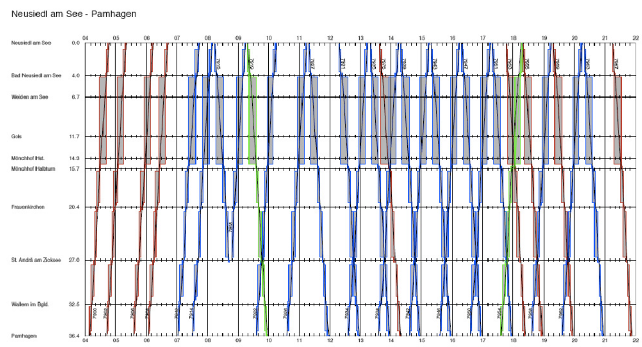


Fig.5. Simulation result of the existing timetable

Figure 5 shows the result from the simulation of the existing timetable. It has to be noted that one course during the day is only going to St. Andrä am Zicksee and not to the terminal station at Pamhagen. Additionally there is no service during the morning hours towards the region between Neusiedl am See and Pamhagen. Exactly the same happens during the evening when there is no service towards Vienna. The reason for this asymmetry in the timetable can be only explained by the saving of operational costs. For pupils there are two additional services during the day to allow them traveling to and back from school. Unfortunately the infrastructure does not allow a crossing between Bad Neusiedl and Mönchhof-Halbturn which would be required to run a 30 minutes interval in both directions. Furthermore the infrastructure model had to be extended with the upgraded track speed limits which had been indicated by markers at the related vertices. Due to the increase of the track speed the crossing shifts from St. Andrä am Zicksee towards Wallern because of keeping the arrival and departure times at Neusiedl am See (see Figure 6).

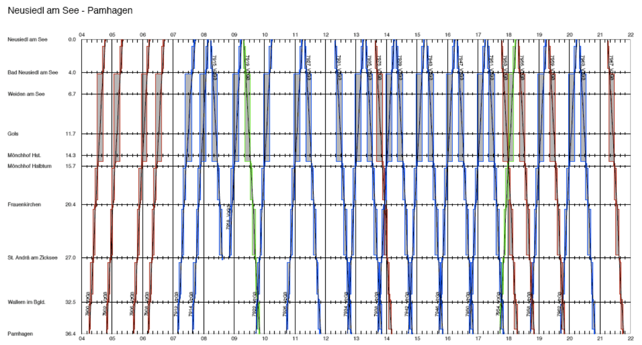


Fig.6. Simulation result of the upgraded infrastructure

Local and regional trains benefit from the increase of track speed by a shortening of running times of 5 minutes each. Local trains which stop at every single station run in 33 instead of 38 minutes and regional trains run in 28 instead of 33 minutes. A shortening of 5 minutes in terms of running time could be also achieved by introducing today regional trains. Of course the increase of the track speed in combination with the introduction of regional trains leads to an overall reduction of running time of 10 minutes for regional trains. An open point for further investigations is the integration of both services at the same time because each crossing of two trains will lead to an increase of running time while one train has to take the siding track in a crossing station. This could require the demand to upgrade also the frequently used switches to allow higher speeds for the siding track.

5. CONCLUSION

OpenTrack is an efficient and effective railroad simulation program. It has been successfully used in many different railway planning projects throughout the world. The program's use of object oriented programming and the RailML data structure makes it particularly effective since the program can be modified relatively easily to address specific applications and since data can be transferred easily to and from other programs based on RailML.

ACKNOWLEDGEMENT

OpenTrack Railway Technology Ltd. would like to thank NeusiedlerSeeBahn and Zillertalbahn for their readiness to apply the software for their purposes.

REFERENCES

[1] Huerlimann, Daniel; Object oriented modeling in railways; ETH Dissertation Nr. 14281; 2001 (in German).
[2] Huerlimann, Daniel and Andrew Nash; OpenTrack – Simulation of Railway Networks, User Manual Version 1.6; OpenTrack Railway Technology GmbH; Zürich, Switzerland; 2010; 160 pages.
[3] www.opentrack.at

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

SIMULATION MODELING OF TECHNOLOGICAL PROCESSES IN SUBWAY STATION

Svetla STOILOVA [1]
Veselin STOEV [2]

Abstract *– A methodology for processes simulation in a metro station has been developed by using a direct-event approach. A metro station has been represented as a multi-level system for mass service. The research has been conducted by using a fully licensed software Arena Academic Rockwell. The exploiting criteria resulted from the simulation are such as time for passengers waiting at the different stages of servicing, availability of servicing machines, etc. Simulation modelling gives very useful information for exploitation of a metro station which could not be observed or gained otherwise such as an average time for passengers waiting at metro stations, an average time of available subsystems. This allows us to suggest technological decisions to improve service. The simulation modelling has been applied to examine the Metro Station Serdika from Sofia's metro system.*

Keywords – subway, subway station, simulation modelling, queue theory, ARENA software.

1. INTRODUCTION

A metro network system represents an ecological and high-speed rail transport which takes an important role helping public transport satisfy any needs for transportation in cities. Metro stations are places where incoming stream of passengers should be served quickly. Simulation modelling allows us to examine and analyse many tehnological situations in different time intervals, with different incoming and outgoing streams of passengers and different technological time for service, with different usage of capacity and capabilities of a metro system, which are very hard to be examined in real time. Metro stations is an intresting subject for simulation modelling and that is the reason why some authors have conducted studies in this area.

A queuing network analytical model of station is created in [1] for calculating subway station capacity, which is built by M/G/C/C state dependent queuing network and discrete time Markov chain. In [2] is elaborated a simulation model of the rail network including a group of four consecutive stations for simulation the vehicle operating and compute special system performance parameters. In [3] a simulation model for streams of passengers has been designed for metro stations. Principal states of systems for mass service have been developed in [4,5,6]. A detailed simulation of the processes in the entrance-hall, validating machines and subway leading to platforms, has not been conducted in the studies mentioned above.

The aim of this study is to develop a methodology of simulation modeling for technological processes in a metro station.

2. A PRESENTATION OF A METRO STATION AS THE QUEUE THEORY

A metro station is presented as a multi-level open system for mass service without priority with four consecutive servicing devices which have their own characteristics, fig.1.

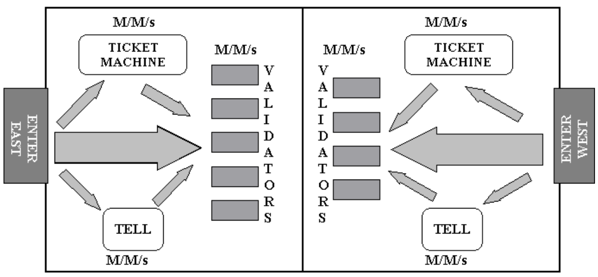


Fig.1. Sheme of metrostation

The stages of the multi-level model are:

- 1st stage: Entrance of the metro station. At this stage, passengers' waiting in the entrance-hall has been observed. As a matter of principle, metro stations might have one or two entrances. In the second case, entering a metro station is accomplished from two

[1] Svetla STOILOVA, Assoc.Prof. PhD, Thechnical University of Sofia, Bulgaria, e-mail: stoilova@tu-sofia.bg.
[2] Veselin STOEV, Msc. Eng. PhD stidents, Thechnical University of Sofia, Bulgaria, e-mail:stoev@tu-sofia.bg

directions (East, West) therefore, entrance-halls are two. Because of that in the next stages servicing devices are examined for both directions separately.

- 2nd stage: Entrance-hall. Here, processes of servicing passengers from the entrance hall to the validating machines have been observed. The focus is on ticket offices and ticket machines.
- 3rd stage: Validating machines. Passengers' going through validating machines is observed closely at this stage.
- 4th stage: Escalators and stairs. Passengers' transition from validating machines to a platform.

In the defined multi-level system, there is not any buffers and that's why it could be seen as compounded of separate single-level systems taking into account the transformations of streams of passengers between them. When the incoming stream of passengers is Poison, and the time of service is exponential and the system is without failures, then the outgoing stream of passengers is also Poison's. In the study, the system M/M/s has been taken for all stages, e.g. Poison's incoming stream of passengers, exponential time for service, and multi-channel system with a number of channels s. When a metro station as only one entrance then for the first level the system is M/M/1.

The intensity of a stream of passengers λ, coming in the metro station is formed by a stream of passengers which enter the entrance-hall from the two entrances of the metro station- East λ_1 and West λ_2.

$\lambda = \lambda_1 + \lambda_2$, passengers per hour; (1)

$\lambda_1 = \gamma_m.\lambda$, passengers per hour; (2)

$\lambda_2 = (1-\gamma_m).\lambda$, passengers per hour; (3)

where: γ_m is the coefficnent which shows the relative part of a stream of passengers coming in a metro station from an entrance with direction West. Dependng on the way of suppliment of tickets, a part of the stream of people goes directly to the validating machines (passengers provided with monthly passes or electronic tickets), another part of the stream of passengerts goes to places issuing tickets (ticket offices and ticket machines).

The intensity of the stream of passengers from an entrance with direction East λ_{1v} which goes directly to te validating machines is:

$\lambda_{1v} = \alpha_{1m}\lambda_1$, passengers per hour (4)

where: α_{1m} is a coeffient which shows the relative part of a stream of passengers that goes directly to the validating machines.

The intensity of a stream of passengers $\lambda_{1t,a}$ from entrance East which goes to buy tickets from ticket offices or ticket machines is:

$\lambda_{1t,a} = (1-\alpha_{1m}).\lambda_1$, passengers per hour; (5)

$\lambda_{1t,a} = \lambda_{1t} + \lambda_{1a}$, passengers per hour; (6)

The intensity of the stream of passengers λ_{1t} from entrance East which goes to buy tickets from ticket offices or ticket machines is :

$\lambda_{1t} = \beta_{1m}.\lambda_{1t,a}$, passengers per hour; (7)

where: β_{1m} is the coefficient which shows the relative part of the whole stream of passengers that goes to ticket offices and ticket machines with a focus on the part that goes to ticket offices only.

The intensity of the stream of passengers λ_{1a} from entrance East that goes to buy tickets from ticket machines is :

$\lambda_{1a} = (1-\beta_{1m}).\lambda_{1t,a}$, passengers per hour; (8)

The intensity of service of a stream of passengers by servicing machines is as follows:

μ_1, μ_2 is the intensity of service at a entrance of an entrance-hall of a metro station with direction East/West, passengers per hour.

μ_{1t}, μ_{2t} is the intensity of service of ticket offices at an entrance-hall with direction East/West, passengers per hour.

μ_{1a}, μ_{2a} is the intensity of service of ticket machines at an entrance-hall with direction East/West, passengers per hour.

μ_{1v}, μ_{2v} is the intensity of service provided by one validating machine at an entrance-hall with direction East/West, passengers per hour.

The number of servicing devices for each stage is:

n_{1t}, n_{2t} is the number of ticket offices at an entrance-hall with direction East/West

n_{1a}, n_{2a} is the number of ticket machines at an entrance-hall with direction East/West.

n_{1v}, n_{2v} is the number of validating machines at an entrance-hall with direction East/West at a metro station.

A mathemathical presentation of the intensity of a s tream of passengers from entrance West is identical to the formulation shown above.

To avoid detention at an entrance of a metro station the condition must be met:

$\lambda_1 \le \lambda_c$ и $\lambda_2 \le \lambda_c$ (9)

where: λ_c is the limit intensity of the incoming stream of passengers where there would be observed a passengers waiting at an entrance of a metro station.

$\lambda_c = p_m.F_m$, passengers per hour; (10)

where: p_m is the coefficient showing the optimal number of passengers per m^2 when conditions of comfort and safety are met, pass./m^2.

(p_m=7pass./m^2.). F_m is the area that could be used by passengers freely (without stepping on any restrict lines). For example, the Metro Station Serdika has λ_c=6706 passengers per hour.

The parametres of the system for mass service are shown in table 1.

Tab. 1. Parameters of system

System queue	Parameters	
	Direction East (1)	Direction West (2)
Entrance: M/M/1	λ_1, μ_1 ,1	λ_2, μ_2 ,1
Tells: M/M/s	λ_{1t}, μ_{1t}, n_{1t}	λ_{2t}, μ_{2t}, n_{2t}
Ticket machines: M/M/s	λ_{1a}, μ_{1a}, n_{1a}	λ_{2a}, μ_{2a}, n_{2a}
Machines for validation: M/M/s	λ_1, μ_{1v}, n_{1v}	λ_2, μ_{2v}, n_{2v}

3. APROBABTION OF THE METHODOLOGY

3.1. Basic parameters

A simulation model of the Metro Station Serdika which is a part of Line 1 (Obelya-Tsarigradsko shose) has been shown in the study. The station is one of the busiest metro stations of Sofia's metro system.

The study is conducted for a peak period in three different ways shown in table 2:

Tab. 2. Cases for simulation

Case	1	2	3
Incoming stream of passengers	λ = 3600 Passengers per hour		λ =6000 Passengers per hour
Coefficients	γ_m =0,70; α_{1m} =0,85; α_{2m} =0,75; β_{1m} =0,7; β_{2m} =0,7		
Tell	$\mu_{1t} = \mu_{2t}$ =360 Passengers per hour		
Ticket machine	$\mu_{1a} = \mu_{2a}$ =1000 Passengers per hour		
Machine for validation	$\mu_{1v} = \mu_{2v}$ =1800 Passengers per hour		
Number of tells	n_{1t} =1 n_{2t} =1	n_{1t} =2 n_{2t} =1	n_{1t} =2 n_{2t} =2
Number of ticket machine	n_{1a} =2; n_{2a} =2		
Number of machine for validation	n_{1v} =5; n_{2v} =4		

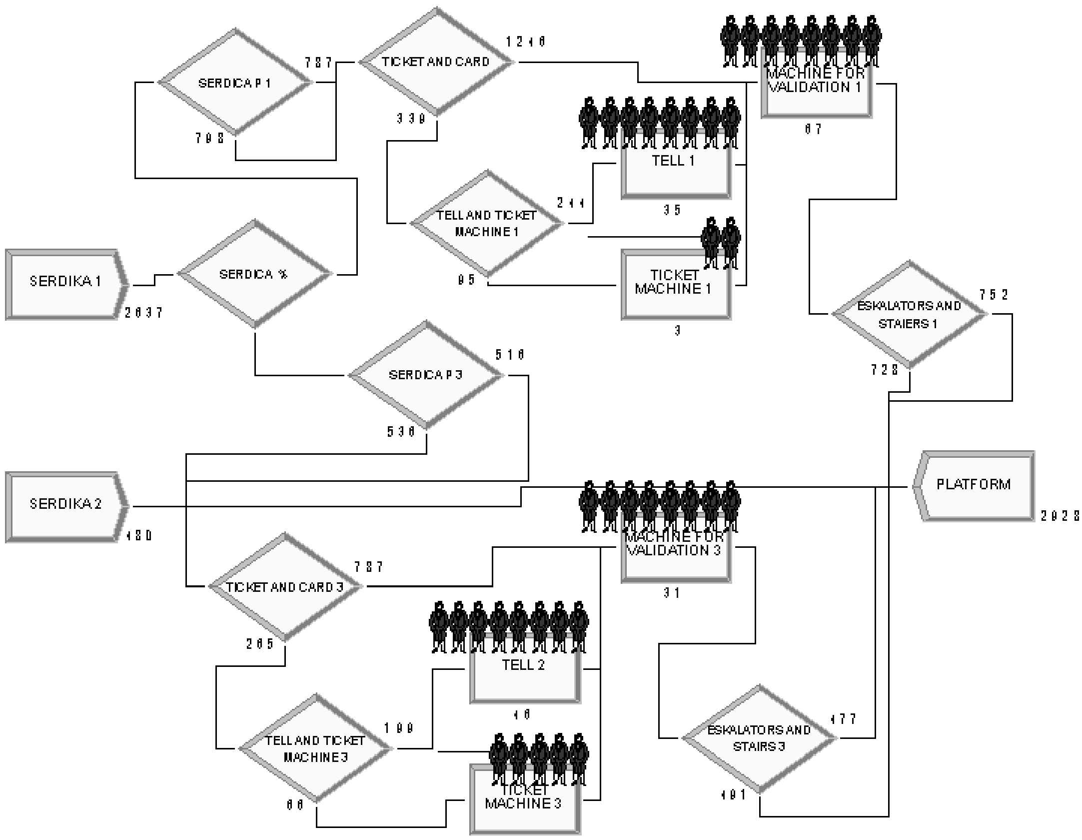


Fig.2. Simulation model in ARENA

3.2. An application of Arena Software for simulation modelling

The system for imitation modelling Arena allows us to shape dynamic model for hereogeneous processes which could be optimased [8]. Modelling is conducted by using the modelling language SIMAN and an animation system. It has been used blocks for modelling which connect to each other in accordance to dependences as well as operations in the studied system.

The simulation model for Metro Stattion Serdika of Sofia's Metro System has been shown in figure 2. Ten replications have been done for each of the cases after that an average value for each observed indicator is reported. A comparision of the results has been shown in table 3.

Tab.3. Results of simulations

Indicator	Variant		
	1	2	3
Number out system, pass.	3608	4061	6511
Total time in system, sec.	37	23	36
Number waiting in queue, passengers			
Machine for validation 1	5	6	20
Machine for validation 2	4	4	8
Tell 1	17	3	21
Tell 2	7	6	9
Ticket machine 1	0	0	1
Ticket machine 2	0	0	0
Waiting time in queue, sec.			
Machine for validation 1	9	10	19
Machine for validation 2	10	10	13
Tell 1	173	29	114
Tell 2	95	84	63
Ticket machine 1	2	2	10
Ticket machine 2	1	2	3
Unavailable device probability			
Machine for validation 1	0,24	0,24	0,40
Machine for validation 2	0,28	0,28	0,31
Tell 1	0,88	0,46	0,78
Tell 2	0,70	0,68	0,63
Ticket machine 1	0,05	0,06	0,18
Ticket machine 2	0,04	0,05	0,08

The maximum number of waiting passengers that would be served at one till in a ticket office is assumed to be ten for the study's purposes. In the first case, the number of tills in ticket offices is not enough for direction East. When an additional till is opened, system state has been imporved (only three customers are waiting). One the other hand, the third case suggests a situation close to the critical point. In this case, both tills in the ticket office are loaded. Opening an additional till depends on the capailities and the infrastructure of the entrance-hall. In the third case, it is important to redirect customers to ticket machines for issuing tickets. The first and the third cases show situations which could happen during a peak hour in case of additional factors such as bad weather, special occasions and so on.

4. CONCLUSION

The conducted research allows us to make the following conclusions:

- A methodology for presenting a metro station as a multi-level system for mass service has been developed sucessfully.
- A multi-level system is examined as a compounded of separate single-level systems with Poison's incoming stream of passengers, exponential time for service and s number of channels (M/M/s).
- The decomposition of levels is consistent with passengers' going through and servicing them by the system: entrance, entrance-hall (ticket offices and ticket machines),escalators and stairs.
- A simulation model of a metro system has been developed with Arena software.

ACKNOWLEDGEMENT

This research is conducted in relation to the execution of a contract № 142ПД0019-04" A simulation modelling of technological processes in main metro stations of the Sofia's subway". The research has been funded by Technical University of Sofia, Bulgaria.

REFERENCES

[1] Zhang,Q., Baoming, H., Dewei., L., *Modeling and simulation of passenger alighting and boarding movement in Beijing metro stations,* Transportation Research Part C 38, pp. 28–43, 2014.

[2] Martinez, F., *Application of SIMAN ARENA Discrete Event Simulation Tool in the Operational Planning of a Rail System,* University of Puerto Rico, 2002.

[3] Ozturk, G., *Simulation & analysis of Izmir metro transportation system,*Department of Industrial Management and Information Systems, Bornova – IZMIR, p.95, 2012.

[4] Karagyozov, K., *Approximation of the moments of processes of traffic flow arrival, interruption and normalization,* Scientific journal "Mechanics, transport, communications"N3, 2013.

[5] Karagyozov, K, *Hierarchical decomposition and synthesis for logistics systems modeling by closed queuing networks,*Scientific journal "Mechanics, transport, communications"N3, 2013

[6] Razmov, T., *Analysis of the trasnport systems through discrete-event modeling,* Scientific journal "Mechanics, transport, communications"N3, 2013

[7] Kachaunov, T., *Modeling and optimization of the transportation processes*, 2nd edition, Publishing house of Todor Kableshkov University of Transport, Sofia, (written in Bulgarian), 2005

[8] http://www.arenasimulation.com

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

MULTICRITERIA SUSTAINABILITY EVALUATION OF TRANSPORT MODES

Nikola PETROVIĆ [1]
Jelena PETROVIĆ [2]
Vesna JOVANOVIĆ [3]
Mladen MITROVIĆ [4]

Abstract *– Transport is a reflection of economic activity with substantial direct and indirect effect on economic growth and development. However, transport is also considered to be the sector with the fastest growth of pollution in environment. The main purpose of this paper is to application the VIKOR (VIšekriterijumsko KOmpromisno Rangiranje - Multicriteria Compromise Ranking) method to assess the sustainability of the transport modes. Criteria that were taken for the evaluation the sustainability of transport modes are: employment, turnover, final energy consumption, transport efficiency improvenment, green gas emissions from transport, people annoyed as a function of noise exposure of dwellings (55db(A)), external costs and number fatalities by transport mode. In paper, authors propose technique to identify according to which criteria some of transport modes needs to be improved and how much improvement is required to attain a certain level of sustainability.*

Keywords – VIKOR, Modes of transport, Development, Pollution, Sustainability.

1. INTRODUCTION

Transport plays a considerable role in the economy with its omnipresence throughout the production chain, at all geographic scales [9]. However, transport is also considered to be the sector with the fastest growth in environmental pollution [3]. Apart from energy generation and industrial processing, transport is a major contributor to pollution [2].

The transport sector is one of the main contributors to emissions of acidifying substances, ozone precursors and particulates. It is expected that the share of the transport sector in national total emissions may also increase in the coming years, due to a greater rate of progress in total emissions reductions from other sectors.

Sustainable development gets its full recognition in transport policy at the beginning 21st century, when this concept has become a priority long-term goal of European development. Orientation to the user, as well as other sociological aspects which introduced White Paper (2001), represent turnaround in the previous policy of transport sustainable development based on the ratio of transport-environment. In order to encourage economic growth, prevailing attitudes of the White Paper (2006) is that transport policy should support and facilitate the mobility instead is limiting. The new paradigm of the modern understanding of the concept of sustainable transportation becomes "sustainable mobility".

According to Richardson (1999), a sustainable transportation system is “one in which fuel consumption, vehicle emissions, safety, congestion, and social and economic access are of such levels that they can be sustained into the indefinite future without causing great or irreparable harm to future generations of people throughout the world [8].” The Environmental Directorate of the OECD defines environmentally sustainable transportation as “transportation that does not endanger public health or ecosystems and that meets needs for access consistent with (a) use of renewable resources that are below their rates of regeneration, and (b) use of non-renewable resources below the rates of development of renewable substitutes [6].“ The best definition of a sustainable transportation system was given by the Canadian Centre for Sustainable Transportation:
„A sustainable transportation system is one that:
- allows the basic acces needs of individuals and societies tobe met safely and in a manner consistent

[1] Nikola PETROVIĆ, Faculty of Mechanical Engineering, University of Niš, petrovic.nikola@masfak.ni.ac.rs
[2] Jelena PETROVIĆ, Faculty of Science and Mathematics, University of Nis, jelenapetrovic619@yahoo.com
[3] Vesna JOVANOVIĆ, Faculty of Mechanical Engineering, University of Niš, vesna.nikolic@masfak.ni.ac.rs
[4] Mladen MITROVIĆ, Faculty of Science and Mathematics, University of Nis, mladen.mitrovic@live.com

with human and ecosystem health, and with equity within and between generations;

- is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy;
- limits emissions and waste within the planet’s ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise [10].“

In order to determine the sustainability of certain modes of transport we will come from transport sustainability indicators that reflect the three components of sustainable development - economic, environmental and social. However, it is important to note that on the basis of one indicator can be determined one level of sustainability of a particular mode of transport, and based on the second some other level of sustainability.

Multi-criteria decision-making refers to situations where decisions are made starting from a large number of usually conflicting solutions. Ranking alternatives to the larger number of criteria simultaneously, contributing realities resolving such situations. Range of applications of multi-criteria decision-making is very wide, but it can be brought some common characteristics of all categories of problems that are solved in this way:

- Larger number of criteria ie attributes, which must create a decision-maker,
- Conflict among the criteria, as far the most common case for real problems,
- Incomparable units of measurement, as a rule, each criterion or attribute has different units of measurement,
- Design the best alternative or selecting the best alternative from a set previously defined finite alternatives [5].

Methods of multi-criteria decision-making allow that on the basis more indicators determine the level of sustainability of certain modes of transport, as well as their ranking. The above mentioned methods have significant application in decision-making in transport, but also to rank the transportation system from the perspective of sustainability.

There are several methods of multi-criteria decision-making that are best methods in the world, ie that are the "higher level" methods. The best-known methods of multi-criteria decision-making are ELECTRE (ELimination and Et Choice translating REality), PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation), AHP (Analytical Hierarchy Process), TOPSIS (Technique for Order Preference by Similarity to Ideal Solutions) and VIKOR (Multicriteria Compromise Ranking).

VIKOR method was developed in the methodological foundations that enable decision makers to choose alternatives that represent a compromise between the different interests of subjects in decision-making. By applying the observed method and weight coefficients is determined the compromise ranking ie compromise solution.

Awasthi et al. investigate four multicriteria decision making (MCDM) techniques namely TOPSIS, VIKOR, SAW and GRA for sustainability evaluation of urban transportation projects [1]. TOPSIS and VIKOR are compared and applied to determine the best compromise alternative fuel mode. The result shows that the hybrid electric bus is the most suitable substitute bus for Taiwan urban areas in the short and median term [11].

The main objective of this work is to perform a comparative analysis of modes of transport from the perspective of their sustainability. To perform the ranking of modes of transport, starting from transport sustainability indicators we will apply VIKOR method.

2. INDICATORS OF SUSTAINABLE TRANSPORT

Indicators are frequently defined as quantitative measures that can be used “to illustrate and communicate complex phenomena simply, including trends and progress over time” [4]. During the last two decades measurement of sustainability issues by indicators has been widely used by the scientific community and policy-makers. Development of sustainable development indicators was first brought up as a political agenda issue at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 [12]. Since then, the indicators represent an important tool for measuring different aspects of sustainable development, including the development of sustainable transport. A number of international organizations have been involved in the development of indicators aiming to achieve a more sustainable transport on the local, regional, and global levels. The differences observed in the mission and policy priorities of various organizations are accordingly reflected in the selection of indicators. However, the three-dimensional framework of indicators based on economic, environmental, and social impacts is a common way to perform an impact-based analysis of transport activities.

3. MULTI-CRITERIA ANALYSIS OF SUSTAINABILITY MODES OF TRANSPORT

To perform the ranking of modes of transport from the perspective of sustainability in below we will define alternatives and criteria in order to apply the Entropy and VIKOR methods. Alternatives that we will consider are: road (a_1), air (a_2) and rail (a_3)

transport. Criteria that will be used to rank alternatives are the indicators of transport sustainability on the example of the European Union (Table 1).

Tab. 1. Details about the indicators selected to evaluate the transport mode sustainability

Dimension	Indicator	Description	Measurement Unit	Source
Economical	CEC1	Employment of mode by transport	Number (In thousand)	Eurostat
	CEC2	Turnover by mode of transport	million eur	Eurostat
	CEC3	Final energy consumption by mode of transport	mtoe	Eurostat
	CEC4	Transport efficiency improvement	% change of consumed toe/Mpkm	European Commission http://ec.europa.eu.pdf
Environmental	CEN1	Greenhouse gas emissions from transport by mode of transport	thousand tonnes of CO_2 equivalent	Eurostat
	CEN2	People annoyed as a function of noise exposure of dwellings (55db(A))	%	WHO
	CEN3	The external costs due to air pollutants, global warming, noise, and accidents	ECU/1000 pkm	ftp://ftp.zew.de/pub/zew-docs/dp/dp0698.pdf
Social	CSC1	Fatalities	number	Eurostat

Tab. 2. The initial decision table

	CEC1 max	CEC2 max	CEC3 min	CEC4 max	CEN1 min	CEN2 min	CEN3 min	CSC1 min
w	0.136	0.065	0.158	0.001	0.257	0.023	0.069	0.291
a_1	4859.5	397685	297.6	13.5	874506	20	44.26	30268
a_2	394.4	122097	7.3	12	16253	30	21.91	6
a_3	678.2	74771	50.5	15.5	7359	10	4.87	38

Tab. 3 – The calculated values for the d_{ij}

	d_{ij}							
	CEC1 max	CEC2 max	CEC3 min	CEC4 max	CEN1 min	CEN2 min	CEN3 min	CSC1 min
a_1	0.0000	0.0000	1.0000	0.5714	1.0000	0.5000	1.0000	1.0000
a_2	1.0000	0.8534	0.0000	1.0000	0.0103	1.0000	0.4326	0.0000
a_3	0.9364	1.0000	0.1488	0.0000	0.0000	0.0000	0.0000	0.0011

Tab. 4 – Ranking of alternatives ie modes of transport

	S	R	QS	QR	Q V=0.5	Q V=0.25	Q V=0.75
a_1	0.7871	0.2910	1.000	1.000	1.000	1.000	1.000
a_2	0.2480	0.1360	0.056	0.053	0.054	0.053	0.055
a_3	0.2162	0.1274	0.000	0.000	0.000	0.000	0.000

Ratings of all modes of transport according to all criteria are given in the initial decision table (Table 2). Weight of criteria can be determined on the basis of subjective or objective approach. Weight of criteria can be determined and by using some of the methods of objective approach. The best-known objective methods are: method of Entropy, CRITIC, FANMA and DEA method. In the paper we apply Entropy method to determine weight coefficients. In each column of Table 2, within each criterion it is necessary to determine the maximum and minimum value, which refers to the observed modes of transport.

Starting from the values given in Table 2, the calculated size of the d_{ij} by all criteria. Starting from the size d_{ij} and weight coefficients are formed three ranking lists given in Table 4. According to the criteria QS_i and QR_i best level of sustainability of transport has achieved rail transport. In total, according to $Q_i(v= 0.5)$, has achieved rail transport.

Testing conditions U_1 [7]:
Condition U_1 is not fulfilled because:

$Q(a_2)-Q(a_3)=0{,}054-0{,}000<0{,}25$

$DQ=\min(0{,}25,\ 1/(3-1))=0{,}25$

Railway transport don't have "insufficient priority" in relation to air transport, which is in second place on the ranking list. Air transport has a set of compromise solutions, as the first alternative, ie railway transport don't have "insufficient priority" in relation to the second ranked alternative.

Analysis of the following alternative (third by rank - the alternative a_1):

$Q(a_1)-Q(a_3)=1{,}000-0{,}000>0{,}25$

Alternative a_3 does not enter in the set of compromise solutions, as the first alternative a_3 has "sufficient advantage" in relation to the third ranked alternative a_3.

Testing conditions U_2 [7]:
Condition U_2 is fulfilled because the alternative a_3 is "sufficiently" stable first place according to all criteria:
1. Alternative a_3 has the first position on the ranking list according to the *QS* and *QR*;
2. Alternative a_3 has the first position on the ranking list according to the Q for $v= 0.25$, $v= 0.50$ and $v= 0.75$.

So, the final solution is defined by a set of compromise solutions in which entering alternatives a_3 and a_2. However, since the alternative a_3, ie rail transport at on the all lists takes first place it can be concluded that this mode of transport with point of transport sustainability is in the first place, while the second is air transport, a third road transport.

4. CONCLUSION

Multiple criteria decision-making is a complex process that is widely used in all areas of human activity. Based on the above, the conclusion is that the multi-criteria analysis can be successfully applied to rank modes of transport with point of sustainability of their development. It was stated shown in the example, which is solved by the VIKOR method. By using this method were ranked road, rail and air transport with the sustainability of their development whereas application of indicators of sustainable transport. The results showed that rail transport has a first position on all the ranking lists and has achieved the highest level of sustainability in relation to other modes of transport.

Using VIKOR method achieves the objective consideration of sustainability modes of transport in the European Union. It should be noted that it is possible to change the criteria and their importance. Also, it is possible to apply other methods of multicriteria analysis when ranking modes of transport with point of sustainability of their development.

REFERENCES

[1] Awasthi, A., Omrani, H., Gerber, Ph. *Multicriteria decision making for sustainability evaluation of urban mobility projects*, Working Paper No 2013-01, 2013, http://www.statistiques.public.lu/catalogue-publications/working-papers-CEPS/2013/01-2013.pdf

[2] Dobranskyte-Niskota, A., Perujo, A., Prerl, M., *Indicators to Assess Sustainability of Transport Activities*, European Commission - DG Joint Research Centre Institute for Environment and Sustainability Transport and Air Quality Unit Via Enrico Fermi 1 , 2007.

[3] EC, Sustainable Development Indicators to monitor the implementation of the EU sustainable Development Strategy, Brussels, Belgium, 2005.

[4] EEA, EEA core set of indicators: Guide - EEA Technical Report, Copenhagen, 2005.

[5] Hwang, C. L., Yoon, K., Multiple Attribute Decision Making: Methods and Applications, New York, Springer–Verlag, 1981.

[6] OECD, http://www.oecd.org/home/

[7] Opricović, S., Tzeng, G., *Extended VIKOR method in comparison with outranking methods*, European Journal of Operational Research, 2007, 178(2):514-529.

[8] Richardson, B., *Towards A Policy On A Sustainable Transportation System*, Transportation Research Record 1999, 1670: 27-34.

[9] Rodrigue,.P., Comtois C., Slack, B., *The Geography of Transport Systems*, New York, Routledge, 2007.

[10] The Centre for Sustainable Transportation, http://cst.uwinnipeg.ca/documents/Definition_Vision_E.pdf

[11] Tzeng, G., Lin, Ch., Opricovic, S., *Multi-criteria analysis of alternative-fuel buses for public transportation*, Energy Policy, 2005, 33(11), p. 1373-1383.

[12] UN, *Agenda 21: Programme of Action for Sustainable Development*, Rio Declaration on Environment and Development, New York, 1992.

Infrastructure

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

THE ORGANIZATION OF CONSTRUCTION WORKS UNDER TRAFFIC ON OVERHAUL OF RAILWAY SECTION DOBOJ – KM 103+500

Ljuban JEROSIMIĆ [1]
Tatjana MIKIĆ [2]
Tatjana SIMIĆ [3]

Abstract *– The basis for the works on the Main railway overhaul is indicated in the Technical conditions, which define the conditions for works, technical inspection and acceptance of works with main overhaul in railway network of former Yugoslavia, which are still valid and used by Beneficiary. The organization of railway traffic during the works is related to organization and the phased technology of the works. The track overhaul has to include all required works on substructure and superstructure in order to reach the corresponding technical conditions of the railway line, to meet traffic volumes along the line and to fulfil traffic safety requirements. Technical solutions defined in ToR, regarding the superstructure type and required extensive rehabilitation of substructure, significantly opting technology and technological approach to the overhaul. They are deriving from the railway rank on the Corridor Vc and by the standards of TER. For them and in all its details to be freely applied, it is necessary in the future definitely adopt and formalize regulations and standards. That is also the presupposition for the subsequent quality and professional supervision on similar projects and for maintenance process during operation. Prior to beginning of works it necessary to prepare and create conditions for accommodation of personnel, equipment, machinery and services, i.e. the preparation of Construction site. Complexity of the construction, dynamic map of various process activities and their mutual compliance as well as compliance with railway traffic during the works, which were an integral part of project documentation in the Main overhaul of section Doboj - km 103+500 on Corridor Vc are the subject of this paper.*

Keywords – railways, main overhaul, construction technology, traffic organization.

1. INTRODUCTION

The subject section Doboj – km 103 + 500 (entrance to tunnel Orline) is located in Republic of Srpska (18.21 km of double track railway)

In short, scope of works in the Main overhaul on railway contains:

- Complete overhaul of the track superstructure on main tracks including at least one siding track and switches at stations Doboj and Ševarlije,
- Rehabilitation of the substructure – railway formation, drainage,
- Rehabilitation of drainage systems on structures and tunnels,
- Rehabilitation/installation of new signaling and interlocking devices at stations and on open line,
- Works on OCL and telecommunication equipment.

The purpose of this overhaul is to bring the railway and its elements into originally designed standards and to meet traffic requirements.

The first prerequisite in order to perform any type of site works in the area of the railway zone is to perform cleaning of the mine fields from the war, done by presence of experts from MAC during the construction works on Main overhaul of railway on section Doboj - km 103+500.

Single track railway was built in 1947 and in 1978 was build a second track. On this double track railway section there are two stations Doboj and Ševarije and five halts Pridjel, Jabučić Polje, Trbuk, Paklenica Donja and Rječica. Due to war activities and poor maintenance, railway is in a very bad condition.

Under general provisions of Rulebooks, it is

[1] Ljuban JEROSIMIĆ, CeS COWI, Južni bulevar 1a/II, 11000 Belgrade, Serbia, ljub@cescowi.rs
[2] Tatjana MIKIĆ, CeS COWI, Južni bulevar 1a/II, 11000 Belgrade, Serbia, tmik@cescowi.rs
[3] Tatjana SIMIĆ, CeS COWI, Južni bulevar 1a/II, 11000 Belgrade, Serbia, tatjana@cescowi.rs

clearly defined when these works should take place and what is the scope of such works. The track overhaul has to include all required works on substructure and superstructure in order to reach the corresponding technical conditions of the railway line, to meet traffic volumes along the line (Figure 1.) and to fulfil traffic safety requirements.

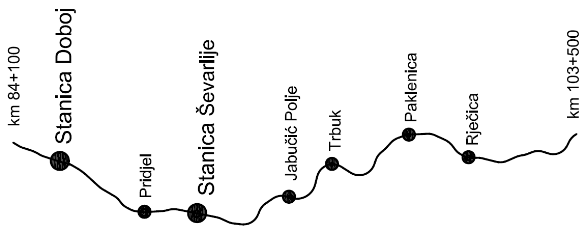


Fig.1. Section Doboj – km 103+500

The works on substructure include overhaul of railway substructure with widening of the formation and placement sand layer, geotextile, transitive and protective layer and rehabilitation of the drainage system in station and on open line.

The works on standing halts consider arrangement of standing halts on open line and construction of side boarding with prefabricated assembly wall for platform (0,55m, MB30) and canopies with benches. Superstructure of open track and station tracks is with 60E1 rails, welded in CWR, on concrete sleepers (2,60 m) with elastic fastenings and ballast of crushed stone of eruptive origin, specified thickness and granulation. According to the Beneficiary request, wooden sleepers were designed on bridges and new switches with 60E1 rails, welded in CWR, on wooden sleepers (2,60 m) with elastic fastenings.

2. DESCRIPTION OF WORKS ON MAIN OVERHAUL

Preliminary works are related to the quality functioning of the process of main overhaul belongs a series of activities that individually or together are conducted by Investor, through its specialized services Contractor and its subcontractors, suppliers and external collaborators. These activities take place before contracting business, during the contracting and after it until the initiation of works.

Geodetic works are very important precondition for execution of works, and require permanent presence of one, or more geodetic teams on the track and in the railway zone. Geodetic teams must include the experienced professionals specially trained and equipped in the field of specific requirements of railway geodesy.

Reconstruction of substructure should be performed with installation a protective layer of soil formation. Soil formation is being protected with geotextile and (or) geocomposite materials which must unconditionally to be laid up to drainage zones. Fifteen-year experience with applying of geotextile and lately especially geocomposite materials shows their exceptional properties.

In technological terms differ:

- Conventional methods of reconstruction with applying classical construction machinery (bulldozers, excavators, loaders, trucks, rollers, etc.) which implies pre-removal of track and
- Modern methods with use of tracks machinery that does not require prior removal of the tracks (individual machines and operating trains).

Replacement of track, depending on applied work technology, can be accessed before simultaneously, or after substructure reconstruction. Experiences with the reconstruction of substructure and ballast before, during, or after the replacement of track are known.

Welding of track in longer sections and its gradual including into CWR track is next after ballast excavation and track replacement, no matter on schedule of these operations. The most rational method is thermite welding (AT).

Purchase, transport, installation and control of ballast material, from the track in the process of excavation and (or) distributing of ballast removed dirty materials must be supplemented with a new amounts. Transport of a new crushed stone material is being carried out with FAD wagons. Unloading is being done directly from the wagons as fair as possible in the ballast prism and gradually in amounts that are appropriate to capabilities of applied tamping machines that are used for levelling and regulation of track in vertical and horizontal alignment.

Dismantled track materials have the title of environmentally hazardous waste. Different types of lubricants, impregnating oils, pesticides and other the materials used in vehicle, rail and railway equipment lubrication, or removal of vegetation, are contained in the dismantled track are true environmental hazard.

Laying of new switches depends on the form in which the switches are going to supplied. Switches can be supplied in three different ways.

- Completely separated switch components (trimming and assembly on site),
- Partially separated switch components (partial assembly on site) and
- Complete pre-assembled switches (on site just assembling and regulation).

Mechanical tamping, levelling and lining of tracks is performed when the new track is being placed in a new layer of loose gravel, it is necessary to lift and lateral shift it, in order to tamp new ballast material below the sleepers. Tamping is carried out according to regulations and the documentation of the performed works through measurement books.

3. ORGANIZATION OF TRAFFIC DURING THE WORKS

3.1 Temporary railway connections

In order to keep the traffic on the section it was nessecary to perform temporary railway connections (Figure 2.) on the entences end exits from the stations, so they could take the traffic from the ones being reconstucted.

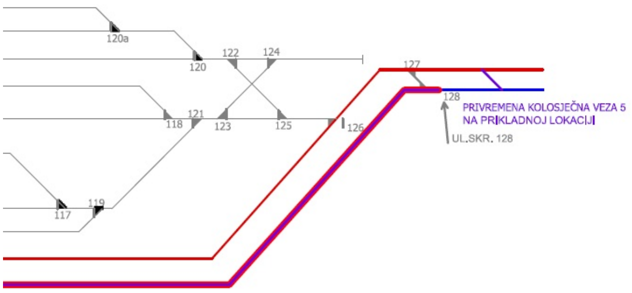


Fig.2. Temporary railway connection

3.2 Phases of construction works

The organization of railway traffic during the works is connected with the organization and the phased technology of the works (Figure 3.).

The train diagram number 60 shall will be out of use during the execution of works. The special train diagram and Instruction on the organization and performing of traffic services during the execution of works will be in application. It will be valid only during the execution of works and they will be made by representatives of RRS

The turnout Ševarlije should be inspected with staff 0^{00} - 24^{00}, prior to start of works.

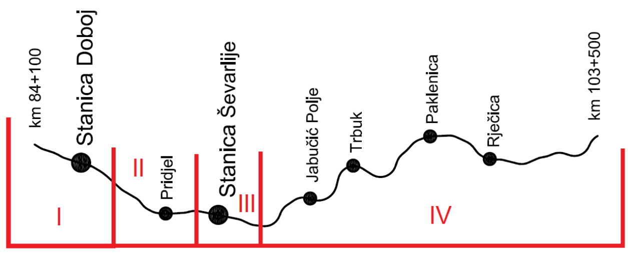


Fig.3. Phases of construction works

Station Doboj – Works in station Doboj are divided in three phases. Phase one takes under consideration station entrance. Regulation of railway traffic is done between station Doboj and adjacent stations with staff. Prior to the commencement of work Traffic Control Center 2 (TCC2) must be put into operation. Phase two takes under consideration station exit. Regulation of railway traffic is done between station Doboj and stations Ševarlije with staff. Traffic Control Center 1 (TCC1) must be put into operation. In the third stage performs the repair of the left and right tracks at the station.

The works are divided to three phases, the first phase should be carried out with device TCC 1 turned off, while other two with device TCC 2 turned off:

1. Phase I represents main overhaul of the input head and 2, 3, 5 tracks and 11 in station Doboj under control of device TCC 1,
2. Phase II represents main overhaul of the output head station of Doboj under control device TCC 2,
3. Phase III is a main overhaul to an exit switches from station Doboj under control device TCC 2.

In Phase I it is preferable to use specialized track machinery, because the work is performed in the station itself, so it is not very convenient to access to it from surrounding roads. Relocation of right tracks is performed from the axle distance of 4.00 m to 4.75 m, this includes extensive works on the relocation of OCL, and access to this area is not possible from nearby roads. Regulating the railway traffic must be made between station inspectors in Doboj and the neighboring stations toward Tuzla and Srpska Kostajnica.

While in Phase II local road located next to the railway line, which provides access from the road. It should not exclude the possibility of a combination of conventional and non-conventional construction methods. Regulating the railway traffic must be made with between station inspectors in Doboj and the neighboring turnout Ševarlije.

In phase III, by establishing a temporary railway connections it is given the possibility of transfer from regular to irregular track toward Ševarlije.

Station Doboj is logistical base not only for this phase, but for the rest of the section. Its capacities will be used for accommodation of work trains and other track machinery, wagons with material for embedding, fastening, sleepers and ballast, as well as the disposal of the removed material.

Section Doboj – Ševarlije – Works are performed first on the left and then on the right track. During the works, traffic is carried like on a single track railway line (on a regular or irregular track, depending on the direction). Traffic regulation is carried out in station distance.

In this phase local road is located next to the railway line, which provides access from the road. It should not exclude the possibility of a combination of conventional and non-conventional construction methods, depending on the efficiency.

Works on halt Pridjel imply the removal of existing platforms, construction of drainage between the tracks, replacement the superstructure, construction of new platforms, relocation of OCL poles out of platforms, as well as their grounding on the rail through the body of platform with plastic pipes and construction of canopies, fences between the tracks and lighting system. Tracks are on such axial distances which requires, during the intervention on one track, the stability of the second track to be ensured with the ramming of sheet piles or some other method in order to enable traffic on second track in regime of restricted running speed.

Station Ševarlije – works will be performed in two phases. Regulation of railway traffic shall be made in announcement interval.

Track capacities in turnout Ševarlije will be temporarily used for supply of materials, as soon as the track are put in function.

In both phases it is preferable to use specialized track machinery, because the work is performed in the station itself, so it is not very convenient to access to it from surrounding roads and due to mine surround mine fields.

By establishing a temporary railway connections it is given the possibility of transfer from regular to irregular track toward Maglaj and Ševarlije.

Section Ševarlije – km 103+500 – All works on this section are similar like on section Doboj – Ševarlije, so the same construction methods are used like there. Due to the length of the section it is divided in three subsections.

With an exception that after a halt Jabučić polje until the end of subsection axial distances between tracks are such that there is no need for ensuring the stability of another track.

4. DYNAMIC PLAN

Dynamic plan of construction works should be developed based on the level of known data and quantities. In the Gantt chart should be given types of works and structures, with the aim to show the approximate time of construction, in phases and in total, phased construction of certain facilities and approximate necessary time, and the order to get needs time for construction works and individual objects (Figure 4.).

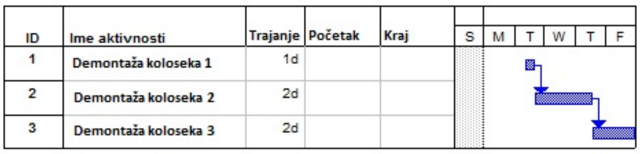


Fig.4. Gant chart

Duration of works are approximate (empirically possible). Detail technology of construction works will be conducted by the Contractor and accepted by the Investor, with special conditions for safe railway traffic that is determined by responsible institutions and accurate time required for main track overhaul of sections.

During the construction works, speed on a neighboring track (within stations or on open track) principally must be reduced and constant control and inspection of tracks.

This is indicated in the initial, approximate the securing of investment material and supply of energy source. For Investor is important as much as possible to reduce the total cost of construction to deliver materials to the site by rail, which coincides with the general social interest in the preservation from environmental pollution. Generally, for procurement of all necessary re-sources it is advised to be procured by domestic producers, if they fully meet the requirements in terms of: quality, quantity and delivery schedules, proximity, and competitive price.

5. CONCLUSION

The task of the Consultant was to propose the optimal technology of works that will be followed by temporary traffic organization. Optimal generally implies quality, deadline and cost of the works. It is necessary to strive for the implementation of organizational and technological measures and solutions that imply the maximum concentration of activities in the railway zone. Any activity out of this zone causes problems with collision with other types of transport or access. When choosing modern machinery and equipment it should be strived towards optimal, not ultimate high-performance solutions and find a balance between construction and railway traffic flow. Temporary traffic organization during the works aims to minimize disruptions in rail traffic to the rest of the rail network and that prior to the commencement of works provide information for all participants in the planning and organization of rail transport. For all the rides on irregular track it is necessary to create a temporary timetable for single track railway.

ACKNOWLEDGEMENT

This paper is done within a framework of a project Track overhaul of the railway sections Doboj – 103+500 on Corridor Vc within Book 8 Organization and technology of construction and with assistance of representatives of PE Railways of Republic of Srpska who provided access to material necessary for preparation of entire Design.

REFERENCES

[1] Tomislav Milićević, Danijel Vučković, *Book 8. Organization and technology of construction*, Project: Track overhaul of the railway sections Doboj – Maglaj i Jelina – Zenica on Corridor Vc PHASE II: Main Design Section Doboj – km 103+500, 2013.

[2] Relevant Rulebooks and Guidelines regarding the railway and road design, construction, traffic and maintenance in Republic of Srpska.

BASIC CHARACTERISTICS OF COMPLETED WATERPROOFING ON REINFORCED CONCRETE BRIDGES ACCORDING TO THE ACCEPTED EUROPEAN STANDARDS

Snejana VALKOVA [1]
Nikolina POROJANOVA [2]

***Abstract** – This report views the basic characteristics of the already applied over the bridge bitumen waterproofing membranes and the significance of these characteristics for the facility durability. The methods for testing of these characteristics and their deployment in the laboratories, which estimate waterproofing materials to be used in the road constructions will be considered.*

Keywords – Waterproofing, reinforced concrete bridge, road construction, characteristic, European standards.

1. INTRODUCTION

Road and railroad bridges waterproofing makes approximately 2% of the facility total price, which is a relatively small part in comparison with the other elements of the construction. However, consequences of a bad choice of the waterproofing, application of inappropriate materials, making defects during the works and others can be drastic for the facility condition.

Prices of repairs and their consequences can exceed manifold the initial investment price. It will be necessary to remove the waterproofing layer, to reconstruct the basis under it. There is also damage due to traffic congestion, which sometimes has to be complete.

2. PROCESS

Most of the railway bridges in the Bulgarian railway system are with damaged waterproofing, which makes them unreliable, not enough secure and with a bad exterior. To ensure a longer life of the concrete and reinforced concrete facilities the waterproofing and the joints are not to allow water penetration to the parts of the construction. Sick concrete becomes porous, its strength diminishes and there are conditions for reinforcement destruction.

The bridges waterproofing has to prevent water penetration to the construction. It is laid directly under the road surface. The materials used for concrete bridge surfaces waterproofing are mainly of three types: cast asphalt, liquid rubber compositions and bitumen-polymer membranes. The bitumen-polymer membranes are quite recently applied and their share in comparison with the other waterproofing materials types is growing. Bitumen is modified with SBS (styrene-butadiene-styrene rubber) elastomer or APP (atactic polypropylene polymer) plastomer. Polyester nonwoven fabric is used as reinforcing basis. Thus waterproofing membranes achieve good temperature resistance and high mechanic performance.

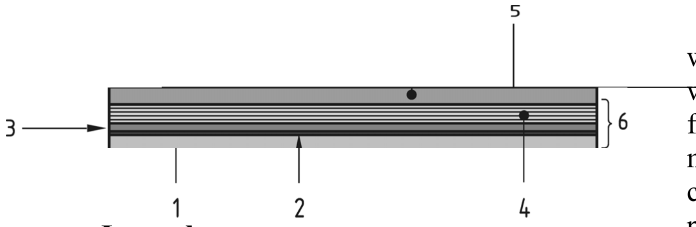
The road surface asphalt or gravel bedding in case of railway bridges is laid directly above waterproofing membranes.

3. CHARACTERISTICS

In 2009 CEN accepted EN 14695, introduced in Bulgaria as BSS (*Bulgarian State Standard*) EN in 2011. This standard specifies basic characteristics and performance of bitumen waterproofing membranes, which are used as waterproofing of concrete bridges and other concrete surfaces for passing of vehicles. It also contains testing methods to check the membranes characteristics and their in-service performance.

A bridges waterproofing system presents layers between the bridge concrete slab and the surface covering (Figure 1). Usually this system consists of a bitumen primer, one or more bitumen membrane layers and a protective layer if it is specified by the manufacturer.

[1] Snejana VALKOVA, VTU "Todor Kableshkov", 158 Geo Milev Str., Sofia, sk@vtu.bg
[2] Nikolina POROJANOVA, VTU "Todor Kableshkov", 158 Geo Milev Str., Sofia



Legend:

1. Bridge concrete slab;
2. Primer;
3. Reinforced bitumen membrane(s);
4. Protective layer;
5. Surface covering;
6. Bridge waterproofing system (2 + 3 and 4, if specified).

Figure 1 – Components of a Bridge Waterproofing System

Bitumen membranes which are part of waterproofing systems have the following basic characteristics:

- visual defects;
- unit area size and weight;
- initial amount of the protective mineral coating;
- strain force characteristics;
- water absorption;
- bending at low temperatures;
- flow resistance at high temperatures;
- size stability at high temperatures;
- thermal aging performance.

The following characteristics are specific only for bitumen waterproofing membranes and application for concrete bridges:

- initial amount of protective mineral coating on the membrane surface mainly with the grain size of more than 0,125 mm. It is important to be determined as too high surface protection may cause sliding between the membrane and the layer above it.
- Size stability of bitumen waterproofing membranes for concrete bridges to be specified according to BSS EN 1107-1, but at the temperature of 160°C. This test simulates the effect of the cast asphalt application above the membrane.
- Thermal aging performance is estimated during exposure to the temperatures from -15°C to +100°C. This characteristic is important for the waterproofing membranes durability.

Characteristics of the laid membranes are estimated beside these characteristics. There is a separate standard for each of them.

All the mentioned characteristics of the ready laid waterproofing are connected with a concrete application and are estimated using special methods specified in the corresponding standard.

These characteristics guarantee that the waterproofing possesses a definite resistance to withstand specific loads and impacts of the bridge facility, i.e. shock, temperature and weather impacts, mechanization load during the asphalt laying and compaction, continuous dynamic loads caused by the passing vehicles, etc. That’s why they are so important and described in the standard. They are to be considered during concrete applications. They are:

- strength of adhesion to the concrete base (BSS EN 13954) – a basic requirement to ensure the waterproofing system durability is to strictly follow the application technology. Very good adhesion to surfaces, especially to the concrete ones is necessary to be ensured to keep the insulation from damages in case of the bridge construction deformation.
- Cutting resistance (BSS EN 13653) determines the resistance to cutting of the waterproofing system laid above a concrete surface, covered with an asphalt layer. This test simulates the dynamic forces impact, e.g. application of vehicles brakes.
- Cracks bridging properties (BSS EN 13224) – ability of reinforced bitumen membranes to resist the concrete surface cracks movement while preserving their quality.
- Compatibility in case of heating (BSS EN 14691) – waterproofing systems laid on a concrete construction are to keep their characteristics for a long period of time. Many of bending membranes used for concrete bridges waterproofing are produced of materials subject to migration, diffusion and absorption of the components inside the system and/or of the ones the system is glued to. These physicochemical effects appear with the time and accelerate with the temperature increase. Accelerated temperature heating test will allow us to estimate changes of the specific mechanic property of cutting resistance for a significantly shorter period of time than a waterproofing system aging under the normal ambient conditions. Using of the cutting resistance test will allow us to state each change in the properties by means of indication of a migration or incompatibility between the glued elements above the separating surface for a long period of time.
- Bitumen membranes behavior during cast asphalt laying (BSS EN 14613) – determines their resistance to the bitumen component increase when laying cast asphalt.
- Water impermeability
- The following requirements are to be observed during bridge waterproofing application:
- the concrete to be the waterproofing basis is to

be laid at least 14 days before and to have a minimal strength of 20 MPa;

- the basis is to be clean, sound and level not to allow the material deformation or rupture in case of big unevenness. It is to be free from dust and organic pollutants;
- application during rain is prohibited;
- the ambient temperature is to be above 0°C. The surface temperature is to be above +2°C;
- the waterproofing is to be covered with a protective layer or a road surface layer as soon as possible;
- the surfaces to be protected are to be obligatory treated with a primer for a better waterproofing adhesion. Thus fine dust particles which could break the adhesion will be additionally removed.

<table>
<tr><td>CE
01234</td><td rowspan="3">CE conformity marking
consisting of the CE mark introduced by Directive 93/68/EEC

Identification number of the certification body

Manufacturer name or identification sign and official address

The last two numbers of the year, when the marking was put

Certificate number

European standard number

Product description
and
information on the mandatory characteristics</td></tr>
<tr><td>AnyCo Ltd, PO Box 21, B-1050

10

01234-CPD-00234</td></tr>
<tr><td>EN 14695

1 m x 10 m x 5 mm, nonwoven polyester, modified bitumen with elastomer, fine mineral sanding, for heat welding only.
For laying of a single layer with asphalt protective layer.
Primer used for testing: primer XYZ…. (trade name)

Strain force in longitudal direction:
900 N/50 mm ± 50 N/50 mm
Strain force in cross direction:
850 N/50 mm ± 50 N/50 mm
Extension in both directions: (45±4) %
Bending at low temperatures: ≤ -20°C
Water impermeability: resistant
Water absorption: ≤ 5%
Cohesion strength:
- for concrete: ≥ 1,0 N/mm^2
- for asphalt: ≥ 0,5 N/mm^2
- for cast asphalt: ≥ 0,8 N/mm^2
Cracks bridging property: type 3 – resistant at -20°C
Cutting resistance:
- asphalt: ≥ 0,2 N/mm^2
- cast asphalt: ≥ 0,3 N/mm^2
Compatibility: 5%
Thermal shock resistance: NPD
Puncture resistance: resistant
Durability:
- water absorption: ≤ 0,5%
- thermal aging performance (-15±5)°C / ≥ 100°C
Compatibility: 5%</td></tr>
</table>

Figure 2 – Example of the CE Marking and Information Provided with the Accompanying Technical Documentation to the Product

BSS EN 14659 standard provides also information on the requirements to the content of the manufacturer technical information:

- product trade name;
- manufacturer / supplier;
- origin / manufacture source;
- product description – type and amount of reinforcing elements; surface layer type; product weight or thickness; surface layer type;
- primer and the amount to be applied;
- protective layer type;
- type of the cover for laying;
- designated use and application method;
- product characteristics and their limits;
- certification mark;
- other information for consumers – e.g. requirements to transportation and storage; safety precautions during the work with the material.

4. CONCLUSION

In conclusion we can say that over the last few years these new European standards have significantly increased the quality requirements to the waterproofing, both planned and under implementation, of bridges and surfaces for the vehicle traffic. This corresponds to the public and economic importance of these facilities, which have an important role to connect countries, cities, towns and even continents.

Bulgarian designers, construction personnel and investors are also to take into consideration the new and very important requirements for the facilities durability and to harmonize the existing regulatory documents, to foresee financial means to equip at least one laboratory to examine all necessary characteristics of this waterproofing type, especially of the ones connected with the useful life.

REFERENCES

[1] BSS EN 14695
[2] BSS EN 1107-1
[3] BSS EN 13954
[4] BSS EN 13653
[5] BSS EN 13224
[6] BSS EN 14691
[7] BSS EN 14613

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

EXTENSION OF ARCHITECTURAL STRUCTURES ON RAIL STATIONS AND SPECIAL REQUIREMENTS OF PLANNING IN INFRASTRUCTURE AND CIVIL ENGINEERING

Tomasz REMUS [1]

Abstract *– Construction at railway stations is a specific task to operators planners and entrepreneurs especially if the perimeter which is to be built is located in close range to the platforms. Here many conditions have to be taken into account. Engineering measures often influence the essential infrastruckture of railway operations which must be maintained at any time. The following presentation deals with the tasks and challenges that have to be overcome primarily by planners and engineers during the design phase to ensure that the implementation of construstion measures can be successfully completed in terms of cost, quality, schedule and train operation.*

Keywords – Railway infrastructure, architecture, civil engineering, construction near railway tracks

1. INTRODUCTION

The railway network of Switzerland is well developed and has expanded as it is at a high utilization level. Switzerlands rail company the SBB is one of the main transport systems of the country for people and goods. Numbers of transported individuals and goods are rising permanently which makes a constant expansion of the infrastructure and stations mandatory.

1.1 Starting point

Extension of architectural content to railway stations is very complex in planning and requires a variety of professional planners and experts. For example, a railway station, which is a listed building and the center of an urban space can in most cases only be expanded underground or by construction of a footbridge over the railway tracks. The adjacent railway tracks and platforms are usually strongly affected by such measures so are the infrastructure of the railway tracks such as electricity, energy and telecommunications.

1.2 Objective

Based on the practical experience this paper is intended to explain the impact of enlargement of railway station buildings during the civil engineering planning in the pre-project phase.

2. CONDITIONS OF CONSTRUCTION NEAR RAILWAY TRACKS

The most important conditions for construction near to tracks can be divided into the following main sections:

- work safety
- operational safety of the track
- preservationof infrastructure for possible operation of the track.

2.1 Work safety and passenger safety

In Switzerland the BAV[1] published a central document which is advising and providing a guideline for construction sites near railway tracks and railway stations it is the AB-EBV[2].

The work safety is the highest priority while constructions near platform areas. It is to be ensured by technical, operational and organizational measures. so the aspects of security have been a top priority in the design phase.

Maintaining the security of passengers follows a simple principle: "The simpler the better." Derived from the complexity of the whole SBB has defined the

[1] *Bundesamt für Verkehr 3003 Bern*

[2] *Ausführungsbestimmungen zur Eisenbahnverordnung; Das Eidgenössische Departament für Umwelt, Verkehr, Energie und Kommunikation: Bundesamt für Verkehr (BAV), 3003 Bern, 2006*

[1] Tomasz Remus, WAM Planer und Ingenieure AG, CH-4502 Solothurn, Florastrass 2, tomasz.remus@wam-ing.ch

following security cascade:

1. traveler safety is maintained primarily by fixed assets (buildings).
2. If the security can not be mantained by a structural measure additional operational measures must be taken (eg: speed reduction).
3. If safety can not be maintained through operational measures the schedule must be adjusted.

Schedule change may cause operational or structural measures (modification Railway station). To maintain the safety of construction the danger potencials have to be identified. Possible dangers can be:

- accidents with electricity
- collisions with train vehicles
- accidents with hanging cables
- high amount of dust or smoke reducing ilumination and vision and therefore limiting rail traffic
- eruptions through e.g. frame work and excavation work.

Danger areas as well as minimum distances to electrified parts (e.g.: overhead wires, railway power systems) for individuals machines and other items. Further the sidewise distances for constructions near to railway tracks have to be respected. The basis for those regulations of all minimum distances are given by the equivalent structure gauges for meter- and normal tracks of SBB.

2.2 Error free operation

To secure the regular operation of the railway during the constructional actions near the rail tracks a surveilance concept has to be prepared to control roadways, overhead lines, temporary bridges, and power systems cables. The components of such a surveilance concept are foreseen by the corresponding regulation published by the SBB.

Depending on the construction plan and the range to the railway track a trouble-free operation might not even be possible without previous planning and approval of the SBB. Therefore the timewindows for service interruptions have to be defined precisely. This means that the planner of the project has to pre calculate the work load of workers and machines at a untypical and dangerous work site. The know-how of railway operators and their support is necerssary to plan such construction work

3. ARCHITECTURE RELATED GOALS AND CONDITIONS OF RECONSTRUCTION PROJECT

Stations are not only platforms for the public, today increasingly also combined transport but also comprehensive service centers. The need for more and more services for the SBB clientele grows restive and causes the need of development of station buildings in construction.

3.1 Project objectives

The project objectives are already defined by the client with the notice of competition and their achievement is already being targeted in the phase of the competition by the architectural team. In general, the goals for the expansion of architectural contents of a railway station building can reasonably be summarized as the following:

1. Long-term consolidation of the commercial site.
2. Increase the quality of stay and usability.
3. Paid to the historical.
4. Optimization of the flow of personnel in and around the building.
5. Functionality and economic solution to the problem.
6. Higher energy efficiency of the building.

If perron or even the track is affected by the project trouble-free rail operations are to be taken into concern.

3.2 Project organization and responsibilities

The organization of complex construction projects is divided into the strategic and operational levels (project level). While composing the strategic level representatives from the building owners and their advisors, including the project level in their core: architects, planners, experts, users and tenants. The core team (Consulting) is supported by various departments within the SBB (finance, law, historic preservation, infrastructure, communications, security, etc.) and the Coordination Office of the passenger traffic of the station concerned. With the creation of a project organization chart and the most responsibilities are clarified within the project and created a base for the comunication and coordination.

3.3 Project costs and schedules

The construction costs of the project are already formulated with the preparation of the study and are calculated with an accuracy of about 20% +/- this is the basis for the budget formation. With increasing processing depth the cost accuracy is about 10% during the construction project. The project budget remains unchanged.

The scheduling framework is first marked out with key milestones and supplemented with the necessary operations. The procedure laid down in the competition phase as milestones remain the same such as: Design, permit procedures, tendering, implementation and end of construction.

4. IMPACT OF ENLARGEMENT OF STATION BUILDINGS ON THE CIVIL ENGINEERING PLANS

The greatest challenge lies in the recognition and then in the formulation of the project task. An expansion project, which extends up to the tracks in the platform area and under the railway brings up the following questions for civil engineering:

1. Can the Perron part or completely be blocked and for how long?
2. Are minimum distances to the track kept?
3. What systems of infrastructre will be affected or interrupted?
4. Are service interruptions of the tracks necessary and possible?
5. Which execution times are disposal?
6. Who is responsible for what?

Answering these questions can only be done with the help of the SBB. Now the greatest challenge for the civil engineer is locating the competent authorities of the SBB. As well as specification of interfaces to the project and coordination of both staff offices (general planning team and SBB) to be compliant to the milestones. If the questions are answered execution times, machinery and materials and the civil engineering costs can be defined.

Furthermore, in all major building renovations strict environmental aspects must be taken into account. So the rain water according to Swiss law has to be led from the roof surfaces has to be seperated from the existing mixing water and sewer systems to be deducted to an infiltration system in the groundwater. The geological conditions such as contamination free sites, drainage capability of the soil, and depth of the groundwater to the ground surface must be met here. For reconstruction of station buildings, it means that due to lack of space on railway station areas, the rainwater infiltration can only be done underground. Often this infiltration system will be built under the existing station building or underneath the rail tracks.

However, the challenge to this is rather the clarification of the presented questions then a engineering solution.

5. CONCLUSION

The early involvement of the civil engineer in the preliminary design will guarantee on time and safe handling of architectural design of railway stations and meet at the same time with the ambitious quality requirements of the operator. Here, the analysis of the structure of various organizational units, governmental offices corporation offices and agencies and their competences and the competences of their staff for the efficient handling of planning is essential. This information guarantees a comprehensive recognition and resolution of project tasks in civil engineering.

REFERENCES

[1] Ausführungsbestimmungen zur Eisenbahnverordnung; Das Eidgenössische Departament für Umwelt, Verkehr, Energie und Kommunikation: Bundesamt für Verkehr (BAV), 3003 Bern, 2006, www.sbb.ch

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

DESIGN SOLUTION OF CONTAINER TERMINAL WAREHOUSE CASE OF FREE ZONE CITY OF NIŠ

Vojislav TOMIĆ [1]
Miloš MADIĆ [2]
Boban NIKOLIĆ [3]

***Abstract** – The paper puts focus onto the procedure of developing a technical project design solution of a railway-highway Container terminal warehouse in the free zone - city of Nis. Container terminal warehouse is complex, serviceable, dynamic and material flow system defined by its own performances: objectives, functions, components and links. They are also the points of intersection between macro and micro-distribution within the supply chains. In the first part of the paper, some basic remarks about container terminals, their functions, structure and characteristics are given. In the second part, special attention is given to design of such a terminal at the location of "Konstantin Veliki" Airport in the city of Nis. In this part of research subsystems of warehouse container terminal are on discussion. The aim of this paper is to attract investments, accelerated industrial development and increase employment rate in the southern part of Serbia.*

Keywords – Container terminal, design, railway, road, logistics.

1. INTRODUCTION

Container Terminal (CT) is a facility where cargo containers are transshipped between different transport vehicles, for onward transportation [1]. CT and their warehauses have one of the most important roles in the logistic supply chains, i.e. in transport networks. Various types of transport meet each other at CT warehauses, where also transformation of material flows is accomplished [2, 3, 4, 5]. One of the crucial factors for a highly efficient distribution network is a suitable choice of CT warehouse design. The main aim of this paper is to find the most suitable design for the CT warehouse.

The paper gives the procedure of developing a technical project design solution of a public CT warehouse in the free zone - city of Nis. In this paper structural and parametric solutions of all necessary elements of the CT warehouse are given, including the design of a public warehouse. Such a system, offers a great synergic effect as well as a great influence onto the industrial development in the city of Nis and southern part of Serbia. [6, 7, 8].

2. LITERATURE REVIEW

The warehouse layout depends on many factors e.g: the items stored, space available, height, the layout of road, and rail tracks around the warehouse, etc. Because of that design planning and location of warehouse has been formally studied and researched as a discipline since the mid 1950s. In literature, Simon [9] suggests that the layout problem is a design problem but the location problem is an optimization problem. On the other hand, according to Francis et al [10] location problem should be treated as a design problem not an optimization problem. In our opinion, the layout and location problems have elements of both design and optimization problems. A confirmation of our thinking we found in the source [11]. In any case, all authors agree in one, warehousing is a time-consuming activity that does not add value. However, the need to provide better service to customers and be responsive to their needs appears to be the primary reason to have warehouse [12]. Based on all stated above, it can be concluded that designing a warehouse is a complex problem. Because of that, Rouwenhorst et al. [13] classify the warehouse design and planning problems into three levels of decisions – strategic, tactical and operational. In this paper, we used the strategic decision as a relevant decision.

3. CONTAINER TERMINAL DESIGN

There are several reasons for building and

[1] Vojislav TOMIĆ, Faculty of Mechanical Engineering, Niš, A. Medvedeva 14, vojislav@masfak.ni.ac.rs
[2] Miloš MADIĆ, Faculty of Mechanical Engineering, Niš, A. Medvedeva 14, madic@masfak.ni.ac.rs
[3] Boban NIKOLIĆ, Faculty of Mechanical Engineering, Niš, A. Medvedeva 14, nboban@masfak.ni.ac.rs

operating warehouses for CT. In many cases, the need to provide better services to customers and to responsive their needs appears to be the primary reason. Although it may seem that the only function of a warehouse is warehousing, that is, temporary storage of goods but in reality many other functions are performed. Because of that, characteristics of flows, which pass through of the CT warehouse, are necessary to analyze before design process. The first step in the design of a CT warehouse is to determine the general flow pattern for material, parts and work in process through the system [11]. Based on the aforementioned, the material flows model of CT warehouse in Niš is analyzed in this paper and it is shown in fig 1. Flow pattern refers to the overall pattern in which the product flows from beginning to end. Beginning started from raw material at the receiving stage (goods are unloaded from wagons), through storage of goods in racks and finally distributed goods in trucks.

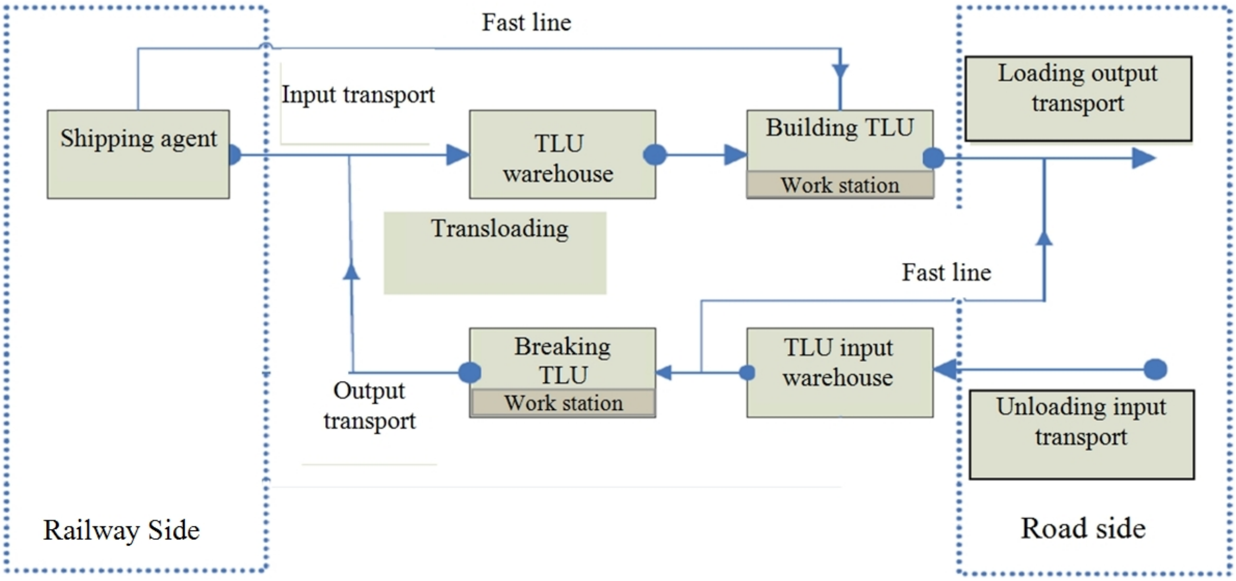


Fig 1. Material flows model of CT warehouse in Free zone Niš

According to the presented flows model of CT warehouse in Niš, the load is delivered to the CT warehouse in transport logistic units (TLU). The load is delivered using both road and rail sides of the terminal. The load arriving in TLU can be directly transformed into the final output TLU using the fast line. The goods that arrive in inadequate TLU, or which are not for any other reason ready to be shipped directly, are sent to the section where TLU are built or broken (work stations).

Such a great amount of load is consolidated into TLU in the construction section using workforce at work stations. After building of an adequate TLU, the goods are directly stored or shipped using the fast line to the output transport.

If the input transport is in inadequate transport logistic units, it is necessary to break it at work stations. At these stations, load is separated, sorted, scanned, and wrapped in thermal shrinking foil, building a compact warehouse TLU. Such new TLU is then stored, and the goods a wait for the commissioner to remove them.

When the commissioner receives an order for removing a certain quantity of goods, TLU are sent to the TLU construction zone, where new TLU are built in accordance with the picking list. As mentioned above, certain TLU do not need to be sent to the construction section, but they are directly moved to the storing zone for shipment preparation. In the same way, certain transloaded transports can be moved directly to the next connection transport over the fast line without the need to break and build TLU again. This happens only in the case when the connection route is compatible with the previous one, that is, when it requires the same TLU containing the exact same goods.

The possible goods at the work stations in this model are:

- output goods that need to be built,
- input goods that need to be broken,
- and transloaded goods that need both to be broken and built.

4. MATHEMATICAL PROBLEM DESCRIPTION

On the basis of general flow in fig 1 we present a design solution of a final Lay-out for CT warehouse on fig 2. 2D design of the warehouse with the surface of 3600 m^2 has been done by AutoCAD software tools.

One of the main tasks of this paper beside design of a CT warehouse is to determine the necessary forklifts for proper functioning of the CT warehouse

system. On the basis of the obtained design it is possible to evaluate the number of the forklifts. The evaluation comprises the following parts:
- calculation of forklifts needed to store/remove goods,
- calculation of pellet turnover on the annual level,
- calculation of forklift time for storing/removing pallets,
- final calculation of forklift efficiency.

In order to determine the required number of forklifts, it is necessary to set the forklift road paths in the receipt area (Fig. 2). Three possible road paths can be noticed: the longest one (S_3), the shortest one (S_2) and the middle/average one (S_1).

The average road path length S_{ms} it is evaluated as a summation of partial paths S_1, S_2 i S_3,:

$$S_{ms} = S_1 + S_2 + S_3 \tag{1}$$

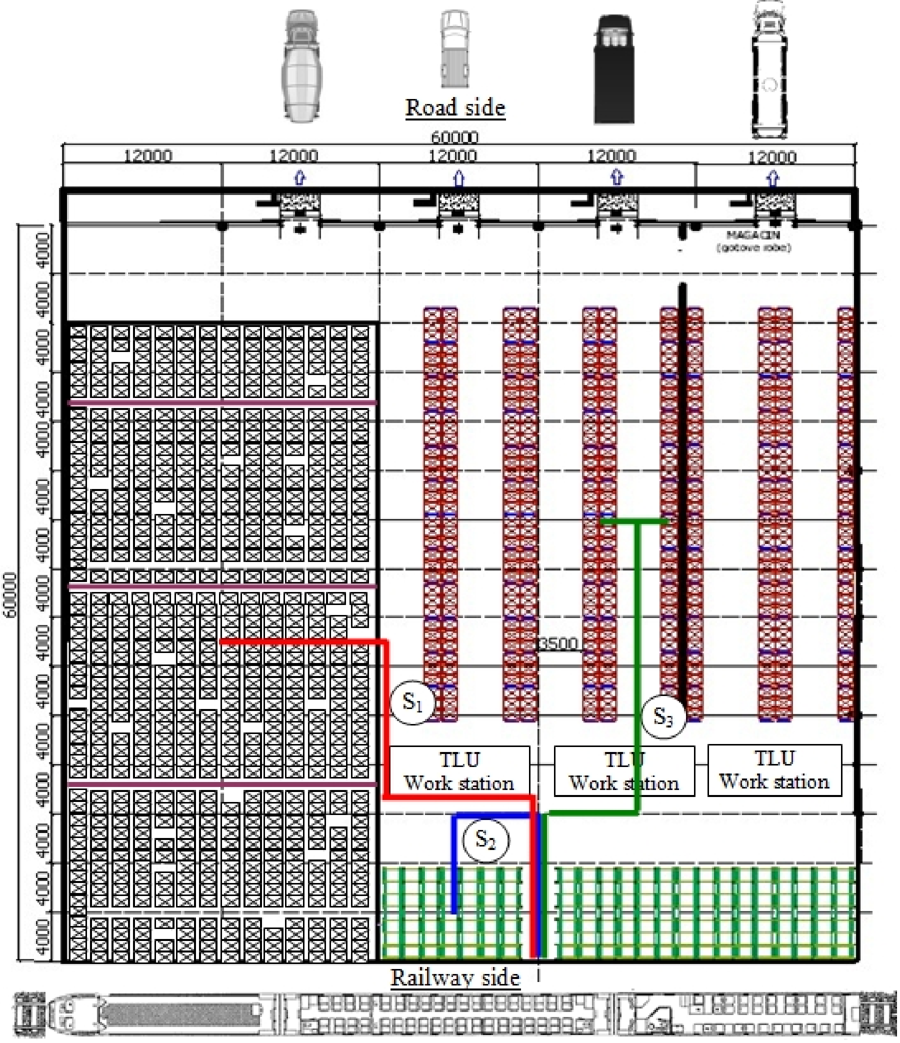


Fig. 2. 2D Lay-out drawing solution of the CT warehouse

The warehouse is divided into three zones:

- S_1 is the average forklift time in the storage area where floor storage spaces are present for the TLU,
- S_2 is the average time for forklifts in the storage area where selective storage shelves are present,
- and S_3 represents the average time for forklifts in the area of storage where only drive-in storage shelves are present.

Using the average path length S_{ms} and the forklift properties provided by the producer, the average time to transport a pallet from a truck to the rack (S_{ms}) and back ($S = S_{ms}$), i.e. the time of an average work cycle (t_{ms}), is determined as:

$$t_{ms} = t_{up} \cdot S_{ms} \cdot t_{pv} + t_s + S \cdot t_e \tag{2}$$

with all the quantities defined in Table 1.

Tab. 1. Times of forklift manipulation

Taking goods from a palletizer t_{up}	0,29 min
Storing goods into a rack t_s	0,43 min
Taking goods from a rack t_u	0,43 min
Loaded forklift drive t_{pv}	0,012 min/m
Unloaded forklift drive t_e	0,008 min/m
Dropping goods onto the ground t_o	0,18 min

In this procedure, the forklift proceeds according to the flow diagram in Fig. 3.

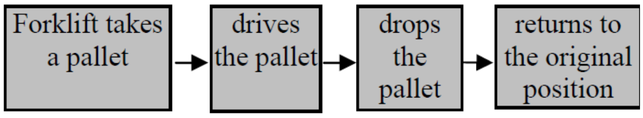


Fig. 3. Forklift pattern road diagram

For the specific task, the time required for the forklift to perform this operation for a single TLU is *0.98 min*. Using this information as well as the annual turnover of the warehouse, which is additionally augmented by 20%, it is a straightforward task to compute the time necessary to store all the pallets in the warehouse (*GOD*):

$$GOD = 1{,}2 \cdot t_{ms} \cdot GOP \qquad (3)$$

where:

GOP – the annual turnover of the warehouse (the total number of pallets).

Assuming *P = 22* as the number of work days per month and *T = 6h* as the number of effective work hours per day, one may compute the number of effective work hours per year *tg* by means of Eq. (4) and, furthermore, the required number of forklifts, N_v, by means of Eq. (5):

$$t_g = 12 \cdot P \cdot T \qquad (4)$$

$$N_v = \left(t_{ms} + t_{is}\right) / t_g \qquad (5)$$

For the considered case, the evaluated number of forklifts is 3, with the usage coefficient of effectiveness is approximately 75%. In practice, this is, however, considered to be quite high usage, so it was decided to take 5 forklifts.

5. CONCLUSION

This research provides an analysis of potentials and obstacles in the process of South Serbia integration in the Balkan logistic system. The idea of this paper is to give the methodology of designing CT warehouse using the multi-modal method access. The first part of this paper gives an analysis of CT warehouses activities (flow activities). The key part of this paper is related to the idea of a design modern CT warehouse that would provide conditions for a successful work of the free zone Nis. Focus is put onto the technological design of a public warehouse within the CT. Upon modeling, a thorough analysis of material flow in the warehouse has been conducted in order to determine the required number of forklifts important for the warehouse functionality. Hence, a functional and parametric analysis of the complex CT warehouse system has been done, which was actually the original aim of this paper.

REFERENCES

[1] Arnold D.: *Material flusslehre*, Vieweg & Sohn Verlagsgesellschaft mbH, Braunschweig / Wiesbaden, 1998.

[2] Lippolt C.: *Lager-und Distributations systeme,* Vorlesung, IFL, Universitaet Karlsruhe, Karlsruhe, 2005.

[3] Zečević S.: *Robni terminali i robno-transportni centri*, Saobraćajni fakultet Univerziteta u Beogradu, Beograd, 2006.

[4] Marinković Z., Marinković D., Tomić V.: *Concept solution of logistic center in the free zone Pirot*, International Conference MHCL 2012., pp. 227 – 230.

[5] Aiying, R., Martin, G.: *Shift designs for freight handling personnel at air cargo terminals*, 2009, Journal of transportation research, pp. 725–739.

[6] Marinković Z., Marinković D., Tomić V., Marković G.: *Značaj osnivanja logističkog (kargo) centra u Nišu i njegov uticaj za privredni razvoj regiona*, TIL 2011., Niš 2011., pp. 31 - 38.

[7] Marković G., Gašić M., Marinković Z., Tomić V.: *Suština i značaj formiranja regionalnog koncepta – strateški pravci razvoja regiona*, TIL 2011., pp. 7 - 14.

[8] Vasić G.: *Inženjerski pristup dizajniranju distributivnog centra u okviru slobodne zone Pirot*, diplomski rad, Mašinski fakultet u Nišu, Niš 2012.

[9] Simon, H.A. *Style in design*, in C.M., Spatial Synthesis in Computer-Aided Building Design, Wiley, New York, 1975.

[10] Francis, R.L., Mc Ginnis and J.A White, *Facility Layout and Location: An Analytical Approach 2ndEdition*, Prentice-Hall, Englewood Cliffs, NJ, 1992.

[11] Sunderesh S. Heragu, *Facilities Design third edition*, Taylor & Francis Group, New York, 2008.

[12] Kulwiec, R.A, *Advanced Material Handling*, The Material Handling Institute, Charlotte, NC, 1980.

[13] Rouwenhorst, B., B. Reuter, V. Stockrahm, G.J van Houtum, R.J. Mantel, and W.H.M. Zijm, *Warehouse design and control: Framework and literatures review*, European Journal of Operational Research, 2000, pp. 515-533.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

MODULAR MICROPROCESSOR LEVEL CROSSING PROTECTION SYSTEM TYPE RLC23 FOR SAFETY INTEGRITY LEVEL SIL4

Zvonimir VIDUKA [1]
Darko BARIŠIĆ [2]

Abstract *– Big differences in speed, weight and braking distance between railway and road vehicles make unprotected level crossings critical places for collisions. Mostly, level crossings in the world are equipped only with St Andrew's Cross or are protected with some kind of old electro-mechanic protection device. Lately, a spotlight is on quality of level crossing protection in order to lower the number of human and material losses. New protection devices are based on microprocessor technology and they have to fulfill highest safety demands required in CENELEC standards EN 50126, EN 50128 and EN 50129. This article describes level crossing protection system type RLC23 which is certified for safety integrity leve (SIL) 4. The system is highly modular and configurable through the PC application which enables easy adjustment to any new kind of railway level crossing situation.*

Keywords – Level crossing protection, SIL4, configurability.

1. INTRODUCTION

In 2006 in Croatia just 30% of the total number of level crossings was equipped with a certain kind of the automated protection devices, usually those were relay based LC control unit at the end of the life time. Similar situation is in many countries all around the world. In this perspective the target of the company ALTPRO was to develop an unique, configurable, modular LC protection system based on a universal microprocessor based platform which will be suitable to solve (from functionality point of view) all the existing requirements not only in Croatia but in the rest of the world too. Special efforts were done to satisfy all the requirements necessary to comply with the highest safety level according to CENELEC standards) SIL4. ALTPRO has finally reached this target with the Level Crossing protection system type RLC23.

Special feature of this system (related to some other concepts with the same functionality) is a simple adaptation to the new customer requirements. Compete functionality is assured by the same software solution without needs for any robust relay interfaces and just with changing configuration data-file. Easy adaptation to any new requirements is also assured by high level of modularity and with very easy maintenance procedures with modern and simple test equipment. The system can also be equipped with some innovative additional subsystems as video-monitoring system with event recorder, additional LED signalization installed on the road surface (before half-barriers), obstacle detectors or additional LC protection devices such as spikes in the concrete (road surface).

2. LEVEL CROSSING PROTECTION SYSTEM RLC23

2.1 System description

Level crossing protection system RLC23 controls light and sound signalization, half barrier drive and driver's indication signals placed on the level crossing area. Basic configuration includes four wheel detectors (axle counter counting points) with two switch-on and one switch off section, two road signals, two main driver's indication signals and two half-barrier with the barrier drive.

Basic structure of the level crossing protection system RLC23 is configuration with driver's indication signals and configuration with remote control functionality. The basic control central units of the system RLC23 are two microprocessor based platforms APIS-RLC23 (A and B) which control all the elements of the system. Control functionality is

[1] Zvonimir VIDUKA, ALTPRO d.o.o., Velika cesta 41, 10020 Zagreb – Odra, z.viduka@altpro.hr
[2] Darko BARIŠIĆ, ALTPRO d.o.o., Velika cesta 41, 10020 Zagreb – Odra, d.barisic@altpro.hr

made by a doubled redundant structure due to the reliability and availability requirements. In basic configuration of the platform system works on the 2 out of 2 (2oo2) principles. And by duplication some of executive modules of the platform (A/B) it is possible to achieve 2 out of (1 out of 2) which additionally increases availability of the level crossing control system.

Central control microprocessor based platform APIS-RLC in the level crossing protection system RLC23 has the following functions:

- It drives red and white lights of the light road signals and sound road signals (bells) depending on the train presence or on the manual LC activation.
- It monitors current of red and white lights of road signals and by that controls their correct function; each platform (A/B) controls the current of absolutely all lights, although it drives only certain lights. Current control is performed continuously while the light is switched on (e.g. while the train is approaching in a case of red light), and by short pulse in configured periods (e.g. each 10 seconds) while the light is switched off (so called "cold check" – refers only to red lights).
- It controls lowering/lifting of (half) barriers depending on a presence of a train or by manual LC switch-on. Optionally it can control blinking of bulbs on barrier arm if they are required, and control their correct function. Certain platform (system A/B) controls lowering of barriers in safety OR-function with other platform (barriers are lowering if at least one system provides lowering command), i.e. lifting of barriers in safety AND-function with other platform (barriers are lifting only when both systems provide lifting command).
- It controls correct function of barrier drive and integrity of barrier arm in a way that it detects final positions of arm (up/down), it measures time of arm lowering/lifting and it detects possible interruption of electrical contact on weakest part of the arm upon break.
- It receives information about track sections clearance/occupancy from axle counter BO23 and about train passage over certain counting point in specific direction.
- It drives indication elements on control board in LC housing/cabinet, and it receives manual commands from switches/pushbuttons for LC switch-on/switch-off, forced manual restoring to the basic state and testing/simulation of disturbance and failure.
- It drives white lights of track driver's indication signals (on LC version with driver's indication signals) depending on correct function/failure and LC switch-on/switch-off state and it monitors their current, i.e. controls their correct function.
- It continuously communicates with microprocessor platform APS-RLC DK in nearest station (on LC version with remote monitoring), and with it exchanges data of LC state (disturbance / failure / correct state, barriers position, switch-on/switch-off of road signals, etc.). Microprocessor platform APIS-RLC DK which controls remote monitoring in station is smaller version of main platform APIS RLC in LC housing/cabinet, in charge for control of indication elements on operators desk in station operator room (optionally on display unit in operator room) and pushbuttons for LC control by station operator (manual switch-on/switch-off, restoring to the basic state, etc.).
- It receives command for switch-on (possible even for switch-off) from station interlocking system (in a case when LC is located near station area or within station area) over microprocessor platform APIS-RLC DK in station. Also, for dependency with interlocking many other functions can be configured; such as keeping the station exit signal on the aspect of forbidden drive for certain time after LC switch-on, etc.
- It controls DC voltage of battery power supplies 1 and 2, correct function of battery chargers 1 and 2, and presence of mains AC voltage.
- It exchanges vital data of LC state with platform APIS-RLC of counter-system (B/A) over two CAN buses (double bus due to redundancy / wider availability).

Maximum capacity of the external devices which can be connected on one RLC23 system is: 8 road signals (not depending on the light technology – LED, bulbs...) with bells, 4 main driver's indication signals, 4 auxiliary driver's indication signals, up to 4 sections on the open track, two pairs of half barriers (third is possible if the functionality is the same as for first pair of the half barriers).

Schematic of the maximal configuration is on figure 1.

2.2 System configurability

The level crossing protection system RLC23 is extremely configurable and flexible for use and adaptation on certain specific application requires minimum time consumption.

Standards, traffic rules, norms and regulations issued by certain railways (country) are different and many suppliers of the signaling equipment very often face problems how to change the basic concept of the system (SW, HW) in order to satisfy these requirements and to keep the required safety integrity level SIL4 at the same time. Depending on specific situation it increases costs of development and seriously aggravates process of certification or approving of safety for these new versions of the systems.

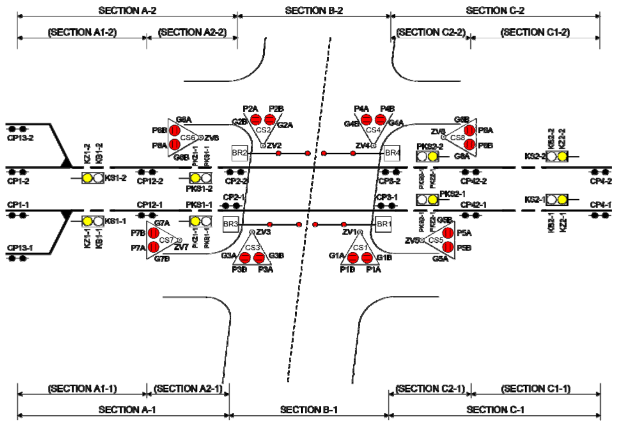


Fig.1. Maximal quantity of the external devices which can be connected on one RLC23 system

Due to these reasons the main engineering challenge was development of the device which should have a unique hardware (HW) platform (power supply modules, module for communication and monitoring inside any redundant system and different number of U/I modules depending on the situation) with the same software (SW) not depending on certain application. With Windows PC application it is possible to configure any situation (application) which meets customer/market requirements.

The biggest amount of time was spent by ALTPRO in analyzing of the standards, traffic rules, norms and regulations issued by the railway authorities all around the world and this application includes huge spectrum of configuration possibilities. As an example we are listing some options which can be chosen by the configurator tools:

- Number and type of road signalization – traffic light principle, two blinking red lights with one/double bulbes.
- Frequency of blinking, period of so called „cold control".
- Lowering/lifting time of the barrier, ringing time (sound signalization), use of heaters, behavior of the system in case of the broken arm/gate, use of the obstacle detectors…
- Number of the sections, switching off time delay, time to return to basic state.
- It is also possible to control which events will set the system into the failure state (which is automatically annulled by eliminating of the condition under which it was created) or error (it is necessary to annulled it manually) etc.

2.3 Product certification

Since ALTPRO has performed a lot of projects all around the world delivering the axle counters, train detectors, switch on/off electronic treadle as the part of modernization of the level crossing system, ALTPRO engineers collected huge experience related to railway signaling. This experience, knowledge and know-how in design, development and certification (according to CENELEC standards) of the signaling products helped company during certification of the level crossing protection system RLC23. Figure 3 shows EMC testing of the system RLC23 according to standard EN50121-4 in TÜV Rheinland EMC labs in Nürnberg. Figure 4 shows SIL4 certificate according to standards EN 50126, EN 50128 and EN 50129.

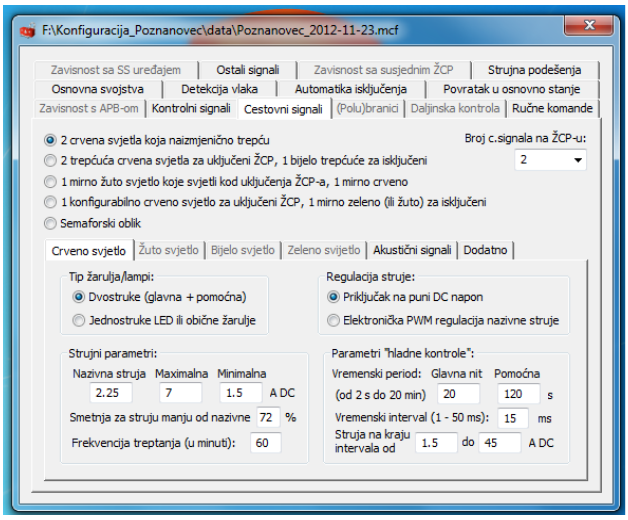


Fig.2. Example of the configuration possibilities for road signals

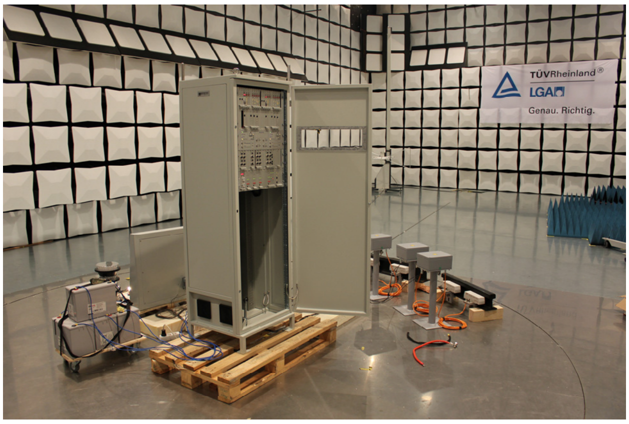
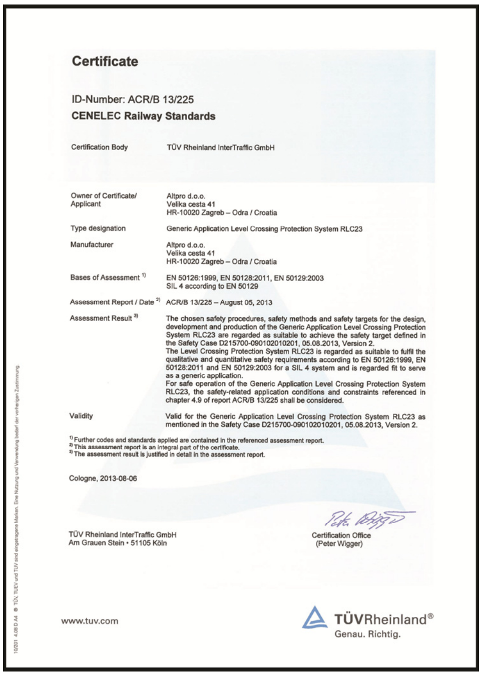


Fig.3. LC protection device RLC23 during the EMC testing

Level crossing protection system RLC23 (figure 5) is sometime (depending on the project requirements) installed with some additional features; a) an innovative additional road signalization consisted of white and red LED diodes installed in the road surface in order to give to train driver one additional warning that they approach the level crossing area, b) on the pillars of the road signals (or on separate pillars) are also sometime installed the cameras for event recording with video event recorder and c) special additional LC protection device as "boom spikes in the concrete (road surface)". Figures 6 and 7 show some of the RLC23 installations all around the world.



Certificate

ID-Number: ACR/B 13/225
CENELEC Railway Standards

Certification Body	TÜV Rheinland InterTraffic GmbH
Owner of Certificate/ Applicant	Altpro d.o.o. Velika cesta 41 HR-10020 Zagreb – Odra / Croatia
Type designation	Generic Application Level Crossing Protection System RLC23
Manufacturer	Altpro d.o.o. Velika cesta 41 HR-10020 Zagreb – Odra / Croatia
Bases of Assessment [1)]	EN 50126:1999, EN 50128:2011, EN 50129:2003 SIL 4 according to EN 50129
Assessment Report / Date [2)]	ACR/B 13/225 – August 05, 2013
Assessment Result [3)]	The chosen safety procedures, safety methods and safety targets for the design, development and production of the Generic Application Level Crossing Protection System RLC23 are regarded as suitable to achieve the safety target defined in the Safety Case D215700-090102010201, 05.08.2013, Version 2. The Level Crossing Protection System RLC23 is regarded as suitable to fulfil the qualitative and quantitative safety requirements according to EN 50126:1999, EN 50128:2011 and EN 50129:2003 for a SIL 4 system and is regarded fit to serve as a generic application. For safe operation of the Generic Application Level Crossing Protection System RLC23, the safety-related application conditions and constraints referenced in chapter 4.9 of report ACR/B 13/225 shall be considered.
Validity	Valid for the Generic Application Level Crossing Protection System RLC23 as mentioned in the Safety Case D215700-090102010201, 05.08.2013, Version 2.

[1)] Further codes and standards applied are contained in the referenced assessment report.
[2)] This assessment report is an integral part of the certificate.
[3)] The assessment result is justified in detail in the assessment report.

Cologne, 2013-08-06

TÜV Rheinland InterTraffic GmbH
Am Grauen Stein • 51105 Köln

Certification Office
(Peter Wigger)

www.tuv.com

TÜVRheinland®
Genau. Richtig.

Fig.4. SIL4 certificate

Fig.5. RLC23 cabinet

3. CONCLUSION

ALTPRO has applied years of its practical experience in fields of railway safety, electromagnetic compatibility and environment conditions in this project of development of the level crossing protection system RLC23 for safety integrity level SIL4. Hardware modules of the platform, interface modules, overvoltage protection modules and train detection (axle counter) modules are designed in Eurocard form in order to facilitate the process of eliminating failures. Wiring is designed in the way to facilitate serial production of the device and any new project (requirements) will differ with existing ones just in the configuration data file what assures uniformity of the systems, very easy maintenance, easy performance control and simple operation. With specially designed testing unit it is possible to test the central unit of the LC system as well as all the peripheral devices connected to the central unit. With this design a uniform system is achieved which allows the simple maintenance for the customer and low life cycle costs. ALTPRO level crossing protection system RLC23 (in different versions) is already supplied and installed in various railways all around the world.

Fig.6. Level crossing protection system RLC23 installation (worldwide)

Fig.7. : Level crossing protection system RLC23 installation (worldwide)

REFERENCES

[1] CENELEC EN 50129:2003, Railway applications – Communication, signalling and processing systems – Safety related electronic systems for signalling

[2] ALTPRO d.o.o. Zagreb, User manual for level crossing protection system RLC23

TOOLS FOR TRANSITION CURVE DESIGN - APPLICATION FOR RAILWAY RECONSTRUCTION

Luka LAZAREVIĆ [1]
Zdenka POPOVIĆ [2]
Milica VILOTIJEVIĆ [3]

Abstract *– European standard EN13803-1:2010 prescribes the application of six forms of transition curves. Two of these six forms are prescribed for the use by Serbian regulation - clothoid and cubic parabola. Entire railway network in Serbia was initially designed using cubic parabola. During recent reconstructions of railway sections, this form of transition curve was still used in order to maintain spatial position of railway centre line. The aim of this paper is to explore the possibility of application of clothoid transition curve on existing railway sections using tools for transition curve design.*

Keywords – railway, transition curve, clothoid, cubic parabola, reconstruction.

1. INTRODUCTION

Transition curve is the element of alignment that connects straight line and circular curve or two circular curves with the same or different radius, which can have the same or opposite direction of curvature [1].

At first, when trains travelled with low speeds, the transition from straight line to circular curve was direct. On the other hand, cant was either not designed or the change of cant was applied on the straight section before the beginning of the circular curve [2]. The later increase of the speed of rail traffic showed disadvantages of this type of alignment - passage from the straight section to the circular curve followed the abrupt centrifugal force i.e. lateral jerk, which influenced the ride comfort, the appearance of damages on transported goods and the potential for derailment. Obviously, transition element that would provide gradual change of curvature and cant was necessary. Transition curve is the alignment element that met these two conditions.

Regarding railway design in Serbia, in 1875. engineer Mihailo Petrović ih his book „Instructions for railway design" suggested the use of transition curve, either in the form of circular curve with twice bigger radius (2R) or in the form of curve with variable radius and curvature. Transition curves were used only in railway design until the end of the World War II. After 1945. transition curves were also introduced in the road design.

Although cubic parabola was used as the transition curve in railway design, it showed to be inapplicable in the road design. It was already known that cubic parabola has the problem with error that increases with length. This error is the consequence of approximations that were adopted in derivation of cubic parabola. Since principles of road design implies the application of longer transition curves (comparing to railways), it was necessary to use different form of transition curve. Therefore, clothoid was presribed as the form of transition curve that should be used in road design.

Current regulations for railway design in Serbia implies the use of both, cubic parabola and clothoid [3], but in praxis there is not even a single case of application of clothoid. On the other hand, clothoid is used in railway design worldwide, especially on many European railways. Also, it is important to emphasize that European standard EN13803-1:2010, among clothoid and cubic parabola, also prescribes the use of Bloss curve, cosine curve, Schramm curve and sine curve [4].

Since all the railways in Serbia were initially designed using cubic parabola, the main reason for its continious application is maintaining the spatial position of railway centre line.

[1] Luka LAZAREVIĆ, MSc, University of Belgrade, Faculty of Civil Engineering, Bulevar kralja Aleksandra 73, Belgrade, llazarevic@grf.bg.ac.rs
[2] Zdenka POPOVIĆ, PhD, University of Belgrade, Faculty of Civil Engineering, Bulevar kralja Aleksandra 73, Belgrade, zdenka@grf.bg.ac.rs
[3] Milica VILOTIJEVIĆ, MSc, PhD student, milica.vilotijevic@gmail.com

After the short history of the applications of transition curves in railway and road design, the paper presents mathemathical background of transition curve and derivation of formulae for calculation of cubic parabola and clothoid. Next part of the paper shows the comparative analysis of these two forms of transition curves, and also the consequences that would arise from the application of clothoid instead of cubic parabola in railway design. The analysis was performed using tools for design of transition curves according to EN13803-1:2010, that were previously reported in [1, 5, 6]. This paper presents the consequences of the application of clothoid for reconstruction of a section on the rail line Belgrade (SRB) - Bar (MNE).

2. THE SHORT HISTORY OF TRANSITION CURVES APPLICATIONS

The first known application of the transition curve in railway design happened in 1828, when William Gravatt used one form of the sinusoidal curve as the transition curve [7]. On German railways, Wilhelm von Pressel applied cubic parabola as the transition curve. His method was published in 1854. in „Eisenbahn-Zeitung“ journal, but he didn't provide practical mapping procedures [2]. This problem was solved by Wilhelm Nordling in 1867, and that was the beginning of the application of cubic parabola in railway design.

Application of the transition curve in the road design came more than 50 years later, although there were numerous investigations and recommendations in this field. The main reason was the fact that car speed became competitive with train speed around 1930s, and there was the need to use the same design principles as in the field of railways. Regulation „RAL-1937” adopted in Germany in 1937. prescribed the use of clothoid as transition curve for road design.

From the current standpoint, it can be noticed that cubic parabola and clothoid were derived from the same starting problem, but using the different presumptions. Both transition curves were derived from the spiral that was first used in 1694. by James Bernoulli. This spiral was later described by Leonhard Euler, who also gave mathematical generalization and solutions in 1744 and 1781 [7]. Hence, this spiral is widely known as Euler spiral.

3. MATHEMATICAL BACKGROUND OF TRANSITION CURVES

Many transition curves, that were used from the beginning, were derived using Euler spiral as the basis. The main reason was the fact that these curves provided good overlaping in the first, relatively stretched part of Euler spiral. Fig.1 shows the relation between Euler spiral and three derived forms of transition curves: cubic parabola, rectangular curve and lemniscate.

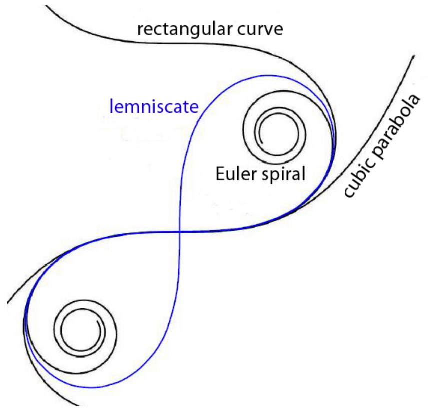


Fig.1. The relation between Euler spiral and three forms of transition curves

As it can be observed, clothoid was not marked in Fig.1. In practical terms, clothoid represents part of the Euler spiral that provides:

- either the change of radius from ∞ (straight line or inflexion point) to R (designed circular curve), or
- the change of radius from R_1 to R_2 (designed circular curves).

Clothoid has linear change of curvature, which means that curvature in arbitrary point (k) is proportional to the distance from the beginning (l), measured along the curve length (L):

$$k = \frac{1}{r} = \frac{l}{L} \cdot \frac{1}{R} \tag{1}$$

If θ is an angle between tangent in the beginning of transition curve and tangent in arbitrary point of transition curve, it follows:

$$\frac{d\theta}{dl} = \frac{1}{r} = \frac{l}{L \cdot R} \tag{2}$$

Solving differential equation (2) and taking the boundary conditions [5, 8], it can be derived formula for calculation of angle θ:

$$\theta = \frac{l^2}{2 \cdot R \cdot L} \tag{3}$$

The derivation of clothoid can be done using local coordinate system, with origin in the beginning of clothoid, one axis parallel to tangent line and another perpendicular [5, 8], as shown in Fig.2.

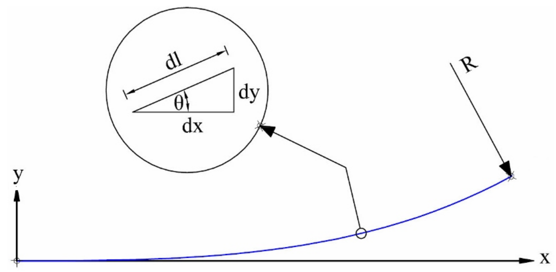


Fig.2.Local coordinate system for derivation of transition curve [5]

From observed, infinitely small element in Fig.2, it follows equations for x and y coordinates:

$$cos\theta = \frac{dx}{dl} \Rightarrow x = \int cos\theta \, dl \quad (4)$$

$$sin\theta = \frac{dy}{dl} \Rightarrow y = \int sin\theta \, dl \quad (5)$$

Integrals (4) and (5) were first derived by Euler. The solution of these integrals can be found using Taylor series for sine an cosine function. Since these are fast converging series, using first two or three series members provides necessary precision for calculation of clothoid. Described method can also be used for any other form of transition curve, regardless of the function of curvature.

4. DERIVATION OF CUBIC PARABOLA

When it began the application of transition curves in railway design, clothoid was already well known. But it was very difficult to calulate it using the existing tools and techniques. Therefore, certain aproximation were adopted - it was assumed that angle θ has small value. This assumption implies that $cos\theta = 1$ and $sin\theta = \theta$. Solving integrals (4) and (5) with these assumptions and taking the boundary conditions [5, 8], it follows:

$$x = l \quad , \quad y = \frac{l^3}{6 \cdot R \cdot L} \quad (6)$$

Rectangular coordinates (6) for cubic parabola were used from the beginning, when short transition curves were applied. Later, with changes in rail vehicle design, longer transition curves were necessary, but longer cubic parabola had larger difference between x and l. Therefore, (6) was modified to provide calculation relative to tangent:

$$x \in [0, l_X] \quad , \quad y = \frac{x^3}{6 \cdot R \cdot l_X} \quad (7)$$

where l_x is orthogonal distance from the beginning to the end of cubic parabola. Cubic parabola was changed once again, when in some cases (larger length) occured the difference between the end of cubic parabola and the beginning of the following circular curve. The corrected form of cubic parabola is known as Heffer curve.

Since equation for l_x is same for both, clothoid and cubic parabola, the difference between these two curves occurs due the different calculation of y coordinate. Equations (8) defines rectangular coordinates for clothoid.

$$x = l - \frac{l^5}{40 \cdot R^2 \cdot L^2} \quad , \quad y = \frac{l^3}{6 \cdot R \cdot L} - \frac{l^7}{336 \cdot R^3 \cdot L^3} \quad (8)$$

Fig.3 shows the matching between clothoid and cubic parabola. Parameter Δy denotes deviation of cubic parabola from clothoid. It can be observed well matching up to L=A. For length L>0.72·A, it began violation of fundamental equation of a transition curve [9]. Therefore, from the aspect of mathematics, there is no reason to use cubic parabola instead of clothoid in cases of construction of new or reconstruction of the existing railway.

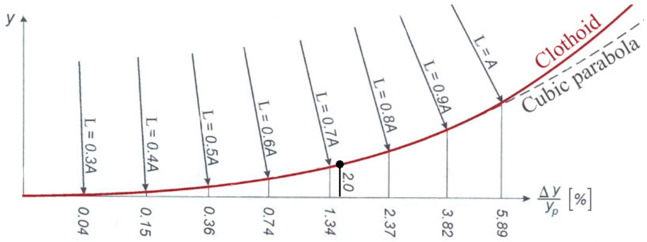


Fig.3.Matching between clothoid and cubic parabola

5. APPLICATION OF CLOTHOID FOR RAILWAY RECONSTRUCTION

As it was shown above, the differences between clothoid and cubic parabola are not significant. However, it would not be practical to use clothoid instead of cubic parabola in the cases when design speed is kept the same.

According to [10], reconstruction of sections on Corridor X in Serbia will imply design speed of 140 km/h. This design speed increases the minimum radius of circular curve. This being the case, high reconstruction costs are expected. Therefore, the use of clothoid should be mandatory.

The analysis of application of clothoid for railway reconstruction, using design tools described in [1, 5, 6], was performed for the section Trebaljevo - Kolašin of the rail line Belgrade (Serbia) - Bar (Montenegro). The length of this section is 8652.14 m and it is located in Montenegro.

According to the longterm plans, speed of passenger trains on this rail line should be 100 km/h and speed of freight trains should be 75 km/h. Design speed of 100 km/h for reconstruction implies the change of minimum radius of circular curve ($R_{min,new}$= 475 m in this case).

Part of the section from station 331+562.33 to station 335+433.28 includes six curves (of eight) with radius R<475 m, which necessarily led to the design of the new railway route on this part.

Second part of the section from station 335+433.28 to station 340+141.72 includes one curve (of five) with radius R<475 m. Tab.1 summarizes the consequences of application of clothoid for reconstruction of this part of the section Trebaljevo - Kolašin. Parameter Δ denotes maximum distance between existing and newly designed railway centre line.

Tab. 1. Application of clotohoid for reconstruction of railway section Trebaljevo - Kolašin

No	R [m]	L[m]	Δ [cm]	Old/New route
1.	800	80	1.70	O
2.	5000	0	0.22	O
3.	20000	0	0.19	O
4.	500	140	2.64	O
5.	400*	100*	707*	N
* - if $R<R_{min,new}$, it was adopted $R=R_{min,new}$=475 m				

As it can be seen in Tab.1, application of clothoid instead of cubic parabola for railway reconstruction would not lead to the significant changes of spatial position of railway centre line. All needed changes could be applied within the existing width of railway embankments. It is important to mention that Δ in the fifth case in Tab.1 is the consequence of curve radius change, which would demand the construction of new track substructure according to the new railway design.

However, all transition curves with linear change of curvature and cant have the problem of irregular curving of outer rail, as it is shown in Fig.4.

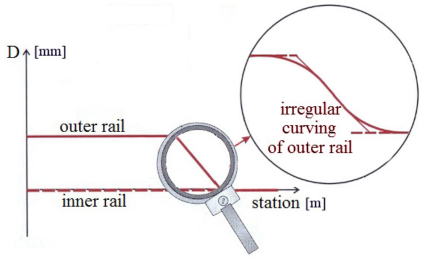


Fig.4. Irregular curving of outer rail

6. CONCLUSION

Transition curve is the most important alignment element of the railway. Since the first solutions for transition from straight section to circular curve, nowadays there are several forms of transitions curves that can be used in railway design.

While European standard EN13803-1:2010 presribes the use of six forms of transition curves, Serbian regulations prescribes the usage of two forms-clothoid and cubic parabola. Although clothoid can be used for railway design, in praxis it is rarely applied.

This paper explored the history of application of transition curves and presented the mathematical method for derivation of transition curves.

As it was shown, cubic parabola is the form of transition curve that is derived from clothoid using ″rough″ approximation. Later adjustments of cubic parabola were the consequence of this approximation.

Application of clothoid instead of cubic parabola was considered for the section Trebaljevo - Kolašin of the rail line Belgrade - Bar. The consequences, as expected, were displacements of the railway centre line. These displacements varied from several millimeters to several centimeters, depending on the radius of circular curve and length of transition (assuming that curve radii remains the same).

Summing up the previous, in cases of construction of new or reconstruction of the existing conventional railway (change of design speed) the use of clothoid is recommended. On the other hand, in cases of rehabilitation or other maintenance works that do not imply change of design speed, the use of existing form of transition curve (cubic parabola) is recommended. Also, due the irregular curving of outer rail (Fig.4), application of transition curves with nonlinear change of curvature and cant is recommmended for the high speed railways and slab track.

Developed tools for design of transition curves [1, 5, 6] according to EN13803-1:2010 makes the work of railway designers more comfortable.

ACKNOWLEDGEMENT

This work was supported by the Ministry of Science and Technological Development of the Republic of Serbia through the research project No. 36012: „Research of technical-technological, staff and organizational capacity of Serbian Railways, from the viewpoint of current and future EU requirements".

REFERENCES

[1] Lazarevic, L., Popovic, Z., Puzavac, L., *Computer aided design for spatial railway transition curves*, First International Conference on Railway Technology: Research, Development and Maintenance, Las Palmas de Gran Canaria, 2012.

[2] Žnideršić, B., *Prelazne krivine na putevima i železnicama*, Ministarstvo železnica, Odeljenje za štampu i propagandu, Beograd, 1949.

[3] Ministarstvo saobraćaja, *Pravilnik o projektovanju rekonstrukcije i izgradnje određenih elemenata železničke infrastrukture pojedinih magistralnih železničkih pruga*, Službeni glasnik Republike Srbije, br. 100, 2012.

[4] CEN, *EN 13803-1:2010 Railway applications - Track alignment design parameters –Track gauges 1435 mm and wider - Part 1: Plain line*, 2010.

[5] Lazarević, L., *Cant transition as spatial element of railway*, MSc Thesis, University of Belgrade, Faculty of Civil Engineering, Belgrade, 2010.

[6] Lazarević, L., Popović, Z., Puzavac, L., Ivić, M., Belošević, I., *Curve with nonlinear change of curvature - 3D modeling*, 19th International Symposium "Recent Challenges for European Railways", Žilina, 2011.

[7] Levien, R., *From Spiral to Spline: Optimal Techniques in Interactive Curve Design*, PhD thesis, University of California, Berkeley, 2009.

[8] Puzavac, L., Popović, Z., Lazarević, L., *Transition curve design according to European standards*, XIV Scientific-Expert Conference on Railways RAILCON '10, Niš, 2010.

[9] Roy, S.K., *Fundamentals of surveying*, PHI Learning Private Limited, New Delhi, 2010.

[10] ITALFERR, *General Master Plan for Transport in Serbia*, 2009.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

AUTHORISATION FOR PLACING IN SERVICE OF STRUCTURAL SUBSYSTEMS PRESENTED ON THE EXAMPLE OF THE SUBSYSTEM "INFRASTRUCTURE"

Mirjana DŽUDOVIĆ [1]
Milan POPOVIĆ [2]
Dragana JOKANOVIĆ [3]

Abstract *– The subject matter of this paper is issuance of authorisations for placing in service of structural subsystems presented on the example of the subsystem "Infrastructure". At the beginning, the paper presents the legal base for issuing of an authorisation for placing in service, the different elements of the subsystem "Infrastructure" and technical rules applied to the subsystem "Infrastructure". Explanations concerning the concept of verification of subsystems and entities carrying out the verification depending on the applied technical rules. Modules for verification of the subsystem "Infrastructure". Explanation concerning the modules SG and SH1 and their different stages. Submission of an application for verification of subsystems and original technical file to be submitted with the application. Control carried out by the assessing entity. Certificate of verification and declaration of verification of a subsystem. Technical file accompanying the declaration of verification. Content of the application for issuing of the authorisation. Technical conformity and safe integration of structural subsystems. Issuing of an authorisation for placing in service of structural subsystems and form of the authorisation. Example of an authorisation for the subsystem "Infrastructure" through different stages.*

Keywords – Authorisations for placing in service, subsystem infrastructure, verification.

1. INTRODUCTION

According to the Railway Safety and Interoperability Law [1], in order for the structural subsystems, interoperability constituents and elements of structural subsystems to be placed in service and used on railway lines of the Republic of Serbia, they must have an authorisation for placing in service issued by the Directorate for Railways.

2. RAILWAY SYSTEM

Railway system consists of structural subsystems and functional subsystems.

2.1 Structural subsystems

Structural subsystems are: infrastructure, energy, control, command and signalling – track side part, control, command and signalling – on-board part and railway vehicles.

2.2 Infrastructure subsystem

The infrastructure subsystem includes railway tracks, switches, engineering structures (bridges, tunnels etc.) and the accompanying infrastructure in stations (platforms, access areas, including parts meant for persons with reduced mobility etc.). The interoperability constituents of the infrastructure subsystem are rails, fastening accessories and sleepers.

2.3 Placing in service of structural subsystems

Structural subsystems may be placed in service only if they have been designed, constructed and installed in such a way that enables them to fulfil the essential requirements applied to them. The essential requirements are defined by the Uniform Technical Prescriptions (UTPs) and national technical rules.

Uniform Technical Prescriptions (UTPs) represent technical specifications that subsystems must comply

[1] Mirjana DŽUDOVIĆ, Advisor, Directorate for Railways, Nemanjna 6, Beograd, mirjana.dzudovic@raildir.gov.rs
[2] Milan POPOVIĆ, Head of the Department, Directorate for Railways, Nemanjna 6, Beograd, milan.popovic@raildir.gov.rs
[3] Dragana JOKANOVIĆ, Assistant Director, Serbian Railways, Nemanjna 6, Beograd, dragana.jokanovic@srbrail.rs

with in order to fulfil the essential requirements and ensure interoperability of the railway system and they are integral part of COTIF [2].

3. VERIFICATION OF SUBSYSTEMS

Verification of subsystems is a prerequisite for issuing of an authorisation for placing in service. It is a procedure in which the notified body checks and confirms that the subsystem fulfils the essential requirements and that it complies with the UTPs and/or national technical rules.

Subsystems shall be verified in each of the following stages:

1. design as a whole:
2. manufacturing: construction, including especially construction works, manufacture, assembling of integral parts and adjustment of the entire subsystem;
3. final testing.

Verification of a subsystem shall be carried out by a Notified Body, in case that a subsystem is subject to UTPs, by the Directorate for Railways if a subsystem is subject to national technical rules, that is, by a Notified Body and the Directorate for Railways if a subsystem is subject to both UTPs and national technical rules.

3.1 Modules for verification of the infrastructure subsystem

The following modules can be used for verification of the infrastructure subsystem:

1. Module SG – Verification based on product verification or
2. Module SH1 – Verification based on full quality management system including design examination.

The verification module shall be chosen by the applicant.

3.2 Module SG - Verification based on unit verification

The verification procedure according to the Module SG includes the following activities:

1. The applicant prepares a technical file enabling assessment of conformity with the applicable rules prescribed within the Module SG;
2. The applicant takes all the necessary measures so that the process of manufacture and/or installation/construction and its supervision ensures the conformity of the subsystem with the requirements of the applicable rules;
3. The assessing entity shall carry out, or have them carried out, examinations and tests defined by the relevant technical rules, as well as a final testing of the subsystem;
4. If the subsystem fulfils the requirements laid down by the relevant technical rules, the assessing entity shall issue a certificate of verification;
5. The applicant shall draw up a declaration of verification;
6. The assessing entity shall compile a technical file accompanying the declaration of verification.

3.3 Module SH1 - verification based on full quality management system plus design examination

The verification procedure according to the Module SH1 includes the following activities:

1. Approval of the quality management system for design, manufacture, final inspection and testing of the subsystem;
2. The applicant shall prepare a technical file enabling conformity assessment with the applicable rules, as defined within the Module SH1;
3. The assessing entity shall examine the design documentation and, where it meets the requirements of the relevant technical rules, it shall issue a Design examination certificate;
4. The assessing entity shall carry out periodical checks in order to ensure that the applicants maintains and applies the approved quality management system;
5. Where the subsystem meets the requirement of the relevant technical rules, the assessing entity shall issue a certificate of verification;
6. The applicant shall draw up a declaration of verification for the subsystem;
7. The assessing entity shall compile technical file accompanying the declaration of verification.

3.4 Certificate of verification of a structural subsystem

Certificate of verification is a conformity document issued by the assessing entity, once the verification of a subsystem has been completed. The certificate of verification shall include:

1. name of the assessing entity which has issued the certificate;
2. title „Certificate of verification" and number of the certificate;
3. title/short description of the subsystem;
4. name and address of the contracting entity or manufacturer of the subsystem;
5. list of technical rules and standards that the subsystem complies with;
6. date of issuance;
7. validity;
8. seal and signature of the responsible person.

The certificate of verification can comprise one or more annexes including a list of the different parts of the technical file, examination and testing results, etc.

3.5 Declaration of verification

Declaration of verification is a document issued by the applicant guaranteeing that the subsystem meets the essential requirements laid down by the relevant rules. It shall include:

1. title „Declaration of verification” and number of the declaration;
2. name of the applicant;
3. title/short description of the structural subsystem;
4. list of technical rules and standards the structural subsystem complies with;
5. name of the assessing entity which has issued the certificate of verification;
6. number of the certificate;
7. limitations and conditions concerning the use of the subsystem, if any;
8. modules applied on the verification of the subsystem;
9. list of annexes – technical file
10. validity;
11. date of issuance;
12. seal and signature of the responsible person.

3.6 Technical file accompanying the declaration of verification

Technical file accompanying the declaration of verification shall consist of:

1. inital technical file;
2. list of interoperability constituents and other elements included in the subsystem;
3. copy of the declaration of conformity for the elements from point 2, including the appropriate calculation documents and a copy of testing and examination reports carried out by assessing entities;
4. intermediate statement of verification and declarations of intermediate statement of verification, if any;
5. certificate of verification of the structural subsystem, including the appropriate calculations in annex, signed by the assessing entity; the certificate shall be accompanied by reports on controls drafted by the assessing entity;
6. report of the independent assessor on the applied Common Safety Method (CSM) on risk evaluation and assessment in order to enable a safe integration of the structural subsystem in the existing system.

4. TECHNICAL CONFORMITY AND SAFE INTEGRATION OF STRUCTURAL SUBSYSTEMS

Before issuing an authorisation for placing in service of a structural subsystem the following issues shall be checked:

1. technical conformity of the structural subsystem with the system it is integrated with and
2. safe integration of the structural subsystem in its environment by application of the Common Safety Method (CSM) on risk evaluation and assessment.

Technical conformity of structural subsystems is one of the essential requirements which must be met by a railway system and it means that technical characteristics of fixed structural subsystems must comply with each other, as well as with technical characteristics of trains used within the railway system.

Technical conformity of structural subsystems with the system they are integrated with is obtained by ensuring their conformity with the applicable technical rules and standards.

Safe integration shall be proved by application of the CSM on risk evaluation and assessment, where the applicant shall:

1. refer to the applicable technical rules and standards, which is considered as „code of practice “ (the first principle of risk acceptance), in case they define interfaces between the concerned subsystem and the surrounding subsystems or
2. if that is not the case, the applicant shall make a comparison with a similar subsystem or make an explicit risk evaluation (second and third acceptance principle)

The correct application of the CSM on risk evaluation and assessment shall be assessed by an independent assessing entity.

5. APPLICATION FOR ISSUING OF AN AUTHORISATION FOR PLACING IN SERVICE

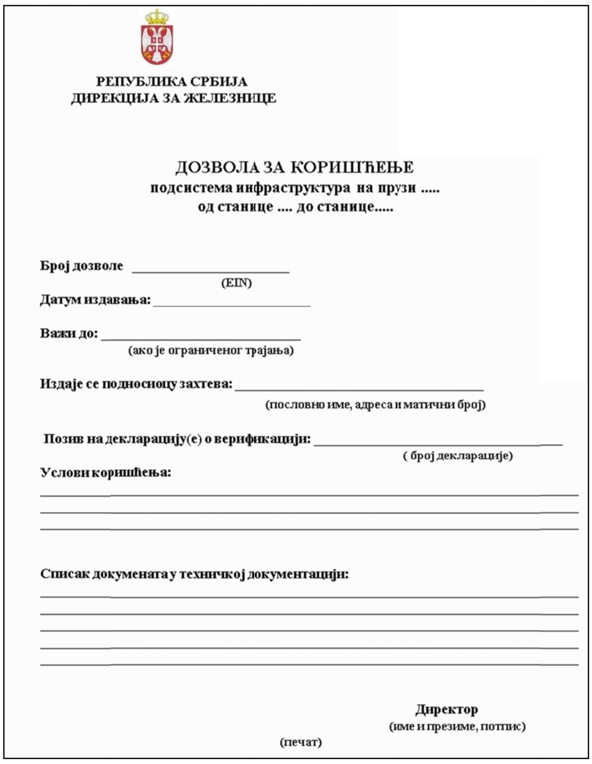
Application for issuing of an authorisation for placing in service shall include:

1) name of the authority the application is submitted to;
2) name, address, seat, TVA number and registration number of the applicant;
3) business register certificate;
4) subject matter of the application (title/short description of the subsystem, its location, etc);
5) name and address of the contracting entity or manufacturer of the subsystem and manufacturer of interoperability constituent and other elements of the subsystem;
6) in annex: declaration of verification of the subsystem including the accompanying technical documentation.

Technical documentation shall be submitted in at least two copies.

6. AUTHORISATION FOR PLACING IN SERVICE

Authorisation for placing in service shall be issued on the form [3] shown in figure 1.



РЕПУБЛИКА СРБИЈА
ДИРЕКЦИЈА ЗА ЖЕЛЕЗНИЦЕ

ДОЗВОЛА ЗА КОРИШЋЕЊЕ
подсистема инфраструктура на прузи .....
од станице .... до станице.....

Број дозволе ______________________
(EIN)
Датум издавања: ______________________

Важи до: ______________________
(ако је ограниченог трајања)

Издаје се подносиоцу захтева: ______________________
(пословно име, адреса и матични број)

Позив на декларацију(е) о верификацији: ______________________
(број декларације)
Услови коришћења:

Списак докумената у техничкој документацији:

Директор
(име и презиме, потпис)
(печат)

Fig.1. Form of the Authorisation for placing in service

7. STAGES OF THE AUTHORISATION FOR PLACING IN SERVICE

Figure 2 shows the stages of the authorisation for placing in service of the new railway line for international traffic with stations and tunnels. UTPs have not been applied in full because of open points and derogations, so national technical rules apply as well. This line consists of Infrastucture, CCS and Energy subsystem, each verified by NoBo (where UTPs apply) and by Directorate for railways (where national technical rules apply). In a given example, Directorate for railways acts as Designated body and as National safety authority.

8. CONCLUSION

The main difference, comparing to the previous procedure for issuing of authorisations for placing in service of structural subsystems, consists of introduction of the verification, that is, conformity assessment of structural subsystems with the requirements of the applicable technical rules carried out by the assessing entity and issuance of the corresponding conformity documents.

The Republic of Serbia still does not have a notified body to carry out the conformity assessment with the UTPs and, therefore, the applicants must engage a notified body from Europe.

According to the Article 17 of the Interoperability Directive, the conformity assessment with national technical rules shall be carried out by a body designated by the Member State. Following the implementation of that Directive in the Railway Safety and Interoperability Law, the Directorate for Railways has been designated as such a body. The reason for such a decision is the fact that, at the time of drafting of the law, the Republic of Serbia did not have a body for conformity assessment of any structural subsystem, appointed by the competent Minister in the railway sector, in accordance with the Law on Technical Requirements for Products and Conformity Assessment [4], and it still does not have one.

Applicant	Notified Body (NoBo)			Designated body (Directorate)	Directorate for railways (NSA)
	NoBo for INF	NoBo for CCS	NoBo for ENE		
Subsystem INF - design - production - final testing UTPs applied in full, except for open points and derogations **UTP + nat. declaration of verification**	Verification procedure for INF, conformity to: - UTP INF - UTP PRM - UTP SRT **UTP certificate of verification + technical file**			Verification procedure for INF, conformity to national technical rules **National certificate of verification + technical file**	
Subsystem CCS - design - production - final testing UTPs applied in full, except for open points and derogations **UTP + nat. declaration of verification**		Verification procedure for CCS, conformity to: - UTP CCS (track side) - UTP SRT **UTP certi-ficate of verification + technical file**		Verification procedure for CCS, conformity to national technical rules **National certificate of verification + technical file**	
Subsystem ENE - design - production - final testing UTPs applied in full, except for open points and derogations **UTP + nat. declaration of verification**			Verification procedure for ENE, усаглашено ст са: - UTP ENE - UTP SRT **UTP certi-ficate of verification + technical file**	Verification procedure for ENE, conformity to national technical rules **National certificate of verification + technical file**	
UTP + national declarations +Risk assessment report **Placing in service**					**Checking tech. comp-atibility and safe integration** **Authorisa-tion for placing in service**

Fig.2. Stages of the authorisation for placing in service [3]

REFERENCES

[1] Railway safety and interoperability law, 2013
[2] Convention concerning International Carriage by Rail (COTIF), 2006
[3] Directorate for Railways, Draft Rule book on issuing authorisation for placing in service of structural subsystems, interoperability constituents and other elements of structural subsystems, Beograd, 2014
[4] Law on technical requirements for products and conformity assessment, 2009

Vehicle and infrastructure maintenance

REPAIRING OF BROKEN LAMINATED SPRINGS OF FREIGHT WAGONS BY WELDING

Dragan PETROVIĆ [1]
Milan BIŽIĆ [2]

***Abstract** – The task of this paper is to explore the possibility of repairing broken laminated springs of freight wagons by welding. Previous studies have shown that fractures of laminated springs are very common, especially for freight wagons used in extreme operating conditions. One of the most economical ways to solve this problem is reparation by welding of the fractured leafs. In that case the question about the behaviours and characteristics of repaired laminated springs rises. The approach in this paper is based comparative experimental testing of repaired laminated springs and new laminated springs. The main aim is to determine the influence of welded leafs on the behaviours and characteristics of repaired laminated springs. The applied methodology is based on static and dynamic tests. The obtained results have shown that welding of leafs does not significantly affect behaviour and characteristics of repaired laminated springs. During the fatigue tests, the fracture in the heat affected zone of welded connection is not registered. As expected, the results also have shown that life-cycle of repaired laminated springs is slightly lower with regard to the new laminated springs. The final conclusion is that welding can be possible solution for reparation of broken laminated springs.*

Keywords – Repairing, broken, laminated springs, freight wagons, welding.

1. INTRODUCTION

The one of the main ways to increase the competitiveness of railway compared to other modes of transport is reducing of the maintenance costs. The failures on railway do not happen often, but when it happens, the consequence is usually derailment accompanied with enormous material damage and losses of human life. In addition, there is huge material loss caused by the interruption of the traffic and reparation of the infrastructure. In the process of resolving of failure consequences on the railway vehicles, two approaches can be applied. The first approach involves replacing the damaged element (subassembly or assembly) with the completely new element. The second approach involves repairing the damaged element and its restoring into the appropriate function in the vehicle. It should be noted that repair is not possible for some damaged elements of railway vehicles (e.g. broken axles or wheels), but for many parts it is an extraordinary way for an enormous reduction in maintenance costs. Of course, the quality of repaired elements must be satisfactory, and their reliability should be at least approximate to the reliability of completely new elements, in order to make this approach techno-economically justifiable.

One of the most important subassembly of each railway vehicle is suspension system. The problems of the suspension system have always been among the central problems in the field of railway engineering. They have been widely analyzed in the large number of literature, scientific publications and professional papers. The main objective of all these research is to identify the behavior and design of the suspension system with the aim of improving the existing performance [1]. The quality of suspension system is one of the most important parameters which determine the reliability, quiet running and running safety of railway vehicles. The fault of suspension system is very important topic that is the subject of many scientific papers [2, 3]. The aim of all these research was to indicate the potential problems and to give the motivation for improvements in existing or newly-designed solutions of suspension systems.

The fractures in the suspension system are very often, especially at freight wagons operating in extreme operating conditions. The suspension system

[1] Dragan PETROVIĆ, University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Dositejeva 19, 36000 Kraljevo, Serbia, petrovic.d@mfkv.kg.ac.rs
[2] Milan BIŽIĆ, University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Dositejeva 19, 36000 Kraljevo, Serbia, bizic.m@mfkv.kg.ac.rs; bizic.milan@gmail.com

of such wagons is usually based on the laminated springs. In most cases there is a failure of main leaf, and the problem is usually solved by replacing the entire laminated spring with completely new, or by changing the broken leaf with completely new leaf. As one of the best solutions to reduce the costs of maintenance, the welding of the fractured leafs is considered. This is a very complex issue as it is well known that spring steels are not suitable for welding. Also, the additional problem is experimental testing and proving the behaviours and characteristics of such repaired laminated springs. This is the motivation for the research presented in this paper. The study was conducted on the laminated springs of Fbd wagons used in railway transportation of coal from mining basin ''Kolubara'' to the thermal power plant ''Nikola Tesla'' in Obrenovac, Serbia. The transport of coal for many years is performed with about 400 Fbd wagons, made in Wagon factory Kraljevo (Serbia).

2. PROBLEM DEFINITION

The four-axled wagon Fbd consists of two two-axle units that are interconnected by joint connection. The gross wagon tonnage is 80 tons, and its purpose is to transport of coal. The wagon is primarily designed and adapted for efficient loading in the mining basin and unloading in the thermal power plant. For this reason, the design of wagon has specific solutions of body, underframe, and mechanisms for unloading. Numerous mechanisms for opening and closing the door in the floor have reduced the space for placing of elements of suspension system. Because of these specifics, the design of suspension system which is based on the laminated spring departs from the standard design solutions. Reducing the length of the laminated spring in relation to the standard solutions and very intense loadings in exploitation caused the increasing of stresses of elements of the suspension system. The steel limiter is fixed for the underframe of wagon and has the task to limit the stroke of laminated spring (Fig. 1).

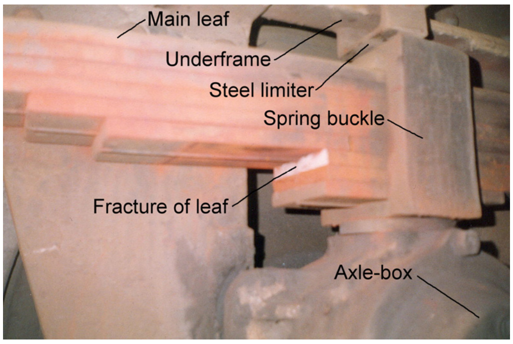


Fig.1. The example of laminated spring fracture

In extreme operating conditions at maximum loads there are intense dynamic rigid impacts of spring buckle in the steel limiter which is very unfavorable for the suspension system and the underframe of wagon. As a result there were very frequent fractures of elements of suspension system and cracks on the underframe. Statistical analysis shows that among the most dominant failures of the suspension system are fractures of elements of laminated springs [4]. Among them, the most common are fractures of leafs (as shown in Fig. 2), and especially of main leafs. The frequent fractures of leafs caused derailments in many cases [5]. The consequences were huge material damage and significant decreasing the efficiency of railway transportation of coal from mining basin to the thermal power plant.

The problem of fractures of laminated springs is usually solved by replacing the entire laminated spring with completely new, or by changing the broken leaf with completely new leaf. Because of frequent fractures, this required a huge funds for the maintenance and purchase of new leafs and laminated springs, which caused decreasing the efficiency and profitability of rail transport of coal. Research of these problems leads to the aim to reduce the enormous costs of maintenance of wagons and it is realized in two directions. The first direction was implied improving the suspension system through subsequently installation of rubber elastic element. This element is very easy to install in all existing wagons, between the laminated spring buckle and underframe [4]. The second direction was implied exploring the possibility for repairing the laminated springs by welding of fractured leafs. That is the topic of this paper, and its main task is to explore the influence of welded leafs on the behaviours and characteristics of repaired laminated springs.

3. EXPERIMENTAL RESEARCH

The basic idea of repairing of damaged laminated spring implies that its broken leaf is welded in the place of fracture, with the aim of preservation of overall designed geometry and function (Fig. 1).

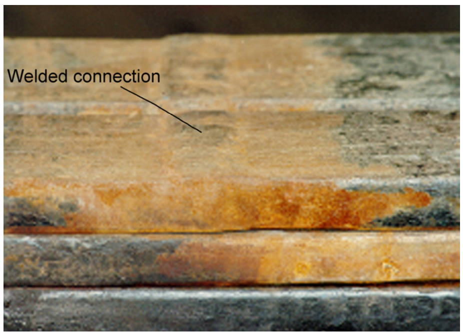


Fig.1. The welded connection of the main leaf

Research related to welding technology is realized by the company "Termoelektro" in Belgrade, Serbia. The technology is intellectual property of mentioned company, and it is not the focus of this paper. The main segments of welding technology are related to the physical, chemical, metallurgical and technological aspects of welding of broken leaf. The technology prescribes the election of welding electrodes, procedure for disassembling of laminated spring, preparation of surfaces for welding, procedure of welding, etc. Based on the projected welding technology, two characteristic laminated springs with fractured leafs in factories "Gibnjara" in Kraljevo and "Željvoz" in Smederevo, Serbia, are repaired. In the aim to explore their behaviors and characteristics, these laminated springs are subjected to the experimental tests.

The experimental tests were performed on pulsator, to the fracture of laminated springs, with prescribed amplitudes and frequency. For this purpose, the test stand for dynamic testing of production "MTS" was used (Fig. 3).

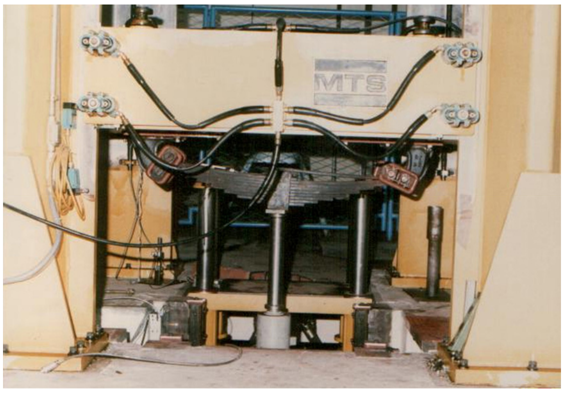


Fig.3. The dynamic testing of laminated springs on the test stand of MTS production

The comparative tests were performed on the following laminated springs:

- previously damaged laminated spring with welded main leaf repaired in a factory "Želvoz" in Smederevo (laminated spring 1),
- previously damaged laminated spring with welded main leaf repaired in a factory "Gibnjara" in Kraljevo (laminated spring 2),
- completely new laminated spring that is not welded (laminated spring 3).

Laminated springs with welded leafs (laminated spring 1 and laminated spring 2) were repaired in according to the prescribed welding technology from Chapter 3. The testing program is designed in accordance with applicable international UIC standards for testing the static and dynamic strength of springs. It included the following tests:

- testing the geometric accuracy,
- identification of static characteristics,
- dinamic fatigue testing to the fracture.

The number of cycles and the amplitudes of deflection of laminated springs are defined in the regulations, and are presented in Tab. 1. The frequency of change of deflection amplitudes is defined in the regulations, and is equal 2 Hz. In dynamic tests, it was necessary to define the static load of laminated spring around which the amplitude of the deflection oscillates.

Tab. 1. The prescribed number of cycles and the amplitude of deflection

Test	Num. of cycles	Amplitude of defl. [mm]
1	260000	12
2	1500	30
3	93000	15
4	2200	27
5	37000	18
6	6300	24
7	18500	21

Taking into account the gross wagon tonnage of 80 t, and subtracting the non-suspended mass of four wheelsets of approximately 6 t, the static load per one laminated spring should be about 9.25 t. However, the static load per one laminated spring was determined from the data of exploitation [5] and is Q_{st}=103 kN, which is about 10.3 t. This value is significantly higher (about 10 %) than the designed static load of one laminated spring with a fully laden wagon. Overloading of laminated springs during the exploitation is caused by uneven distribution of load on the wheels during the filling of wagons with coal. Given in mind the increased static load of 103 kN, it can be expected to obtain a lower life-cycle for all three tested laminated springs, compared to the values given in Table 1. In addition, the amplitude is also increased in relation to the prescribed. The aim of research in this phase was primarily to lead laminated springs to the fracture, and to determine if the fracture occurs in the heat affected zone of welded connection. Thus, the dynamic tests were performed with the static load of 103 kN and the amplitude 15 mm, with the frequency of 2 Hz.

4. RESULTS

In the first step, according to the prescribed testing program, the geometric accuracy of all three laminated springs was tested. It is concluded that it is within the prescribed limits. In the second step, the static characteristics of laminated springs 1, 2, and 3 were tested. It is concluded that deviation of static characteristics of laminated springs with welded leafs (laminated springs 1 and 2) from the static characteristic of not welded laminated spring 3, is less than 1%. Of course, a similar deviation should be obtained in the case of all three laminated springs whose leafs are not welded. Based on that, it can be concluded that all three tested laminated springs have almost identically static characteristic. The diagram of static characteristic of laminated springs is shown in Fig. 4. The results obtained by the experimental fatigue tests of laminated springs are shown in Tab. 2.

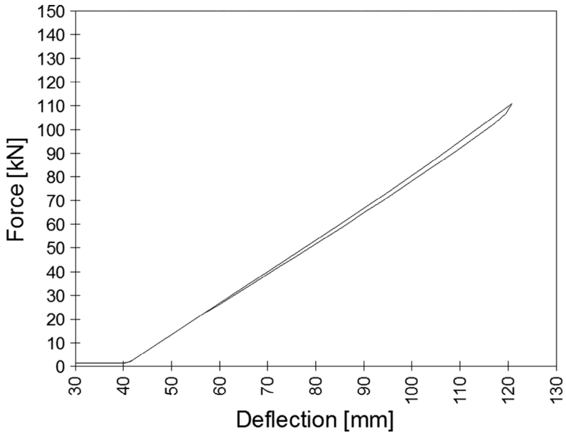


Fig. 4. The static characteristic of laminated springs

Tab. 2. The number of cycles until the fractures

Lam. spring	Num. of cycles	Remark
1	161820	Fracture of main leaf
2	92820	Fracture of third and fourth spring leafs viewed from below
3	216240	Fracture of main leaf

In the case of laminated spring 1, 161820 cycles were achieved to the occurrence of fracture of main leaf. In the case of laminated spring 2, 92820 cycles were achieved to the occurrence of fracture of third and fourth leafs viewed from below. At the end, in the case of laminated spring 3, 216240 cycles were achieved to the occurrence of fracture of main leaf. In experimental tests of both laminated springs with welded leafs it was concluded that fracture did not occurred in the zone of welded connection or heat affected zone. These extremely important results are shown in Figs. 5 and 6.

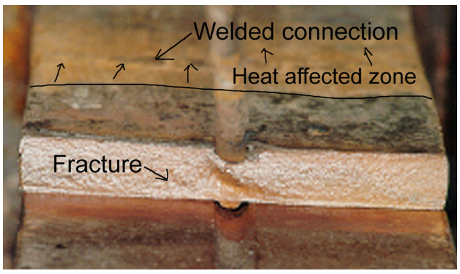


Fig. 5. The fracture of laminated spring 1

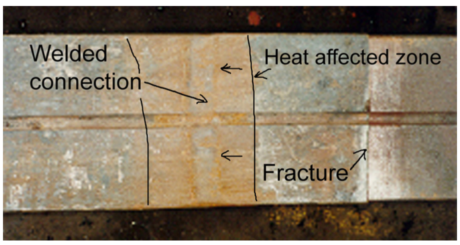


Fig. 6. The fracture of laminated spring 2

As expected, it was concluded that in these fatigue tests have not reached the expected lifetime of the laminated springs. The reasons for this lie primarily in the inadequate quality of embedded material, as well as in the increasing of static stress during the exploitation and in the aforementioned experimental tests. Poor quality of material is caused by the presence of chemical impurities, as already noted in previous researches [5], with the aim of solving the problem of frequent failure on the suspension system of Fbd wagons.

5. CONCLUSION

It can be concluded that welding can be possible solution for reparation of broken laminated springs. Repairing of broken leafs of damaged laminated springs by welding can allow to restore these laminated springs into exploitation. The welding does not affect the behaviours and characteristics of laminated springs. More precisely, behaviours and characteristics of repaired laminated springs almost completely satisfy the demands of the design and exploitation. Of course, in this statement should be taken into account that these laminated springs are already used and that their life-cycle is slightly lower compared to the completely new laminated springs. Therefore, in consideration of application of this solution in practice, it is necessary to conduct techno-economic analysis of its feasibility in specific case. However, practical application of this solution in Fbd wagons for coal transportation in thermal power plant "Nikola Tesla" in Obrenovac, Serbia, has enabled the enormous reduction of costs of maintenance of these wagons. This has enormously increased the efficiency of railway transportation of coal from mining basin to the thermal power plant.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Serbian Ministry of Science and Technology for supporting this paper through project TR35038.

REFERENCES

[1] Garg V K, Dukkipati R V. *Dynamics of Railway Vehicle Systems*. New York: Academic Press, 1984.

[2] Huichuan Fan, Xiukun Wei, Limin Jia, Yong Qin. *Fault detection of railway vehicle suspension systems*. Computer Science and Education (ICCSE), 5th Int. Conference on Computer Science and Education, 2010, 1264–1269.

[3] Hayashi Yusuke, Tsunashima Hitoshi, Marumo Yoshitaka. *Fault Detection of Railway Vehicle Suspension Systems Using Multiple-Model Approach*. Journal of Mechanical Systems for Transportation and Logistics, 2008, Vol. 1, Iss. 1, 88–99.

[4] Petrović D, Bižić M. *Improvement of suspension system of Fbd wagons for coal transportation*. Engineering Failure Analysis, 2012, Volume 25: 89 – 96.

[5] *Identification of the causes of the fractures of main leafs of laminated springs on the Fbd wagon*. Study, Test Center of Wagon Factory Kraljevo; 1983. [in Serbian]

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

DATABASE TO SUPPORT OPTIMIZATION OF ROLLING STOCK MAINTENANCE IN SERBIAN RAILWAYS

Slađana JANKOVIĆ [1]
Života ĐORĐEVIĆ[2]
Irina BRANOVIĆ[3]
Snježana RAJILIĆ[4]
Slavko VESKOVIĆ [5]

Abstract *– Timely detection of technical irregularities and avoiding subsequent damage to rolling stock vehicles offers many advantages in daily railway transport: increased security, avoiding traffic disturbances, reducing expenses due to avoiding accidents, extension of revision and wagon maintenance deadlines, optimization of rolling stock maintenance. The first step in the process of monitoring and optimizing rolling stock maintenance procedures is to install the checkpoints for dynamic control of wagons' technical state. The second step is to process and analyze data collected from monitoring equipment. In this work we describe the database developed for the purpose of storing and analyzing data collected from the measuring equipment. The information system consists of a relational database, numerous queries, forms, and reports. Generated queries, forms and reports in the IS can provide useful input parameters for the process of optimizing maintenance of railway stock.*

Keywords – Rolling stock, dynamic monitoring, measuring equipment, database, maintenance.

1. INTRODUCTION

Regular and safe functioning of railway transport depends on flawless organization, but also on the technical state of rolling stock and infrastructure. Besides increasing safety level and avoiding traffic disturbances, an important contributing factor for decreasing total transportation expenses is timely maintenance of railway stock. Transport cost is decreased by avoiding traffic accidents, delaying wagon revision and maintenance deadlines, and optimizing rolling stock maintenance. For these reasons Serbian railways decided to install measuring stations for dynamic control of rolling stock technical state. Such a system should enable detection of overheated axle bearings, flat surfaces on rolling wheels' garland points, excess weight by axle, excess of loading gauge railway vehicles etc. Measuring stations should integrate measuring equipment and automatic control of aforementioned variables. Measuring are expected to be done on the track, during train operation.

In this paper we describe the development of database to store information collected from the measuring checkpoints. Besides organizing collected information, the database allows for generating numerous useful queries. Continuous monitoring of source data from measuring stations and analyzing results of predefined queries are expected to contribute to optimization of rolling stock maintenance.

The remaining sections of the paper are organized as follows: the second section describes devices and measuring equipment integrated into measuring checkpoints, and details the way they operate. The third section details the design and structure of the database, with description of some queries that can be generated over it. We conclude with the analysis of possibilities and benefits of using developed database.

2. DIAGNOSTIC SYSTEM OF BATAJNICA MEASUREMENT STATION

The pilot project, measurement checkpoint **Batajnica**, contains devices for detecting overheated bearings of axle boxes and locked brakes with label TK99, as well as devices for dynamic measurement of train weight and detection of flat surfaces of garland

[1] Slađana JANKOVIĆ, Faculty of Traffic and Transportation, University of Belgrade, s.jankovic@sf.bg.ac.rs
[2] Života ĐORĐEVIĆ, Serbian Railways, zivota.djordjevic@srbrail.rs
[3] Irina BRANOVIĆ, IEEE Member, ibranovic@ieee.org
[4] Snježana RAJILIĆ, Municipal Novi Grad, snjayana_rajilic@yahoo.com
[5] Slavko VESKOVIĆ, Faculty of Traffic and Transportation, University of Belgrade, veskos@sf.bg.ac.rs

points (dynamic balance) G-2000. [1]. Measurement checkpoint is installed on the left side of the double track railway line *Beograd-Šid* at km 22+908. Checkpoint has an internal part (module 1), and an external part which is integrated into the track (modules 2, 3, 4 and 5), as illustrated in Figure 1.

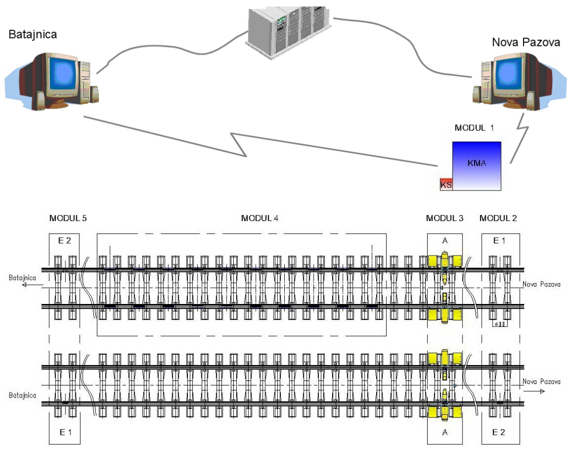


Fig.1. The scheme of the Batajnica measurement checkpoint

The internal part of Batajnica measurement checkpoint for dynamic control of technical state of rolling stock has an electronic equipment rack for management, industrial personal PC for processing of measurement data, modem to forward data to a remote user, and a module for uninterruptible power supply.

Modules 2 and 5 are identical, and have a sensoring device for counting wheels - axle boxes **RSR180** (segments E1 and E2 in Figure 1).

Module 3 contains devices for detecting overheated bearings of axle boxes and locked brakes labelled **TK99** [2] and is installed on both tracks, it also contains central sensor for counting wheels – axle boxes RSR180 (Figure 2). Function of the central sensor for counting wheels - axle boxes (labelled with the letter A on Figures 1 and 2) is to activate the device for detecting overheated bearings of axle boxes and locked brakes, to read and store measured data in a given moment.

TK99 device registers temperature of the case of axle bearing boxes, by applying sensors installed at the left-hand and the right-hand side of the track (*NOA*); wheel's part, by applying sensors installed within the track (*FOA*) and brake disk, by applying sensors installed within the track (*SOA*).

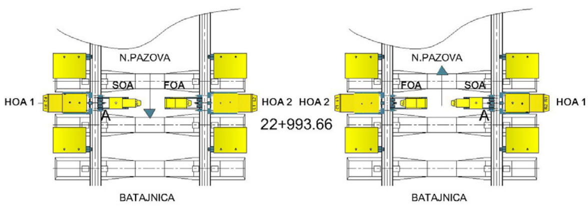


Fig. 2: Module 3 of the Batajnica measurement checkpoint

Module 4 contains G-2000 device for detecting and registering flat surfaces on a wheel [3]. Measuring tape, as well as sensors, are central elements that measure deflection of the rail due to the force by which the wheel sits on the rail [5]. Sensors are installed on the track, between railway sleepers, at axle distance of 1.2m. The total of 10 pairs of sensors are installed on the track. A computer connected to measuring tapes, receives measurement data when the train crosses the measurement checkpoint; the appropriate software detects flat surfaces and calculates axle loads of every wheel of the axle boxes. Cables which connect sensors of the device for detecting and registering flat surfaces on a wheel are installed on the external side of the track to the point where a device TK99 for detecting overheated bearings of the axle boxes and locked brakes is situated. From this point onwards, the cables are put inside plastic protective pipes, and forwarder below gravel to a cable chamber and the internal part of the measurement checkpoint.

Batajnica measurement checkpoint is equipped with an industrial PC whose purpose is to store, process, and display information collected from measurement devices. To display measured data and to report on irregularities, a Windows application paired with the equipment and developed by the manufacturer of the equipment is used. For every train crossing the measurement checkpoint data collected from different measurement devices are displayed [1]. When an irregularity in train crossing the measurement checkpoint is detected, the application emits the sound alarm and visually displays registered irregularities. In such a way, the functioning of the measurement checkpoint directly contributes to increasing security level of railway traffic on the line no 5. However, the existing application does not allow generating new queries over measured data; for optimization, a periodic more complex analysis of data measured on the checkpoint should be enabled [4]. Since the existing application does not allow for such data analysis, in this paper we describe the design and application of such a database. In the future, this database could be also used for accepting an processing information collected from different measuring checkpoints.

2.1 Database structure

The basic principle when designing a database was to accurately and consistently model the measurement checkpoint and physical properties it measures on one side, while at the same time enable development of new queries, if needed. Based on information already displayed by the existing Windows application, we developed a relational data model, and subsequently formed a relational database SERBIAN RAILWAYS ROLLING STOCK DIAGNOSTICS. Database is created by using relational DBMS Microsoft Access 2013; entity-relationship diagram of the database is illustrated in Figure 3.

The basic entities of the relational data model are: railway, device, measurement equipment, train, and alarm. Given the fact that different measurement equipment generates different information about the train that is crossing over it, a real-world train entity can be modelled by two relational entities: TRAIN and TRAIN – GRD. Similarly, the real-world alarm entity (irregularity warnings)can be modelled by as many as three relational entities: *ALARM*, *ALARM – GRD* and *ALARM – GRD – FLAT SPOTS*. The mentioned entities model different types of alarms, generated by different devices. Following are descriptions of database table structures, that illustrate mentioned differences between similar entities.

RAILWAY entity models the real-word entity of the same name from the Serbian railway network. Its purpose is to enable the analysis of the registered irregularities of the technical state of the rolling stock from the viewpoint of the railway in which the irregularity was discovered. Basic attributes of this entity are: railway number and railway name, the same used by Serbian railways.

DEVICE entity models different device types found on the track. Devices contain different measurement equipment and allow for measuring certain parameters of the rolling stock' technical state. This table serves for analyzing registered irregularities of the rolling stock technical state from track and kilometer position viewpoint on the track where the irregularity was discovered. Such analysis could identify track sections on which irregularities are registeres more frequently respect to the others, if such sections exist.

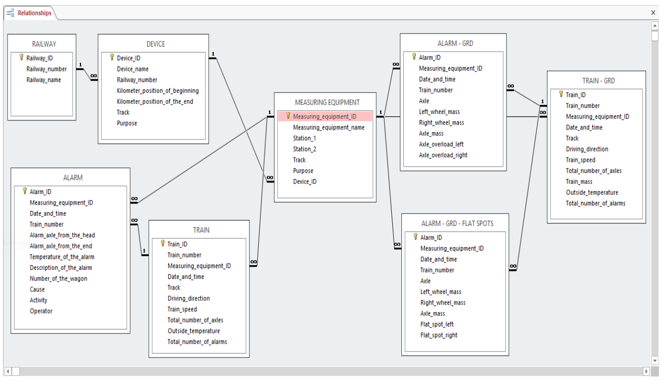


Fig. 3: Entity-relationship diagram of the SR rolling stock diagnostics database

MEASURING EQUPMENT entity models different types of measuring equipment, such as:

Equipment for detecting overheated bearings of axle boxes (*HOA*), which measures temperature of axle boxes bearings;

Equipment for detecting of locking of axle boxes in breaking (*FOA*), which measures the temperature of the wheel body 2 cm above upper level of the rail;

Equipment for detecting overheated disk brakes (*SOA*), which measures the temperature of disk brakes;

Equipment for detecting car and axle weight (*GRD*), which measures the force that wheel acts on the rail on the rail-wheel contact and detects flat spots on wheel, if there are such.

Train entity models trains which cross over measuring equipment for overheating detection (HOA, FOA, SOA). Important attributes of this entity are: number, date and time of the train, track, driving direction, train speed, and outside temperature. *TRAIN – GRD* entity models trains which cross over equipment for measuring car and axle weight and identifying flat spots on the wheel, if there are such (GRD). *TRAIN – GRD* entity has the entity total train weight, which is missing in the entity *TRAIN*.

Alarm axle is the ordinal number of the axle where the irregular temperature was measured; temperature of the alarm is the measured temperature of axle box bearings, wheel or disk brake which activated the alarm. The alarm description attribute specifies the type of measurement: HOA, FOA or SOA, and the type of overheating: warm or hot. Every instance of the *ALARM* entity is related to a single instance of the *TRAIN* entity, and a single instance of *MEASURING EQUIPMENT* entity, so that for every warning we know the train that caused it and the measuring equipment which measured the irregular values.

ALARM – GRD entity models alarms, i.e. warnings generated by measurements of axle loads. The important attributes of this entity are: date and time, axle, left wheel mass, right wheel mass, axle mass, axle overload left and axle overload right. Every instance of *ALARM – GRD* entity is related to a single instance of the *TRAIN – GRD* entity and a single instance of the *MEASURING EQUIPMENT* entity. *ALARM – GRD – FLAT SPOTS* entity models alarms – warnings, generated by detection of flat spots on wheels. The important attributes of this entity are: date and time, axle, flat spot left and flat spot right. Every instance of the *ALARM – GRD – FLAT SPOTS* entity is related to a single instance of the *TRAIN – GRD* entity and a single instance of the *MEASURING EQUIPMENT* entity.

2.2 Predefined Database Queries

Purpose of the *SERBIAN RAILWAYS ROLLING STOCK DIAGNOSTICS* database is to make data collected from measuring checkpoints available for further use and processing. The usefulness of this database becomes clear only when queries over it are generated. Figures 4 to 7 illustrate the result of execution of four selected queries over this database: generating the list of all measurement devices, grouped by railways and tracks, creating the list of all alarms caused by different types of overheating of axle boxes, displaying the list of all trains detected by the device for measuring axle loads, and generating the list of all alarms grouped by the alarm type and cars where alarms are detected. The total number of queries generated is unlimited: queries can be added, modified, and deleted according to current needs.

Devices for diagnostics of rolling stock

Railway_number	Track	Device_name	Kilometer_position_of_beginning	Kilometer_position_of_the_end	Purpose
5	1	E2-TK99	22+951,66	22+951,66	Device for detection of overheated axle bearing and blocked brake
5	1	G-2000	22+979,86	22+990,66	Device for detection of overloaded wheels and flat spots
5	1	A-RSR180	22+993,66	22+993,66	The device of axle counters
5	1	E1-TK99	23+035,66	23+035,66	Device for detection of overheated axle bearing and blocked brake
5	2	E1-TK99	22+951,66	22+951,66	Device for detection of overheated axle bearing and blocked brake
5	2	A-RSR180	22+993,66	22+993,66	The device of axle counters
5	2	E2-TK99	23+035,66	23+035,66	Device for detection of overheated axle bearing and blocked brake

Record: 1 of 7 No Filter Search

Fig. 4: Result of the query Devices for diagnostics of rolling stock

List of alarms

Measuring_equipment_name	Train_	Track	Driving_direction	Alarm_axle_from_the_head	Alarm_axle_from_the_end	Temperature	Description_of_the_alarm
Batajnica 1	125	1	2	4	7	213	HOA - the difference in temperature - right
Batajnica 1	125	1	2	6	5	267	HOA - the difference in temperature - left
Batajnica 1	126	1	2	6	19	215	HOA - the difference in temperature - left
Batajnica 1	126	1	2	8	17	243	HOA - the difference in temperature - left
Batajnica 3	129	1	2	14	11	209	SOA - overheat
Batajnica 3	129	1	2	10	15	256	SOA - overheat
Batajnica 3	129	1	2	12	13	224	SOA - overheat

Record: 1 of 7 No Filter Search

Fig. 5: Result of the query List of alarms

List of trains - GRD

Railway	Device	Measuring_	Train_numb	Date_and_time	Track	Driving_direction	Train_speed	Total_number_of_axles	Train_mass	Total_number_of_alarms
5	G-2000	102	125	12.10.2012. 11:00:09	1	2	115	10	98,56	0
5	G-2000	102	126	12.10.2012. 10:56:59	1	2	116	24	221,58	1
5	G-2000	102	127	12.10.2012. 10:52:37	1	2	98	72	906,56	1
5	G-2000	102	128	12.10.2012. 10:54:21	1	2	129	10	125,78	1
5	G-2000	102	129	12.10.2012. 10:39:12	1	2	129	24	320,15	0
5	G-2000	102	130	12.10.2012. 10:26:39	1	2	78	72	889,14	1

Record: 1 of 6 No Filter Search

Fig. 6: Result of the query List of trains – GRD

List of alarms by type and number of wagons

Description_of_the_alarm	Number_of_the_wagon	Date_and_time	Train_number	Temperature_of_the_alarm
HOA - the difference in temperature - left	50 80 2173 225 1	23.11.2012. 10:50:13	1	267
HOA - the difference in temperature - left	50 80 2173 225 1	28.10.2012. 10:58:45	2	235
HOA - the difference in temperature - left	50 80 2173 225 1	12.10.2012. 10:56:39	2	243
HOA - the difference in temperature - left	50 80 2134 234 3	30.10.2012. 10:54:23	2	215
HOA - the difference in temperature - left	50 80 2134 234 3	29.10.2012. 10:55:45	2	222
HOA - the difference in temperature - right	50 80 2173 225 1	12.11.2012. 10:54:12	1	213
SOA - overheat	50 81 2312 124 2	25.10.2012. 10:13:23	5	256
SOA - overheat	50 81 2312 124 2	23.10.2012. 10:15:24	5	209
SOA - overheat	50 81 2312 124 2	12.10.2012. 10:17:50	5	224

Record: 1 of 9 No Filter Search

Fig. 7: Result of the query List of alarms by type and number of wagons

Total number of alarms by type and number of wagons

Alarm description	Number of wagon	Total number of alarms
HOA - the difference in temperat	50 80 2134 234 3	2
	50 80 2173 225 1	3
HOA - the difference in temperat	50 80 2173 225 1	1
SOA - overheat	50 81 2312 124 2	3

Fig. 8: Total number of alarms by type and number of wagons: a report

Many reports and forms are also generated over this database, and these can be modified according to current needs. Reports are a very powerful tool for grouping and sorting records, as well as displaying selected data in a printer-friendly manner. Report in Figure 8 displays the total number of alarms of a certain type and for a certain wagon number. The report from Figure 8 allows for easy identification of cars with the highest number of alarms. For every car, the report displays all related alarms, with information on date and time of the alarm, train number and alarm temperature. Alarm temperature refers to the temperature of a certain part of the axle boxes on which the irregularity is registered.

3. CONCLUSION

Installation of measuring checkpoints for dynamic control of rolling stock technical state will increase reliability level and quality of service. Serbian railways will become a part of modern European transportation system, and Batajnica measuring checkpoint is one of the first efforts in this direction. Preliminary results show that the new system is able to identify 75% of the causes for excluding cars from the Serbian railway traffic [1]. Presented database allows for multicriteria analysis of railways rolling stock technical state. Using database queries, reports and charts does not require any particular informatics knowledge; moreover, the fact that it is designed in widely used MS Access DBMS (a part of MS Office package) means that it does not require new licenses and software installations. The next logical step for extending this work will be to design an application as a front-end interface to a database.

ACKNOWLEDGEMENT

This work has been supported by research project TR 36012, funded by the Ministry of Science and Technological Development of Serbia.

REFERENCES

[1] Karner, J., Maly, T., Schöbel, A., *TK99 - the Austrian solution for hot box detection*, Proceedings of XIII Scientific-Expert Conference on Railways, pp. 57-60, 09-10 October 2008, Niš.

[2] Đorđević, Ž., Karner, J., Schöbel, A., Mirković, S., *Batajnica checkpoint for wayside train monitoring*, Proceedings of XIV Scientific-Expert Conference on Railways, pp. 189-192, 07-08 October 2010, Niš.

[3] LeDosquet, G., Pawellek, F., Müller-Boruttau, F., Lasca: *Automatic monitoring of the running quality of railway vehicles*, RTR No. 2, 2007, pp. 34-39.

[4] Radosavljević, A., Đorđević, Ž., Mirković, S., *Concept for Wayside Train Monitoring At Serbian Railways - Pilot Project Batajnica*, RTR Special, 2011, pp. 6-11.

[5] Schöbel, A., Karner, J., *Components for wayside train observation in Austria*, Proceedings of XII Scientific-Expert Conference on Railways, pp. 25-27, 19-20 October 2006, Niš.

FIRST RESULTS OF THE CHANGE OF THE CRITERIA FOR REGULAR REPAIRS OF SERIES 441 TRACTION VEHICLES

Dragan B. RAJKOVIĆ [1]

Abstract *– During 2012 and 2013, locomotives from the series 441 (and series 461 and 444) were, according to the kilometer criterion, supposed to be withdrawn from traffick. By the Decision of the Executive Board of Serbian Railways JSC, tentative extension of running interval for 200000 km was performed. After two years of locomotives follow up, number of defects on 100000 km, that have occurred at the time of running of the extension of interval for regular repairs. First three out of five locomotives from the series 441 in which the extension of running interval was applied also run the kilometer that was added to the initial interval and tolerance. Comparison of the number of defects on 100000 km for series 441has been made, as well as the analysis of defects, comment of the defect trend and comparison of the mean of defects for the series for the period of last 10 years. Series 461 and 444 have been analised too.*

Keywords – Interval for regular repairs, Regulation book 241, locomotive series 441.

1. INTRODUCTION

Executive Board of SERBIAN RAILWAYS JSC made a Decision on change of interval for exploitation of traction vehicles after the expiration of kilometer criterion defined in Regulation book 241, in order to check condition of parts, joints of devices and vehicle's aggregate regarding wear-out and damages, with an aim to change intervals of certain types of regular maintenance. The Decision has been made based on provisions of the Article 5 of Regulation book 241, which envisage that:

1. Systemic examinations and controls should be performed in order to determine condition of the parts, joints, devices and aggregates regarding wear-out and damages, as well as because of replacement of that condition with time. These examinations and controls enable obtaining certain data used to determine cycles and intervals for performing follow up examinations and regular repairs.
2. Examinations and controls are organized by Railroad transport organizations and Association of YR, in cooperation with workshops responsible for the maintenance of vehicles in question, when needed, and especially on the occasion of:
   - performing first regular repairs on the new type of vehicle for YR,
   - determining new follow up examination or new regular repair,
   - change of intervals for some types of regular maintenance,
   - change of existing scope of works for certain types of regular maintenance.

1.1 Object of maintenance interval change

Reached Decision referred to series of traction vehicles 441, 444, 461, 661, 644, 666, 812/814 and 710. In this paper we will only speak about series 441 and only mention series 444 and 461 in review.

Intervals for maintenance of series 441 and 461 are defined by Regulation book 241 (medium repair/main repair) 600000/1200000±15% km for all vehicles of this series which were not modified according to the modification program, and 80000/1600000±15% km on vehicles on which modifications were performed according to the modification program, and series 444 had maintenance intervals 1000000±15% km.

New intervals for performing, according to the decision of the Executive Board of ZELEZNICE SRBIJE JSC have been change so that intervals are increased for 200000 km.

1.2 Manner of locomotive follow up

Five locomotives from each series have been selected for tentative extension. Locomotives that were selected were the ones which were close to the end of eligible kilometer limit with tolerance. Locomotives with numbers 701, 702, 704, 312, 522 were selected from the series 441. From series 461 locomotives with numbers 006, 002, 139, 153, 122

[1] Dragan B. RAJKOVIĆ, Dipl.ing maš. Novi Sad, Drage Spasić 8, draganbrajkovic@gmail.com

were selected, and from series 444 locomotives with numbers 001, 003, 008, 016, 030. Task of the follow up was assigned to a committee composed of proficient mechanical and electrical engineers. Follow up process consisted of the following: exmaination of the locomotive by the committee, making a protocoll about the condition of the locomotive at examination, follow up of locomotives during the exploitation and after the fulfilment of kilometer criterion of all locomotives from the series, analysis of locomotive behaviour in the period of extension by number of defects per 100000 km and making a stand about successfulness or unsuccessfulness of the locomotives. For the comparison of reliability, number of defects per 100000 km has been adopted, which is a data monitored in the Sector for the traction of trains, as exploitation figure.

Examination by the committee was performed at the time when the locomotive had higher rank control examination. Following the committee's examination of the locomotive the committee made a protocol which contained a condition that in order for the extension to be given works that are necessary for each of the locomotives have to be executed. Together with the protocol, measurement list attestation of tachometer, diagram of the break, lists of control examinations with pertaining measurement list were submitted. During the follow up of locomotives there was a damage to a locomotive, so the locomotive 441 – 312 was excluded from the follow up and instead an extension was made for the locomotives 441-706.

2. RESULTS OF THE FOLLOW UP

First locomotive from the series 441 was examined on 19.03.2012, and it was locomotive 441 – 704. Table 1 shows date of extension, rank of the control examination, total number of crossed kilometers since putting in traffic until the examination, and kilometers crossed from the regular repair (RR) until examination.

Table 1. Dates, examinations, kilometers total and since RR

Locomotive	Date of extension	Examination	Total km	Km at examination
441-522	19.06.12	P3	4124284	918302
441-701	06.06.12	P3	4228280	917096
441-702	30.05.12	P3	4020026	918207
441-704	19.03.12	P 12	3963529	920038
441-706	06.08.13	P12	4198710	920897

Until 30.05.2014, and since the date of extension, locomotives 441 – 701, 441 – 702, 441 – 704 reached kilometer limit, and according to the assessment remaining two have less than a year before they reach it. Table 2 shows data from exploitation significant for evaluating the behavior of the locomotives in the time of extended kilometer limitation.

Table 2. Crossed km since RR, extended km, total number of defects in extension

Locomotives	Passed km od RO	Extended km	Total no of defects
441-522	1092617	174315	22
441-701	1161579	244409	8
441-702	1158983	240776	14
441-704	1164993	237055	38
441-706	1050574	129677	3
Total	5628746	1026232	85

For series 441, from the total number of defects and total of crossed kilometers (for locomotives whose limit according to kilometer criterion was extended) number of defects per 100000 km is **8,28**. The following Table 3 shows number of defects per year, since the last regular repair for locomotives in question and number of defects per 100000 km for the whole series 441 and number of defects per 100000 km in extension.

Table 3. Number of defects per year since last regular repair

Locomotives	Date RR	2005	2006	2007	2008	2009	2010	2011	2012	2013	Ext.
441-522	10.2005	14,8	10,1	15,0	16,0	19,5	10.6	10.7	13.4	13.5	12,6
441-701	02.2007	-	-	3.7	10.7	4.7	2.9	7.9	5.8	4.9	3,2
441-702	02.2007	-	-	4.3	2.7	6.1	9.7	4.9	8.4	4.6	5,8
441-704	02.2007	-	-	10.4	4.6	9.8	13.6	9.2	12.4	15.7	16,0
441-706	03.2007	-	-	9.3	7.7	18.6	11.7	2.9	12.9	3.5	2,3
For series	-	13.4	11.7	11.7	12.5	12.7	11.5	10.0	13.1	10.6	8.3

3. COMMENTS OF THE RESULTS

For locomotives that have met the additional kilometer limit (701, 702, 704), data given in the table show that these three locomotives are in the average of the selected five, and with smaller number of defects per 100000 km for the whole series of 441 per year.

Table 4. Exploitation data of locomotives per extended kilometer

Locomotive	Crossed km	No of defects	No of def. per 10^5 km
441-701	244409	8	3,3
441-702	240776	14	5,8
441-704	237055	38	16,0
Total	722240	60	8,3

Analyzing the number of defects per 100000 km by locomotive and by years in which the locomotive is in exploitation, it can be deduced that there is no steadiness, nor that any kind of rules can be established, since the locomotive has 18,6 per 100000 km defects in one year and 3,5 in another and that after four years later spent in exploitation (441-706).

Reasons for these events can be several. The first reason is maintenance of locomotives in several depots. Depots don't have information that the damage has occurred and that the damage actually repeats and that the approach to it should be changed. Change in the approach means that if the damage repeats, one should approach it more seriously since the damage occurs for several reasons, while only one is being remedied, the one that is first identified. If the damage is not remedied with special attention, it is eliminated for a short time and repeats, several times, which diminishes locomotive's reliability, increases the number of defects per 100000 km and increases immobilization (time spent out of exploitation i.e. out of traffic). Second reason is performing regular repairs at various repair shops which don't have same approach and the same technology when performing regular repairs, although the contracted scope of works is the same with all repair shops. Third reason is lack of spare parts in the process of regular maintenance, so the locomotives are being repaired by building in low quality parts or the parts are removed from locomotives that are removed from the traffic because they reached all limits for being sent for regular repair (those parts are battered and are actually in new deadline for repair but have not been repaired).

Table 5 shows values of the number of defects per 100000 km for the last 10 years, for the comparison of the reliability of the series 444 and 461.

Table 5.Number of defects per 100000 km

Series	2004	2005	2006	2007	2008
444	-	4,2	2,0	2,1	1,84
461	22,7	21,0	18,1	16,4	15,8
461 200	-	10,9	12,6	7,5	6,0
Series	2009	2010	2011	2012	2013
444	2,9	3,4	3,3	5,1	4,3
461	18,8	20,7	19,8	24,7	19.5
461 200	6,3	10,7	8,8	10,5	7,6

Regarding the results about the number of defects per 100000 km for the locomotives for which limit for regular repair is extended for 200000 km, from the series 444 and 461, situation is similar. Situation is better with series 444 than for series 441, while it is worse for series 461 than for series 441, but situation is the same even when locomotives are within regular limits for repair. From the locomotives from the series 444, locomotives 008 (1383195 km) and 016 (1383975 km) run the extension of 200000 km + 15%. There are no data for series 444 and 461200 for the year 2004, since the locomotives were put in use in 2005.

4. CONCLUSION

Based on the results presented in this paper, which are not final, it can be said with certainty that the trend will not change. For the remaining two locomotives, they need to cross approximately 150000 km and if in that time they make 30 defects, which is not likely, number of defects per 100000 km for the series 441 will be less than 9, which is better than the average for the whole series 441 in the last 10 years. The fact that the number of defects per 100000 km is smaller than the total for the whole series can be justified by the fact that locomotives from the sub-series 700 are of better quality than other sub-series, even though they crossed approximately 4000000 km and that the last regular repair in the repair shop was done better than in other repair shops. It is important to note that in neither of the series 441, 461 and 444 there was no increase in the number of defects per 100000 km, which shows that increased number of crossed kilometers has no significant influence on the reliability of the locomotives. Despite the problems that occur in the maintenance because of the organization, lack of spare parts and lack of money for the procurement of all materials needed in the maintenance of locomotives, increase of the kilometer limit between two repairs is justified, but care should be taken regarding the quality of the repair shop who should perform the next regular repair. During the running time of the locomotives whose limit for regular repair has been increase for 200000 km, one regular repair has been saved (appr. 240000 EUR), since five locomotives crossed 1026232 km and when tentative extension is finished that will be more than one limit for one locomotive for which the limit is extended (1150000 km).

Final conclusion is that the tentative extension was successful and that results are such that the limit for regular repair can be extended for 200000 km.

REFERENCES

[1] Dragan B. Rajković, Određivanje roka redovnih opravki za vučna vozila, IV Međunarodni simpozijum NOVI HORIZONTI SAOBRAĆAJA I KOMUNIKACIJA, Doboj, 22. i 23. novembar 2013. godine (strane 265-269)r.

[2] Dragan B. Rajković, Promena kriterijuma za redovne opravke vučnih vozila serije 441, PROCEEDINGS (Zbornik radova) XV ŽELKON '12,Niš, 04-05.oktobar 2012(strane 161-163)

[3] ZJŽ Pravilnik 241, Beograd ,1983.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

METHODOLOGIES OF EXPERIMENTAL DETERMINATION OF WHEEL-RAIL CONTACT FORCES

Milan BIŽIĆ [1]
Dragan PETROVIĆ [2]

Abstract *– This paper analyses the most relevant methodologies of experimental determination of wheel-rail contact forces. The basic principles of realization of measurement systems, as well as advantages and disadvantages of different methodologies and technical solutions are considered. The special attention was paid to the technical solutions of instrumented wheelsets which are nowadays usually used for measurement of wheel-rail contact forces. The contemporary trends and the most important problems in development of instrumented wheelsets are identified and discussed. The basic guidelines and directions for resolution of key problems in order to obtain high sensitivity and measurement accuracy are given.*

Keywords – Methodologies, experimental determination, wheel-rail contact forces, instrumented wheelset.

1. INTRODUCTION

The derailment mechanism is very closely connected with forces in the wheel-rail contact which is realized via the contact area of a few square centimetres. There are very intensive forces which cause vibrations, wear, thermal effects, noise, fatigue, failure, and the other adverse effects on elements of vehicles and track. Of utmost importance are vertical force Q and lateral force Y whose relation Y/Q is crucial for assessment the safety against derailment (Fig. 1).

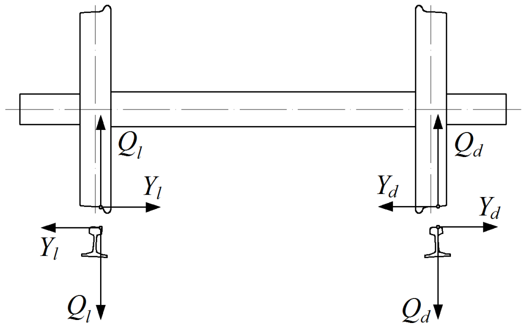


Fig.1. The wheel-rail contact forces

Given in mind their dominant influence on the railway vehicle dynamics, determining wheel-rail contact forces is of great importance. Due to the complexity of the wheel-rail geometry, precise determination by analytical way is very heavy and in many cases impossible. The analytical methods are usually based on large number of approximations in order to solve the very complex equations. In addition, wheel-rail contact forces can be determined numerically using specialized software for simulation of railway vehicle dynamics. However, their algorithms are also based on certain approximations. Also, there are problems of verification of models and numerical results. Consequently, the most reliable way for determination of wheel-rail contact forces is their experimental examination or measurement [1, 2]. International regulations UIC 518 and EN14363 in certain cases require measurement of wheel-rail contact forces as mandatory testing during the certification process of newly-designed or modified railway vehicles [3, 4]. It is important to note that the exact way of carrying out of this experimental testing is not defined by standards. For this reason, the individual railways and test centres are in the past developed their own methods which are largely differed. Even today there is no unique method that can be declared as the best. Each method has certain advantages and disadvantages compared to the others. In that sense, the aim of this paper is analysis of the most relevant approaches and methodologies for experimental determination of the wheel-rail contact forces. The paper can be very useful for researchers and engineers dealing with these and similar problems, or entering into the development of system

[1] Milan BIŽIĆ, University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Dositejeva 19, 36000 Kraljevo, Serbia, bizic.m@mfkv.kg.ac.rs; bizic.milan@gmail.com

[2] Dragan PETROVIĆ, University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Dositejeva 19, 36000 Kraljevo, Serbia, petrovic.d@mfkv.kg.ac.rs

for measurement of the wheel-rail contact forces.

2. BASIC APPROACHES

All methods of experimental determination or measurement of wheel-rail contact forces are based on the two basic approaches: measurement from the track side and measurement from the vehicle side. These approaches are stemmed from the impossibility to measure forces directly in the place of their existence - wheel-rail contact. The problem solving lies in the fact that forces causing certain deformations of structures in its vicinity during the train running. By measurement deformations of these structures (elements of track or vehicle) forces in wheel-rail contact can be determined in an indirect way.

3. TRACK-SIDE MEASUREMENT

The technical solutions of track-side measurement are usually based on checkpoints placed at certain points along the track. They are equipped with sensors (usually strain gauges) placed on the track elements (usually rails), which measure strains during the train passing. The first steps in introduction of track-side measurement have been made by ORE (later ERRI). In report published 1970. ORE has identified the key problems and gave general guidelines for their solution, but without defining of unique measurement method. Since then, different technical solutions of such measurement systems are developed. The most of them are based on the measurement of rail strains using the strain gauges. The typical solutions are based on the application of strain gauges placed on the rail and connected in the Wheatstone bridges (Fig. 2).

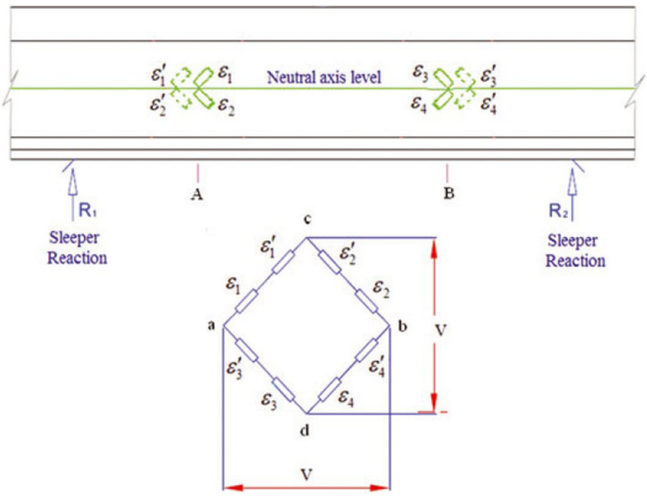


Fig.2. The example of measurement of wheel-rail contact forces using the strain gauges on the rail [5]

Determination of strain gauges positions is usually based on the FEM analysis of rail strains. The key problem is to find locations with the highest sensitivity on Q and Y forces, as well as minimal crosstalk. Calibration of measurement system can be based on the FEM results or can be done using special tools and equipment in near-real conditions. The main task of calibration is identification of individual influences of Q and Y force and changes of contact point position on strains of the rail.

The main advantage of track-side method is that the measurement is performed for each wheelset of any train that passes through the checkpoint. The main disadvantage of this method is that it does not allow continuous measurement during the train running. Measurements are carried out only at discrete points on the line which are estimated as critical from the point of quality of dynamic behaviour of vehicles. However, the process of certification of railway vehicles in accordance with mentioned international standards involves the continuous measurement of parameters of dynamic behaviour of vehicles along the certain track sections. Therefore, the application of track-side measurements is limited on the field of monitoring of vehicles that are already in exploitation. It is important to emphasize that contemporary solutions of track-side systems, in addition to the measurement of wheel-rail contact forces, provide the measurement of contact point position during the wheels passing. The current problems related to these measurement systems are finding the optimal number, layout and way of connection of strain gauges, as well as algorithm of inverse identification and way of calibration in order to obtaining the highest possible sensitivity and accuracy of measurement.

4. VEHICLE-SIDE MEASUREMENT

Vehicle-side measurements of wheel-rail contact forces are usually based on instrumented wheelsets. They are equipped with sensors (usually strain gauges) which measure certain strains during the running of tested vehicle, on the basis of which wheel-rail contact forces can be determined in an indirect way. Generally, all technical solutions of instrumented wheelsets are based on two approaches: measurement over the axle and measurement over the wheel.

The first solutions of measurement over the axle appeared in early seventies of the 20th century. Although they are in the meantime significantly improved, their main characteristic is based on the measurement of the bending and torsion moments in certain sections of the axle. A typical example of such instrumented wheelset is shown in Fig. 3.

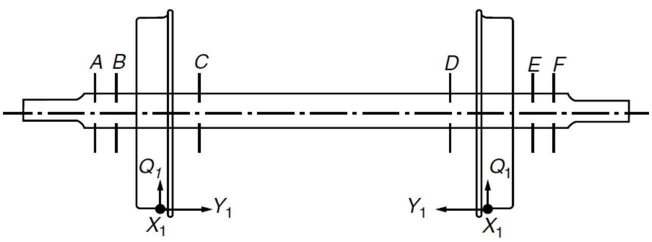


Fig.3. The example of instrumented wheelset based on the measurement over the axle [6]

The solution in the Fig. 3 is based on the measurement of bending and torsion moments in six different sections of the axle. In this way it is possible to determine the approximate values of the six wheel-rail contact forces that caused the measured moments. Moments are measured using the strain gauges connected in the proper configurations of Wheatstone bridges. Advantages of these solutions are based in relative simple measurement system and in possibility for changing wheels of instrumented wheelset. The more important are their disadvantages which are primarily reflected in the impossibility to compensate measurement error due to changing the contact point position. The measurement over the axle was used a long time in German Railways. Because the mentioned disadvantages, this method is replaced with the modern solutions.

First concrete solutions of measurement over the wheel of instrumented wheelset emerged in the fifties of the 20th century. From that time until today, the large number of technical solutions of measurement over the wheel of instrumented wheelset is developed. All solutions are based on two approaches: measurement over the wheel with spokes and measurement over the standard monoblock wheel.

The largest contribution to the development of instrumented wheelsets with spoked wheels gave the British Railways during the seventies and eighties of the 20th century. The solution is based on measurement of strains using the strain gauges placed on the certain sensitive locations of spokes (Fig. 4). The strain gauges are in certain configurations connected into the Wheatstone bridges in order to obtain the highest possible sensitivity and measurement accuracy.

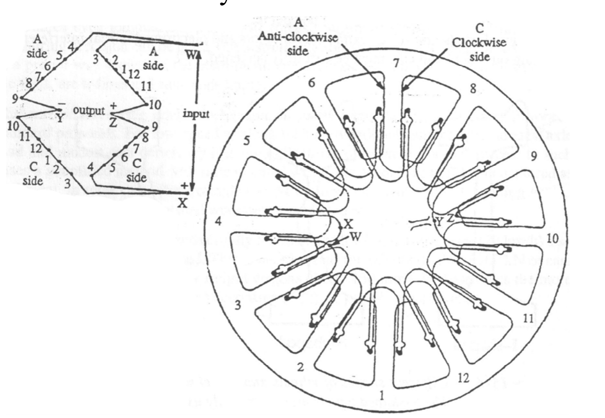


Fig.4. The example of instrumented wheelset based on wheels with spokes [7]

With intelligent selection of spokes and locations of strain gauges it is possible to obtain the signals which are approximately proportional to the wheel-rail contact forces. The advantage of this method is in better sensitivity on the effects of Q force due to the higher elasticity in the vertical direction. In addition, these solutions allow to achieve high measurement accuracy. The main drawback is a very complex and expensive machining of spokes that require high precision. This method is rarely used today, although it has long been in use in the UK and Switzerland.

Instrumented wheelsets with measurement over the standard monoblock wheels appeared in the fifties of the 20th century. After the occurrence of method of Olson and Johnsson, the development of such instrumented wheelsets flowed upward with the increasing of sensitivity and accuracy of the measurement. In the eighties of the 20th century in this area a significant step forward is made in region of former Yugoslavia. At that time, Prof. Jovanovic and colleagues developed instrumented wheelset based on the application of strain gauges placed on the standard monoblock wheels. The measurement of wheel-rail contact forces using the instrumented wheelsets based on the standard monoblock wheels is today most common method that is widely used in countries such as France, Germany, USA, Japan, Sweden, China, etc.

The key advantage of vehicle-side measurement is that it allows continuous measurement. The main disadvantage is that the measuring system is connected with the one wheelset. Since the design of wheelsets for different types of railway vehicles can vary significantly, the instrumented wheelsets must be adapted to the specific types of vehicles or bogies. This cause the high costs of their development and production.

5. CONTEMPORARY INSTRUMENTED WHEELSETS

In contemporary solutions of instrumented wheelsets, the strain gauges can be placed on inner or outer side of wheel disc on the certain radial distances (Fig. 5). The optimal radial distances are selected on the basis of FEM analysis of the wheel (Fig. 6). This is one of the most significant problems to be solved in development of instrumented wheelset.

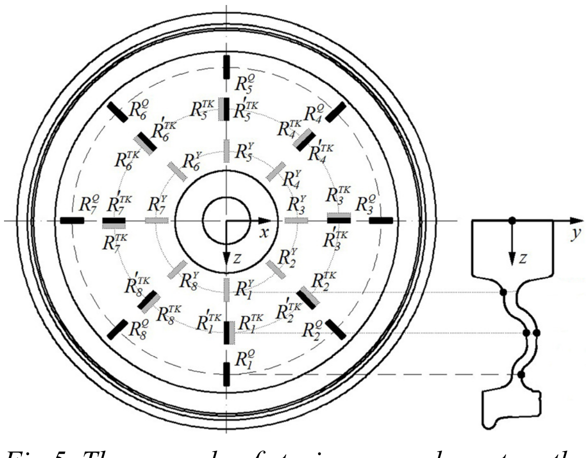


Fig.5. The example of strain gauges layout on the instumented wheelest with monoblock wheels

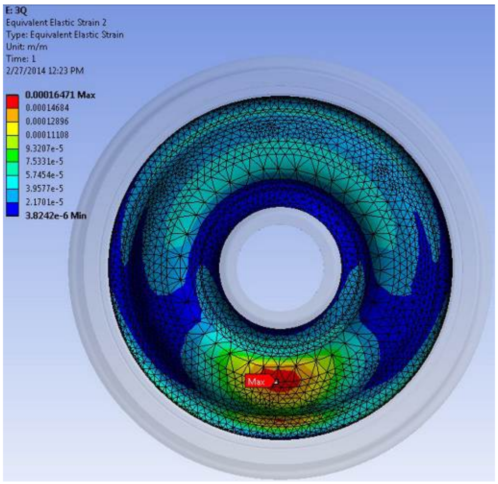


Fig.6. The FEM analysis of the wheel

Finding locations with highest sensitivity on parameters being measured and minimal crosstalk should be based on detailed stress-strain analysis of the wheel. The FEM model also enables solution of very important problems such as finding of optimal number, layout and way of connection of strain gauges in the Wheatstone bridges. The centrifugal and temperature effects should be taken into account and compensated. In order to increase the sensitivity on *Q* force, in the wheel disc very often there are circular holes for strain gauges placing. In the last time, this solution is very rarely and the tendency is to use the standard monoblock wheel without any additional machining (Fig. 7).

Fig.7. The instrumented wheelset with standard monoblock wheels

In addition to the measurement of wheel-rail contact forces, the contemporary instrumented wheelsets allow measurement of the contact point position. The most significant problems to be solved are also the development of algorithm for inverse identification of measured parameters, the development and production the test stand for calibration, data transmission, etc. This process requires the systematic approach and participation of experts from the different sectors of technique. The key task is providing the highest sensitivity and accuracy of measurement system.

6. CONCLUSION

During the last decades, many different methods and technical solutions for experimental determination of wheel-rail contact forces has been proposed. Each of them has certain advantages and disadvantages. Track-side measurements are more used in monitoring while vehicle-side measurements via the instrumented wheelsets are primarily used in certification process of railway vehicles. Standards do not define technical solution of instrumented wheelset as well as the necessary accuracy. The most of contemporary solutions are based on the standard monoblock wheels equipped with the strain gauges. There are many different approaches when it comes to locations of strain gauges, their layout, number, way of connection, signal transmission, etc. Also, there are many different approaches of calibration and the algorithm of inverse identification. There is no universal solution for which can be said that is the best. Each manufacturer has its own solution of instrumented wheelset that is more or less different from the others, and that has certain advantages and disadvantages. In every case, the key problem in development of every measurement system or instrumented wheelset for experimental determination of wheel-rail contact forces is obtaining the highest sensitivity and accuracy.

ACKNOWLEDGEMENT

The authors express their gratitude to Serbian Ministry of Education, Science and Technological Development for supporting this paper through project TR35038.

REFERENCES

[1] Iwnicki S.D., *Handbook of Railway Vehicle Dynamics*, CRC Press, Taylor & Francis Group, Boca Raton, 2006.
[2] Andersson E., Berg M., Stichel S., *Rail Vehicle Dynamics*, Railway Group KTH, Stockholm, 2007.
[3] UIC CODE 518 OR, *Testing and approval of Railway vehicles from the point of view of their dynamic behaviour – Safety – Track fatigue – Running behaviour*, 4th edition, International Union of Railways – UIC, 2009.
[4] EN 14363, *Railway applications – Testing for the acceptance of running characteristics of railway vehicles – Testing of running behaviour and stationary tests*, European Committee for Standardization – CEN, 2005.
[5] Askarinejad, H., Dhanasekar, M., Boyd, P., Taylor, R., *Field Measurement of Wheel–Rail Impact Force at Insulated Rail Joint*, Experimental Techniques, in press, 2012.
[6] Berg H., Gößling G., Zück H., *Radsatzwelle und Radscheibe - die richtige Kombination zur Messung der Kräfte zwischen Rad und Schiene*, ZEV - Glasers Annalen, Vol. 120, Nr. 2, pp. 40-47, 1996.
[7] Allen R.A., *A Superior Instrumented Wheelset*, Wheel/Rail Dynamics Society, 1980.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

DAMAGES OF RAILWAY INFRASTRUCTURE INDUCED BY CORROSION

Dušan PETKOVIĆ [1]
Goran RADENKOVIĆ [2]
Jelena DIMITRIJEVIĆ [3]

Abstract – *Transport and transport services are important necessities of modern civilization. Railway infrastructure is one of the major important elements of railway transport. Corrosion is the destructive attack of a metal by chemical or electrochemical reaction with its environment. The most structural parts in railway made from metals, so the corrosion appearance is inevitably. Railway bridges present critical components of a transport network, so that the safety of bridges is crucial to people's daily life and to the national economy. The most common form of corrosion of the steel bridges is atmospheric corrosion, resulting from the wetting and drying process. The corrosion of steel reinforcement in the concrete railway bridges can result in cracking or spalling of the cover concrete and reduction in structural strength. Corrosion prevention techniques include appropriate design and material selection, prevention through chemistry, protective coating, cathode protection as well as using of anticorrosive paints.*

Keywords – Railway infrastructure, corrosion, railway bridge, atmospheric corrosion.

1. INTRODUCTION

In the modern industrial world, the transport of goods and people by rail is getting bigger day after day. Railways are one of the most important means of transportation in the world and reasons for that can be specified as high transport capacity and effective use of energy with lowest damage to the environment. Therefore, the reliability and safety of rail transport is of the great economic and universal importance to the society in general. Existence of a safe and technically acceptable railway infrastructure is one of the major conditions for that. Undoubtedly, bridges present critical components of a transport network, so that the safety of bridges is crucial to people's daily life and to the national economy.

It was reported that more than 60% of the railway bridge stock in Europe was over 50 years old and more than 30% was over 100 years old [1]. These bridges are subjected to higher loads and speeds than those for which they were designed. To satisfy the present and future demands, some bridges are in need of strengthening or replacement.. After tens of years' service, many of steel railway bridges become old and need to be strengthened integrally for the whole bridge or repaired locally for certain steel members. Considering the relatively high cost for replacing or strengthening integrally, as well as the great impact on the public transportation, preventive maintenance on the old steel members is an effective way. Structural repairing or maintenance technique has been a hot issue in recent years due to the increasing aging problems of old railway bridges.

Girder bridges, like other structures, deteriorate over time due to environmental effects, material fatigue and overloading. As a consequence, their closure or traffic capacity reduction causes major inconveniences for the users and result in significant losses to the economy. In this regard, special attention should be paid to the condition of railway bridges.

For steel railway bridges, one of the dominant problems are fatigue and corrosion. Corrosion is the destructive attack of a metal by chemical or electrochemical reaction with its environment. The increase in load, traffic volume and speed yields higher stress ranges and a larger number of stress cycles resulting in a shorter fatigue life. A number of

[1] Dušan PETKOVIĆ, University of Niš, Faculty of Mechanical Engineering, A. Medvedeva 14, Niš, Serbia, dulep@masfak.ni.ac.rs
[2] Goran RADENKOVIĆ, University of Niš, Faculty of Mechanical Engineering, A. Medvedeva 14, Niš, Serbia, rgoran@masfak.ni.ac.rs
[3] Jelena DIMITRIJEVIĆ, University of Niš, Faculty of Civil Engineering, A. Medvedeva 14, 18000 Niš, Serbia, jelena.dimitrijevic@gaf.ni.ac.rs

strengthening methods to increase the fatigue life and to repair already damaged structures have been tested and presented in the literature. Some methods require that the bridge is closed for traffic during construction. For most traffic intensive railway networks in Europe this poses a big problem since it is very costly to have long interruptions in traffic. It is also costly if the work can only be performed during the night when there usually is less or no traffic. The best method would be one where all the work could be performed without disturbing the traffic at all.

2. COST OF CORROSION

Corrosion is defined as the destruction of materials caused by chemical or electrochemical action of the surrounding environment and it is affected by several factors, including electrochemical, metallurgical, physicochemical, and thermodynamics [2]. In other words, corrosion presents an unvoidable natural tendency of metals to return their natural state.

There are three main reasons for the importance of corrosion, such as economics, safety, and conservation. To reduce the economic impact of corrosion, corrosion engineers aim to reduce material losses, as well as the accompanying economic losses, that result from the corrosion of piping, ships, bridges, tanks, metal components of machines, marine structures, and so on [3]. Corrosion can compromise the safety of operating equipment by causing failure with catastrophic consequences. Loss of metal by corrosion is a waste not only of the metal, but also of the energy, the water, and the human effort that was used to produce and fabricate the metal structures in the first place. In addition, rebuilding corroded equipment requires further investment of all these resources — metal, energy, water, and human.

Economic losses are divided into direct losses and indirect losses. Direct losses include the costs of replacing corroded structures and machinery or their components. Repainting structures where prevention of rusting is the prime objective and the capital costs plus maintenance of cathodic protection systems for underground pipelines are examples of the economic losses too. Studies of the cost of corrosion in Australia, Great Britain, Japan, and other countries have also been carried out. In each country studied, the cost of corrosion is approximately 3 – 4 % of the Gross National Product [4].

Indirect losses are more difficult to assess, but a brief survey of typical losses of this kind points out that they add several billion dollars to the direct losses. Indirect losses include shutdowns, loss of productivity, loss of efficiency, contamination of products, overdesign, etc.

3. CORROSION OF METALIC RAILWAY BRIDGES

Deterioration of steel bridge infrastructures constitutes a major worldwide problem in transportation engineering and maintenance management industry. Corrosion and fatigue cracking may be the two most important types of damage in aging structures. Various kinds of failures and the need of expensive replacements may occur even though the amount of metal destroyed is quite small. One of the major harmful effects of corrosion is the reduction of metal thickness leading to loss of mechanical strength and structural failure, causing severe disastrous and hazardous injuries to people [5].

In the engineering practice, the damage of the steel bridges frequently occurs on the longitudinal and horizontal beam connection joint due to severe corrosion and fatigue. For steel railway bridges subjected to large train impact and vibration, fatigue is more critical than corrosion. Besides, as welded structures have been widely used for railway line including bridges, various corrosion and fatigue damage problems have been reported. In order to avoid the unrecoverable damage of the railway bridge, high cost of the rail line owners and the great impact on the public transportation, effective preventive maintenance methods on the old steel railway bridges are necessary.

A typical steel railway bridge with welded joints is shown in figure 1, which has been used in service for tens of years. In order to avoid the possible damage, fracture or failure caused by fatigue and corrosion, preventive maintenance on this connection joint is necessary [6].

Fig.1. Old steel railway bridge [6]

Corrosion as a phenomenon that occurs on the metal parts can appear in different forms. Certainly the most often and the most common form of the railway infrastructure corrosion is atmospheric corrosion. Besides that, it can be noticed crevice corrosion mode on the joints of two or more parts in which exist holes and sheltered gaps where moisture may keep more than on the surface.

3.1 Atmospheric corrosion

Atmospheric corrosion can be defined as the corrosion of materials exposed to the air and its pollutants, rather than immersed in a liquid [7]. An important domain of atmospheric corrosion is the degradation of the infrastructure. Bridges, commercial and residential buildings, electrical power distribution systems, rail system components, utility poles, communication systems and marine structures are relevant examples. Atmospheric corrosion damage has played a major role in the degradation of the metal bridges, such as the Golden Gate Bridge [8].

Conventional atmospheric parameters that may lead to metal corrosion comprise of weathering factors such as temperature, moisture, rainfall, solar radiation, wind velocity, etc. Air pollutants such as sulphur dioxide, hydrogen sulphide, oxides of nitrogen, chlorides have also been found to contribute to atmospheric corrosion [9]

3.2 Localized corrosion

Localized corrosion is defined as the selective removal of metal by corrosion at small areas or zones on a metal surface in contact with a corrosive environment, usually a liquid. It usually takes place when small local sites are attacked at a much higher rate than the rest of the original surface. Localized corrosion appears when corrosion acts at the same time with other destructive processes such as stress, fatigue, erosion, and other forms of chemical attack. This type of corrosion leads to hidden thinning of the bridge parts. The end result is premature failure of the parts, which is a great safety problem. Intense corrosion takes place at the locations where moisture from the atmosphere is colected [9]. The form of localized corrosion is commonly referred to as crevice corrosion. The region where oxygen is depleted (i.e. inside the crevice) becomes anodic with respect to the rest of the exposed material. This leads to an intense attack at the crevice location. The process is autocatalytic and more importantly, the attack is not easily visible to the naked eye. Crevice corrosion is accelerated in the presence of chloride ions, which are present in environments near the sea coast as well as in discharge from the toilets of passenger trains.

3.3 Ways for reduction of corrosion rate

Corrosion prevention methods are required for the both forms of corrosion that affect railway infrastructure. One of the most effective ways of them is by insulating the contact between materials or components with different chemistries that have a tendency to form galvanic pairs. However, this is close to impossible because perfect insulators do not exist. The simple corrosion control philosophy, for prevention of crevice corrosion, will be to apply a protective coating on the surface so that the environment will not flow into the crevice. With this aim, many researches were conducted to check the efficiency of different coatings. Polymeric coatings were not effective due to their degradation in the atmospheric environment [10].

3.4 Reparing of the steel railway bridge structures

Major steel bridges are rather costly to construct, maintain and rehabilitate. Therefore, the design, maintenance, management and rehabilitation of this kind of structures are complex and challenging tasks. Consequently, they have to be performed using state-of-the-art technical solutions and the best practice gained over many years of experience. [5].

Efficient maintenance, repair and rehabilitation of existing bridges require the development of a methodology that allows for an accurate evaluation of the load carrying capacity and prediction of remaining life. In the past few decades, several experimental studies and detailed investigations of corroded surfaces were done by some researchers in order to introduce methods of estimating the remaining strength capacities of corroded steel parts.

In recent years, engineers all over the world have been working on repairing or strengthening of old steel railway bridge structures. Wallin et al. [1] investigated two different strengthening methods for a through-girder steel railway bridge (Soderstrom Bridge) in the city of Stockholm, Sweden. Experimental and numerical investigation was performed by Lin et al. [6, 11, 12] on an old steel railway bridge which had been used for 100 years in Japan. The results demonstrate that the use of rapid hardening concrete, GFRP, and reinforcing bars can effectively improve the fatigue strength, reduce the structural noise, and extend the residual service life of the old railway bridges. Finally, the group of the authors concluded that the common choice for engineers to strengthen the old structures by integrating with new structural members or materials [6].

4. CORROSION OF REINFORCED CONCRETE RAILWAY BRIDGES

After long-term atmospheric exposure, many reinforced concrete structures throughout the world have started to exhibit signs of carbonation-induced reinforcement corrosion and therefore require maintenance to extend their service lives [13]. The corrosion of steel reinforcement and the bursting stress caused by rust, which occupies a much larger volume than the parent metal, can result in cracking or spalling of the cover concrete and reduction in structural strength [14]. Corrosion rate of the steel in concrete, mainly depends on the amount of the ions through the electrolyte concrete, its relative humidity and temperature, as well as the quality of the protective concrete layer, which affects the transfer rate of corrosive elements from the outside to the steel surface [15].

New reinforced and post-tensioned concrete structures are still built worldwide. In all these structures such as bridges, power plants, towers etc. tendons containing the high-strength steels are structural elements contributing decisively to the serviceability, safety and durability of pre-stressed concrete structures. A new generation of concrete railway bridge is shown in figure 2 [16].

Fig.2. Concrete railway bridge [16]

4.1 Remedial treatment of concrete railway bridge structures

Several approaches have been used in the remedial treatment of long-term atmospheric exposure concrete structures. They include partial replacement of concrete cover, electrochemical re-alkalisation, cathodic protection, and surface application of corrosion inhibitors [17]. Regarding the use of surface-applied corrosion inhibitors of different types, several aspects of their performance are poorly understood and there is limited published information on the conditions needed to achieve and sustain adequate inhibitor concentrations at the depths of corroding reinforcement in real structures [18].

5. CONCLUSION

It is of great importance condition and reliability of railway infrastructure for safe and rapid transport of goods and people. Bridges are a significant part of the infrastructure and only in Europe there are thousands of them with different looks, sizes and designs. Since most of them made a half century ago, it is necessary to point out the problems related to corrosion damage that will occur during their further exploitation. It has not been dealt with this problem enough so far, but the growth of the service life of them imposes necessity to find ways to check their state and revitalization. The authors' intention was to draw attention to the tasks that are increasingly imposed by the engineers who work on the railway infrastructure maintenance

ACKNOWLEDGEMENT

This paper is done within a framework of the project ON174004 financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

REFERENCES

[1] Wallin, J., Leander, J., Karoumi, R., *Strengthening of a steel railway bridge and its impact on the dynamic response to passing trains,* Engineering Structures 33 (2011) 635–646.
[2] Fontana, M.G. and Greene,N.D., *Corrosion Engineering*, Materials Science and Engineering Series, McGraw-Hill, Second Edition, pp. 464, 1978.
[3] Revie, R.W. and Uhlig, H.H., *Corrosion and corrosion control,* John Wiley & Sons, Inc., Hoboken New Jersey 2008.
[4] Kruger, J., *Cost of metallic corrosion* , in Uhlig ' s Corrosion Handbook, Wiley , New York , 2000.
[5] Appuhamy, J.M.R.S et al., *Consequence of Corrosion on Dynamic Behaviour of Steel Bridge Members*, International Journal of Modern Engineering Research, 2 (2012) 281-288.
[6] Lin, W. et al*., Preventive maintenance on welded connection joints in aged steel railway bridges*, Journal of Constructional Steel Research 92 (2014) 46–54.
[7] Pohlman, S.L., *Atmospheric Corrosion*, Metals Handbook, 9th ed., Vol. 13, ASM International, MetalsPark, OH, 1987.
[8] Mohn, D.E., *Fifty Years of Corrosion on the Golden Gate Bridge*, Mater. Perform., 28 (1989) 65-70.
[9] Petković, D., Radenković, G., *Corrosion problem in railway*, Proceedings of the XV Scientific-Expert Conference on Railways - Railcon'12, Niš (2012) 181-184.
[10] Balasubramaniam, R., *Callister's Materials Science and Engineering*, Wiley India, New Delhi (2007) 613–617.
[11] Lin, W. et al., *Numerical study on hybrid structures renovated from the old railway steel bridges*. J Struct Eng JSCE 58A (2012) 925–934.
[12] Lin, W. et al., *Performance of strengthened hybrid structures renovated from old railway steel bridges*. J Constr Steel Res 85 (2013) 130–139.
[13] Parrott, LJ., *Damage caused by carbonation of reinforced concrete*. Mater Struct 23(1990) 230–234.
[14] Kubo, J. et al., *Application of electrochemical organic corrosion inhibitor injection to a carbonated reinforced concrete railway* viaduct, Construction and Building Materials 39 (2013) 2–8.
[15] Radenković, G., Petković, D., *Uticaj korozione sredine na brzinu korozije čelika u betonu*, XI YUCORR international conference, Tara, (2009) 54-59.
[16] Hu, N. et al., *Recent development of design and construction of medium and long span high-speed railway bridges in China*, Engineering Structures 74 (2014) 233–241.
[17] Page, CL., *Corrosion and protection of reinforcing steel in concrete*. In: Page CL, Page MM, editors. Durability of concrete and cement composites. Cambridge: Woodhead (2007) 136–86.
[18] Soylev, TA., Richardson, MG., *Corrosion inhibitors for steel in concrete*, Constr Build Mater 22 (2008) 609–622.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

MEASUREMENT OF PRESTRESSING FORCE TO DETERMINE QUALITY OF CONCRETE SLEEPERS

Slobodan JOVANOVIĆ [1]
Dragan S. JOVANOVIĆ [2]
Slaviša PLANIĆ [3]

Abstract - *Prestressed concrete structures are characterized by high resistance to pressure which is characteristic of concrete and prestressing reinforcement to get good load bearing capacity of the stretching. To achieve the projected capacity prestressed concrete structures is the most important controllable tension force in the steel cables or wires, depending on what is used in the construction. Force control can be carried out force sensors or strain gauges. This paper presents the methods of measurement of prestressing force in different types of structures. A special importance is given to tension wire with concrete sleepers because it directly affects the quality and durability thresholds, as shown in the thresholds such as "B70". For quality sleepers in addition to the intensity of force has significant influence and uniform load distribution on individual wires in the upper and lower zone threshold, which is a very important technological parameter in the production threshold with grits recipe concrete.*

Keywords* – *Concrete sleepers, tension force meassurement, uniform load distribution of wire.

1. INTRODUCTION

Construction of prestressed concrete is characterized by a large payload due to the fact that the appropriate number of steel wires or cables enter the appropriate force preload. Technology means that you need to perform tension wires or cables and keep them in the stretched condition and complete construction of "pour" concrete corresponding characteristics. Design of prestressed structural engineers engaged in civil engineering to define the required number and arrangement of wires, the load in the wires that need to be achieved as well as the brand strength of concrete, its granulation (structure), methods of drying concrete, the addition of suitable additives for concrete and more important for prestressed concrete structures. Quality of design and production is confirmed by examining the elements of prestressed concrete structures. However, any errors that occur are manifested only after the final test it had already been invested a certain amount of materials and labor to prestressed structures implemented. To avoid errors it is necessary to perform periodic control device for the measurement of prestressing force which is the legal obligation of the manufacturer of prestressed concrete structures, but there is also the interest of producers to produce quality elements of prestressed concrete. Concrete sleeper is shown at Fig.1. This paper discusses two methods for control of prestressing force of steel wires and cables that are used in making concrete structures prestressed concrete.

Fig. 1. Concrete sleepers

2. MEASUREMENT AND TESTING FORCE IN STEEL CABLES PRESTRESSED CONCRETE ELEMENTS

The principle of most machines for wire (or kable) tension in prestressed concrete is relatively simple: Use a hydraulic cylinder (cylinders) that over a suitable tool tightens wires (cables) to the required

[1] Slobodan JOVANOVIĆ, Faculty of Mechanical Engineering, University of Niš, slojo@masfak.ni.ac.rs
[2] Dragan S. JOVANOVIĆ, Faculty of Mechanical Eng., University of Niš, dragan.jovanovic@masfak.ni.ac.rs
[3] Slaviša PLANIĆ, DIV Betonski pragovi d.o.o. Svrljig , slavisa.planic@divgoruop.eu

tension, then watering is done with concrete and removal system for tensioning wires in an appropriate manner when complete the maturation process of the concrete. Although simple and well-known method brings a certain risk in the wires do not bring sufficient force prescribed by the designer on the one hand, or to exceed the setpoint force which risks should break wires or cables after load structure. This risk is particularly present the fact that the hydraulic elements are of leakage of fluid through the gaps. For measuring tension wires used indirect methods which are mainly based on the measurement of fluid pressure, which is displayed on an analog or digital display. Information on the measured pressure contains the pressure in the installation and not pressure that acts on the tool string and occasionally significantly checked the actual force that is entered into the wire (kable) for prestressed construction. Control tests are possible in two ways: 1. measuring the force generated in the wires - cables measuring cell forces; 2. measuring the dilation of wire strain gauges and calculating the force

Certainly cheaper and more reliable method of directly measuring the force, but it is not always possible due to the way the applied tensile wire. This method can be used for larger concrete structures when such elements are used for the prestressing cables for prestressing. Fig. 2 shows the method of measuring forces in the prestressing cables used by the factory pre-stressed concrete structures "Prefabrikati" Ltd from Krušce near Nis.

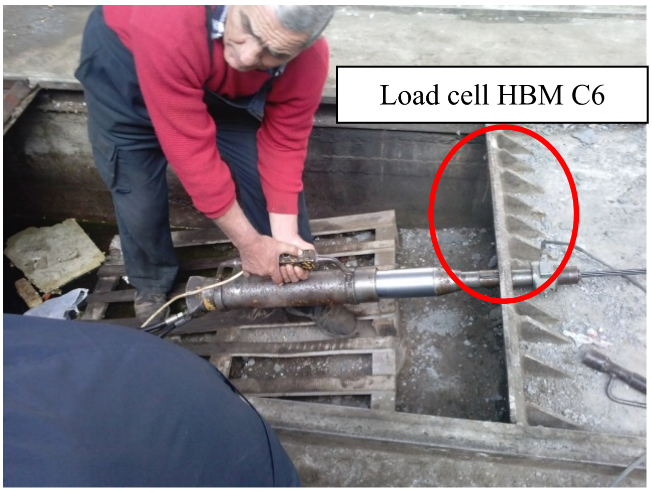


Fig. 2. Measurement of force in the prestressing cables

The factory "Prefabrikati" Ltd. from Krušce used hydraulic "guns" to tighten cable for prestressed concrete structures whose movement is achieved by special segment tools for locking cable. Tightening is realized on the runway for tightening the cables where there are special nests where cables are a necessary force to tighten. Control of the "old runway" is done by reading the gauge where on the basis of the control test achieves the required force in the cables (see Fig. 3.).

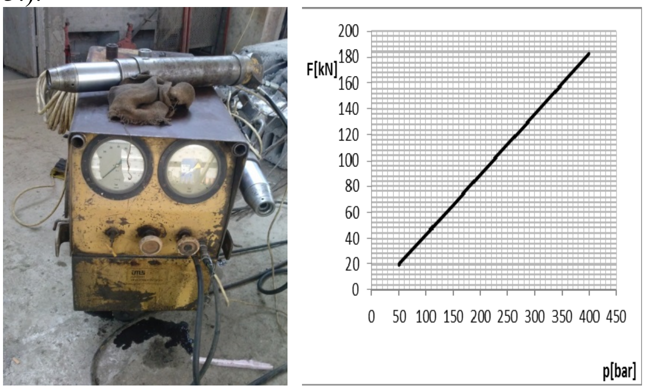


Fig. 3. Diagram of real forces in the cables and the manometer reading

Another "gun" to tighten cable is modern and has an adjustable hydraulic relief valve when reach the desired (specified) force in the cable cuts off the fluid in the hydraulic cylinder and includes adequate acoustic signal informs the operator that the achieved power. In Fig. 4 is shown the device for the pre-stressing cables.

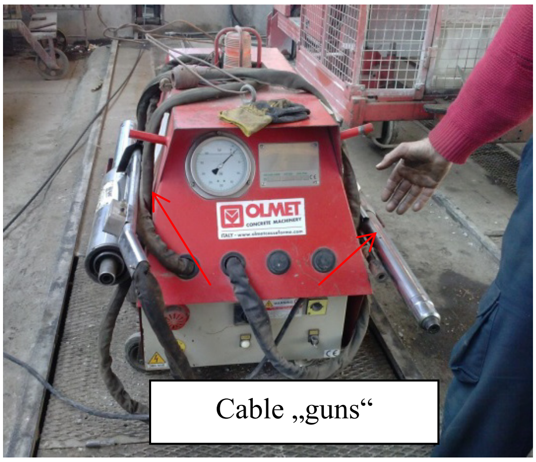


Fig. 4. Automatic "gun" for tensioning cables

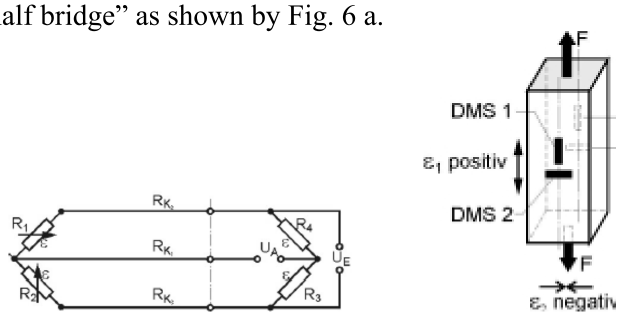
In these examples shows it is shown the control by the first method when direct force sensor is used to measure the force of prestressing cables. In this case, it adjusts the valve to a given power of user-defined for a given cable diameter while in the second case performs calibration gauge in relation to the proceeds of prestressing force.

A very important group of prestressed concrete elements are concrete sleepers. According to the current state of the railways in Serbia need for this product is great. In addition to concrete sleepers there are other supporting elements of rail as a concrete crossover thresholds and other products. Factory of concrete sleepers DIV concrete sleepers Ltd. Svrljig very much invested in the methods of control of concrete sleepers. A significant element in the quality of production of concrete sleepers for the size wire tensioning forces and their uniform distribution. Fig. 5

shows the position of the tension wires in the concrete sleepers.

Fig. 5. System for tensioning the wire in the tool for concrete sleepers used from DIV Svrljig

Due to the design of tools is not possible to measure the force exercised by the hydraulic cylinders peg. Therefore, it was necessary to apply a different method, which is more expensive, and it is a measurement of expansion of the individual wires. Since the wire is relatively thin it is necessary to use a special measuring tapes which are in this particular test was HBM 1.5LY21 which are connected to a "half bridge" as shown by Fig. 6 a.



a) *b)*

Fig. 6 Wheatston bridge used in measurement

Because of the stress state of pure stretching of the government in the wires had to be measuring tapes are perpendicular (Fig. 6b) and a factor measuring bridge was 1.3 (σ + 0,3σ). Measuring the expansion is easy to determine the force computation using the expression (1)

$$\sigma = \frac{F}{A} = \varepsilon \cdot E \rightarrow F = A \cdot \varepsilon \cdot E \qquad (1)$$

where the elements are known A-wire cross-section in mm^2, ε-dilation measured in µm / m and E modulus of elasticity in N / mm ^{2} and the calculation should take into account the dimensions However, it is much safer to make a comparison dilatation assembly wires and experimentally determine the relationship of tension and expansion wire, because in this way take into account the real situation in the tool to tighten the wire. Fig. 7 shows how test relation between force and dilatation and in Fig. 8 and 9 the results of control forces in the wires of real sleepers.

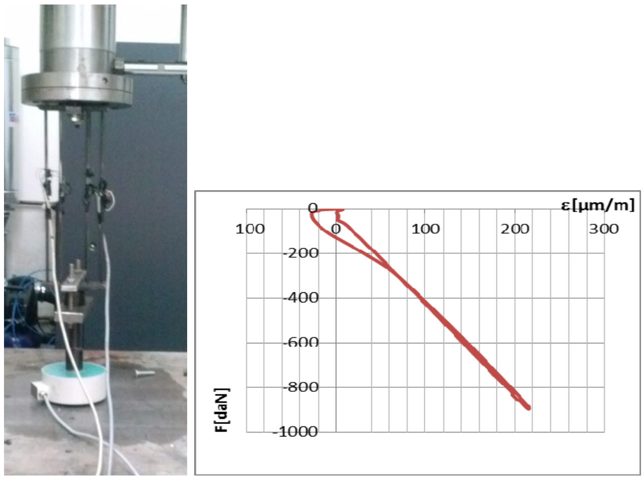


Fig. 7. Relation between force and dilatation in wire

Based on the calibration dilatation by tension force is obtained by tensioning the wire diagram.

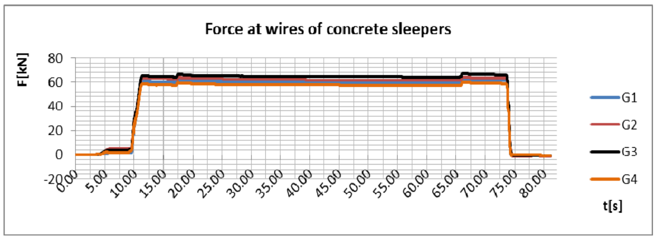


Fig. 8. Uniformity of force by individual wires

Based on these measurements it was concluded that the distribution of tension force in the wire evenly, and all the wires are evenly tensioned force that is about 60kN corresponding values for the elastic limit of the applied material wires.

It remains only to perform calibration and adjustment of pressure that achieves the desired force and this was accomplished with a 228 bar, as indicated by a pressure gauge on the keyboard device for tensioning wire.

Fig. 9. Indicating gauge on the control panel device for tensioning wire

All results of testing thresholds according to EN 13230, which has a DIV Concrete sleepers Ltd. from Svrljig indicate the quality of all the elements in the production of concrete sleepers where the achievement of equitable and projected force in wires in prestressed concrete sleepers has a very important role.

3. CONCLUSION

In this paper, the methods of experimental testing the uniformity and intensity of tension wires and cables in the preparation of pre-stressed concrete elements. The control exerted by the tensioned wires in the preparation of concrete sleepers significantly affect the quality of concrete sleepers which later confirms the testing thresholds according to EN 13230 and the instructions of ŽS. Although the costs of these tests for large applied methods to implement them is necessary if we want to obtain high quality and reliable products.

REFERENCES

[1] E.Curić, A.Savić, D.Drenić: “Kapacitet nosivosti prednapregnutog betonskog praga nakon dejstva zamornog opterećenja”, 4 Internacionalni naučno stručni skup, Građevinarstvo nauka i praksa, Žabljak CG, 2012

[2] D.Damjanović, M. Rak, I.Duvnjak, M. Bartolac, M. Frančić: Statičko i dinamičko ispitivanje prednapetih jednodijelnih željezničkih pragova (Static and dynamic testing of prestressed monoblock sleepers), SABOR HRVATSKIH GRADITELJA 2012: Graditeljstvo - poluga razvoja / Lakušić, Stjepan (ur.). - Zagreb : Hrvatski savez građevinskih inženjera , 2012, 619-630

[3] D. Drenić: „Prikaz ispitivanja prednapregnutog betonskog železničkog praga tipa B70“ ,Međunarodni naučno stručni skup ISTRAŽIVANJA, PROJEKTI I REALIZACIJE U GRADITELJSTVU Institut IMS, Beograd, 2010. 133-139

[4] SRPS EN 13230-2:2010: Primene na železnici — Kolosek — Betonski pragovi za kolosek i skretnice — Deo 2: Prethodno napregnuti jednodelni pragovi

[5] S.Jovanović: “Ispitivanje ravnomernosti naponskog stanja žica za prednapregnute betonske pragove tipa B70”, Zavod za mašinsko inžinjerstvo Mašinskog fakulteta br 612-22-81/10, za MIN-DIV Svrljig, 2010

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

THE THERMAL ELASTIC BEHAVIOR OF THE CYLINDRICAL ROLLER BEARING FOR RAILWAY VEHICLES

Vladimir BLANUŠA[1]
Milan ZELJKOVIĆ [2]
Aleksandar ŽIVKOVIĆ [3]

Abstract – *This paper presents a calculation model the thermal behavior of the cylindrical roller bearing for railway. The present mathematical model allows to define the value of the moment friction due to lubrication, the friction moment due to the radial and axial loads. Heat generated in the bearing calculated based on the value of previously defined moments. Also, it shows the method of calculating the coefficients of conduction and convection of heat in bearing. Using programming system general purpose analyzed thermal elastic behavior of the cylindrical roller bearing for railway. Finite element method determined by temperature values in the bearing depending on the speed bearing for different time periods.*

Keywords–Thermal elastic behaviour, cylindrical roller bearing for railway, finite element method.

1. INTRODUCTION

The advent of railway in the mid-nineteenth century certainly represents a significant technological innovation and it has a revolutionary role and enormous contribution to the industrial development and economic progress of society. The rapid development of the construction and exploitation railways has made a significant impact on the development of strength science and theory construction, [10], because it appeared a series of new problems (particularly in relationship with the design and construction of railways, bridges, locomotives, vagon and etc..) that should be solved.

Although in comparison with other forms of transport railways has a number of advantages in terms of economic viability (lower power consumption and especially environmental sustainability), inefficiencies created railway regulations set limits in industry that prevented effective competition. Delays in railway technology innovation and inadequate response to the significant increase in the quantity of goods of small packages, with a reduction of goods suitable for transport by rail (such as ore and coal) are the primary explanation for why, for example the share of railways in freight traffic to the United States after World War II was close to 70% of intercity ton miles, until 1975. dropped to 37% [11].

The European Union today treats Railways as a transport of the future and seeks to reaffirm the European level as rail transport, the requirement of a competitive, secure and high-quality transport all kinds of goods. Achieving these goals requires among other things the construction of modern cars custom market challenges, specific technological requirements and systems that allow rapid performance of loading / unloading operations.

Cylindrical roller bearings for railways are the key components of the point of towed vehicles and their cancellation could have disastrous consequences. Bearing temperature is one of the most important parameters bearing whose monitoring is possible to determine the condition of bearing in service. That is why we investigate the use of different lubricants (fat) and based on the test results, it is concluded that the lubricant has a significant influence on the bearing temperature during operation.

2. MECHANISM OF HEAT GENERATION

2.1 Introduction

Bearings assembly wheel railway wagons can make different types of bearings (cylindrical roller bearing, spherical roller and taper roller). In this paper discusses the bearing assembly wheel with cylindrical roller bearings (mark of the bearing 324 NJ EC.M1C4 VA301). Figure 1 shows assembly wheel as well as

[1] Vladimir BLANUŠA, Faculty of Technical Sciences, Novi Sad,Trg Dositeja Obradovića 6, blanusa@uns.ac.rs
[2] Milan ZELJKOVIĆ, Faculty of Technical Sciences, Novi Sad, Trg Dositeja Obradovića 6, milanz@uns.ac.rs
[3] Aleksandar ŽIVKOVIĆ, Faculty of Technical Sciences, Novi Sad, Trg Dositeja Obradovića 6, acoz@uns.ac.rs

details bearings mounted on the axle.

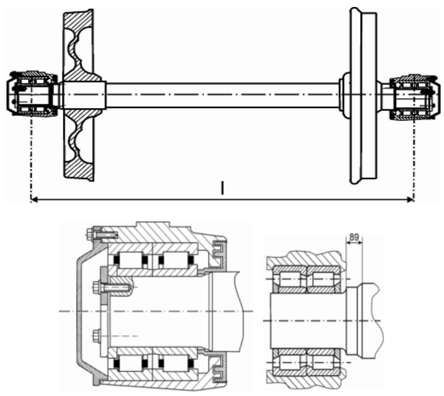


Figure 1. Assembly wheel with details bearings

This paper considers only the heat generated in the bearing (without heat generated by the movement of wheel on railway line). The heat generated determined on the basis of the friction torque due to lubrication and friction moment due to the load (axial and radial) [1].

2.2 Determination of the moment of friction

$$M = M_0 + M_1 + M_2 \text{ \{Nmm\}} \quad (1)$$

M_0- friction moment due to lubrication,
M_1- friction moment due to the radial load,
M_2- friction moment due to axial load.

$$M_0 = 10^{-7} \cdot f_0 (\nu \cdot n)^{\frac{2}{3}} \cdot d_m^3 \text{ \{Nmm\}} \quad (2)$$

f_0 – coefficient depended of the bearing type and lubrication type (for cylindrical roller bearing it value is 3),
ν- kinematic viscosity of the grease ν=18,
n- bearing speed [rev/min],
d_m - middle diameter bearing (d_m=190 mm).

$$M_1 = f_1 \cdot F_r \cdot d_m \text{ \{Nmm\}} \quad (3)$$

$$F_r = \frac{G}{4 \cdot n_t} \quad (4)$$

f_1 - coefficient which depends of the bearing type (for cylindrical roller bearing it value is between 0,0003-0,0004),
F_r- radial static load acting on one bearing (F_r= 55181 N),
G- weight of the vehicle,
n_t- number of wheel sets.

$$M_2 = f_2 \cdot F_a \cdot d_m \text{ \{Nmm\}} \quad (5)$$

f_2-based on n d_m ν i F_a/A,

$$A = k_B \cdot 10^{-3} \cdot d_m^{2,1} \quad (6)$$

A-surface,
F_a-axial load bearing.

The axial load bearing occurs when the train move a curve. For a radius curvature R=500 m and height superelevation on one side stripes h=110 mm can be defined by the maximum permitted speed move of the train in a curve, and it is v=68 km/h. The value of axial load calculated for the speed of move the train in a curve of v=50 km/h.

Table 1 shows the values of the friction moment due to lubrication, radial and axial load, and the total value of the friction moment M for the different speed movement of the train.

Table 1. The values of the friction moment

n {rev/min}	M_0 {Nmm}	M_1 {Nmm}	M_2 {Nmm}	M {Nmm}
300	629	4193	25080	29902
450	991	4193	25080	30264
700	1107	4193	25080	30380

2.3 Determination of the heat generated in the bearing

Heat generated in the bearing determined by the equation (7):

$$Q_{uku} = 1{,}05 \cdot 10^{-4} \cdot d_m \cdot n \left[f_0 (\nu \cdot n)^{\frac{2}{3}} \cdot d_m^2 \cdot 10^{-7} + f_1 \cdot F_R + f_2 \cdot F_a \cdot 0{,}1 \right] \text{ \{W\}} \quad (7)$$

In table 2 shown the values of heat generated during movement of the train at speed of 50, 80 and 120 km/h (operational speed bearing). Accepted that the vagon has such a path in exploitation to move 90% straight and 10% in the curve (5 % left and 5 % right curves and the speed of movement in curve v=50 km/h, this values have been adopted on the basis of recommendations for calculation bearing wheel car).

Table 2. Value of the generated heat

n {rev/min}	Q_{uku}{w}
300	231
450	364
700	573

3. THE HEAT TRANSFER MECHANISM IN THE BEARING

Heat transfer mechanism at bearing is convection due to the rotation, conduction between the inner ring and the axle and the outer ring and housing [1].

3.1. Convection due to rotation the bearing

Heat transfer through the bearing is realized only between bearing and surroundings air. Absorbed heat from the grease, in this paper is not discussed. Because of the small difference in temperature, radiation could be neglected; coefficient of the heat transfer is calculated according to condition of the flow air through bearing which belong to the turbulent motion. At this transfer, total airflow velocity, caused by the bearing rotation, is calculated from the axial and tangential component.

Coefficient convection is calculated according to [1]:

$$\alpha = (c_0 + c_1 \cdot U^2) \ \{W/(m^2 K)\} \quad (8)$$

In table 3 shows the values of the coefficient of convection during rotation bearing, depending on the speed.

Table 3. The values of the coefficient of convection during rotation bearing, depending on the speed

Speed bearing {rev/min}	Coefficient convection $\{W/m^2K\}$
250	10,5
450	35,3
700	71,2

3.2. Heat convection between ring and housing and ring and axle

The coefficient of thermal conductivity depends on the gap between the outer ring and the housing and the inner ring and axle. Thermal conductivity between the two elements can be determined on the basis of equation [7]:

$$\lambda_{ij} = \frac{\ln\left(\frac{r_j}{r_i}\right)}{\frac{\ln\left(\frac{r_j}{r_1}\right)}{\lambda_j} + \frac{R_W}{r_1} + \frac{\ln\left(\frac{r_1}{r_i}\right)}{\lambda_i}} \quad (9)$$

where are λ_i i λ_j thermal conductivity of ring and housing. Other marks are shown in paper [7].

In the previous equation R_w represents the thermal contact resistance on place of contact of the ring with housing, and according to [7] can be calculated as follows:

$$R_w = \frac{r_1}{\lambda_{ij}} ln\left(\frac{r_1+\Delta}{r_1}\right) \quad (10)$$

where is Δ - clearance between outer ring and housing.

On similar method are determine conduction at contact between the inner ring and axle.

In Table 4 shows the values coefficient thermal conductivity of certain based on the previous equation.

Table 4. The values of coefficient thermal conductivity between the ring and the housing and ring and axle

Place contact	Coefficient conduction $\lambda \{W/m^2K\}$
Inner ring/axle	60,5
Outer ring/ housing	90,9

4. MODELING THERMAL ELASTIC BEHAVIOR

Setting the coordinate system, the choice of contact pairs (CONTA 174, 53 contact pairs), defining the heat generated in the bearing, the choice of the type of finite element (SOLID 87, mesh than 8021 elements and 31720 nodes) and defining the elements between which there is conduction and convection heat transfer has been done in the framework of preprocessing.

After the calculation and after postprocessing obtained is graph showing the temperature distribution on elements bearing for speed n=700 rev/min, respectively with speed moving a train of 120 km/h (Figure 2). The maximum temperature is marked with red color and equals to 64 °C and minimal with blue and equals to 52 °C in the steady temperature state bearing.

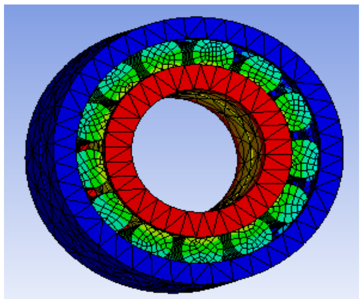


Figure 2. Graphical representation temperature on elements bearing

Based on results of modeling in Figure 2 show temperature changes on rings bearing in depending from time for three different speeds movement of the train (v=50, v=80 i v=120 km/h. In diagram maximum temperature represents temperature of the inner ring and the minimum temperature is the temperature of the outer ring. Observation diagram shows in Figure 3 can see that the steady temperature state bearing with highest speed motion (n=700 rev / min, v=120 km/h) reached in shortest period of time.

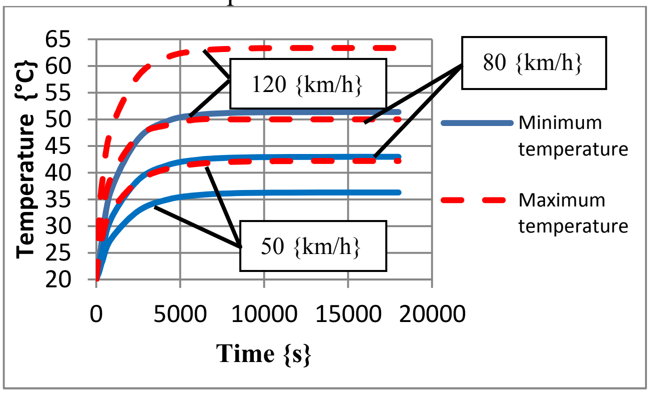


Figure 3. Change of the temperature on rings bearing depending on the time and speed of movement

Based on the previously defined thermal model (temperature fields) can be determined by displacement in nodes bearing. The thermal load is defined on basis of the results of thermal analysis, and it represents the temperature of in nodes of the bearing. On elastic model is necessary to define limits displacement and it is shown in Figure 4.

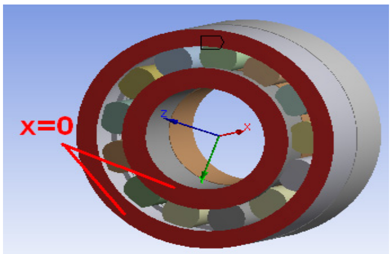
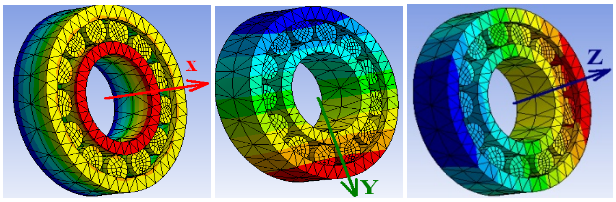


Figure 4. Constraints displacement

In Figures 5 a. (displacement in the direction of x-axis), 5 b. (displacement in the direction of y-axis) and 5 c. (displacement in the direction of z-axis) shows the computer models of cylindrical rolling bearings for railway after heat load for bearing speed n=700 rev/min in the direction x, y and z axes.



a. b. c.

Figure 5. The results of computer modeling of elastic behavior of the bearings after effects of heat load

The obtained results can be seen that maximum displacement in the axial direction (x-axis) was 51 μm, and in radial direction displacement were 55 μm (y and z axis).

Stress (Von Misses's) appearing in bearing have a maximum value at the place of contact rollers and outer ring bearing and the amount 58 N/mm^2.

5. CONCLUSION

In this paper were analyzed thermal elastic behavior cylindrical roller bearings for railway with application finite element method. Based on the results of thermal behavior can be seen that the maximum temperature bearing was 64 °C which is considerably less than the maximum permissible temperature of 120 °C.

The calculated bearing life corresponds to the required recommendations EN C (2006) 3345 and amounts 1000000 kilometers.

ACKNOWLEDGEMENT

In this paper presents the results of the research on project "Modern approaches in the development of special solutions bearings in mechanical engineering and medical prosthetics" TR 35025, financed by Ministry of Education, Science and Technological Development of Republic of Serbia.

REFERENCES

[1] Bossmanns, B., Jay, F.: A thermal model for high speed motorized spindles, International Journal of Machine Tools and Manufacture, ISSN: 0890-6955, Vol. 39, Pages 1345-1366, 1999.

[2] Brkljač, N.: Proračunski modeli nosećih konstrukcija sa primenom na rešenja železničkih vagona za prevoz tereta, Doktorska disertacija, Fakultet tehničkih nauka, Novi Sad, 2013.

[3] Cole, D., K., Tarawneh, M., C., Fuentes, A., A., Wilson, M., B., Navaro, L.: Thermal models of railroad wheels and bearings, International Journal of Heat and mass transfer, ISSN:0017-9310, Volume 53, Issue 9-10, Page: 1636-1645, 2010.

[4] Fekete, G., Varadi, K.: Thermal FE analysis of a one side brake block test equipment (Part 1), Periodica polytechnic, Mechanical Engineering, doi: 10.3311/PPme.7014, Page: 27-33, 2013.

[5] FKL, Tehnička dokumentacija za ležaj NJ 324 EC.M C4 VA301, Br. 9560, Temerin, 2009.

[6] Gerdun, V., Sedmak, T., Šinkovec, V., Kovše, I., Cene, B.: Failures of bearings and axles in railway freight wagons, Engineering Failure Analysis, ISSN: 1350-6307, Volume 14, Issue 5, Page: 884-894, 2007.

[7] Jedrzejewski, J.: Effect of the thermal contact resistance on thermal behavior of the spindle radial bearings, International Journal of Machine Tools and Manufacture, ISSN: 08909-6955, Vol.28, No.4, Pages 409-416, 1988.

[8] Lundberg, J., Parida, A., Soderholm, P.: Running temperature and mechanical stability of grease as maintenance parameters of railway bearings, ISSN: 1751-8520, Volume 7, Issue 2, Page: 160-166, 2010.

[9] Sostarics, G., Balog, V.: Vasúti járművek, Tankönyvkiadó, ISBN: 963 18 3113 2, Budapest, 1991.

[10] Timošenko, S. P.: Istorija otpornosti materijala, Građevinska knjiga, Beograd, 1965.

[11] Winston, C.: The United States: Private and deregulated, str. 135-153 / Competition in the railway industry: An international comparative analysis, Massachusetts, SAD, 2006.

Strategy and Policy

QUANTIFYING LANDSCAPE FRAGMENTATION DUE TO RAIL INFRASTRUCTURE

Nataša BOJKOVIĆ [1]
Marijana PETROVIĆ [2]
Snežana PEJČIĆ TARLE [3]

Abstract *– Landscape fragmentation caused by railroads and other linear infrastructure poses ecological implications which are increasingly coming into focus of attention of transport planning and policy. The paper highlights the potentials of the effective mesh size as a tool for quantification and monitoring landscape fragmentation. The sensitivity of this metric to the location of crossing structures that increase the permeability of railroads is demonstrated within an illustrative example.*

Keywords – Fragmentation metric, railroad, effective mesh size, crossing structures.

1. INTRODUCTION

Fragmentation of landscapes is increasingly recognized as a serious threat to population viability and ecological balance, thereby it became an important ecological issue. The division of contiguous areas into smaller fragments/patches adversely affects the inhabited population. Fragmentation processes limit the movement of living beings and thus expose them to an increasing risk of extinction. The persistence of population in fragmented landscapes in great deal depends on the characteristics and properties of the species in terms of their mobility/dispersal, area requirements or dependence on a certain type of habitat.

Together with agriculture, urbanization and other built-up areas, transport infrastructure is one of the main causes of fragmentation. The necessitate to preserve habitats on one side and the growing need for transportation of people and goods on the other, call for joint efforts in resolving conflicts between infrastructure projects and environment.

The construction of transport infrastructure directly splits natural habitats into small fragments, but it also affects further alteration of landscapes by stimulating new activities around. Because of the higher network density and intensive traffic, fragmentation caused by road transport routes has been investigated more than railways. However, with the increasing speed, rail becomes less adapted to landscapes features as well. Such as roads, railways increase the accessibility for human population, and induce radical transformation of land-use. On the other hand, the establishment of high speed railways (HSR), with the unique structural and functional characteristics and construction requirements raised the need to study its impact on wildlife. Fences that surround HSR network allow safe traffic but also create barriers such as those imposed by highways.

At the European level, the important initiative which demonstrates the effects of habitat fragmentation caused by both road and rail infrastructure is the COST 341[1] project. This project highlights the significance of evaluation of fragmentation and barrier effects in the process of transport infrastructure planning. One of the project findings is that the mitigation measures will be more effective in the early stage of planning. It means that the environmental effects should be accounted for at different level of planning processes. Within Strategic Environmental Assessments (SEA), the environmental considerations should be integrated in the decision-making process for all new large-scale planning policies. At the project planning phase, the

[1] *COST 341 Habitat Fragmentation due to Transportation Infrastructure*

[1] Nataša BOJKOVIĆ, Faculty of Transport and Traffic Engeneering, University of Belgrade, Vojvode Stepe 305, n.bojkovic@sf.bg.ac.rs
[2] Marijana PETROVIĆ, Faculty of Transport and Traffic Engeneering, University of Belgrade, Vojvode Stepe 305, marijanap@sf.bg.ac.rs
[3] Snežana PEJČIĆ TARLE, Faculty of Transport and Traffic Engeneering, University of Belgrade, Vojvode Stepe 305, s.tarle@sf.bg.ac.rs

Environmental Impact Assessments (EIA) is to be made for the specific infrastructure project as well as for alternative solutions. Experts in various fields have input in these assessments - transport engineers, planners, conservation biologists, landscape ecologists. For the defined study area, the EIA consists of several phases including: Inventory stage (mapping and assessment of natural features); Evaluation of possible conflicts and assessment of risk of fragmentation; Iterative process of project location and design (changes of routing and alignments, planning of mitigation measures and other types of environmental adaptation); Selection of alternatives to be considered in the EIA process; Planning of mitigation and compensatory measures.

An important issue which facilitates the selection of best possible solutions is the development of appropriate ways to quantify landscape fragmentation. Some of the existing metrics are listed in the next chapter.

2. LANDSCAPE FRAGMENTATION METRICS

To indicate the degree of landscape fragmentation, a variety of environmental variables are used. Although in most applications a single metric is not enough, this does not diminish a need to develop indices for assessing and monitoring the level of fragmentation that can be easily used by transportation planners and decision-makers. The indices should provide time- series data about landscape fragmentation that can be used for monitoring the state of the landscape and changes over time. Among other things, the existing metrics differ by their effectiveness in the description of the various changes in the structure and configuration of the landscape. Some standard measures are: Number of Patches - NP, Mean Patch Size - MPS, Patch Size Coefficient of Variation – PSCV, LSI - Landscape Shape Index - LSI, Largest Patch Index – LPI, Aggregation Index – AI, Landscape dissection index LDI, etc. For the comprehensive review and analysis, see [1], [2].

In addition to the above, there are metrics suggested specifically to fragmentation resulting from transport corridors like: Density of Transportation Lines (DTL; in relation to total area of the landscape) and the Number of the remaining large Undissected Low-traffic Areas, larger than 100 km2 (nUDA100) [3]. In terms of practical use, the metric called effective mesh size (m_{eff}) proposed by Jaeger [4] has become a standard measure to compare the fragmentation on a large scale - at the level of countries and regions. Since its suitability for practical application, it is included in EEA – TERM 2011 indicators (European Environment Agency - Transport indicators tracking progress towards environmental targets in Europe). In addition, a user-friendly geographic information system (GIS) tool for calculating the effective mesh size was developed to monitor the differences among regions according to the degree of landscape fragmentation [5]. This allowed the inclusion of quantitative data on the degree of landscape fragmentation in the environmental reporting.

Beside mathematical simplicity, important feature of effective mesh size is its consistent/monotonic response to the different stages of fragmentation processes. Effective mesh size has been proved to be suitable for different fragmentation phases like: perforation, incision, dissection, dissipation, shrinkage and attrition, as investigated in [4]. Mathematical expressions of m_{eff} as well as some upgrades are described below.

3. EFFECTIVE MESH SIZE AND ITS ADAPTATIONS

The metric is based on the probability that two randomly chosen points in the study area are not separated by any artificial barrier, i.e. are located in the same unfragmented area-patch. The m_{eff} can be interpreted as a measure of biodiversity conversation, since the probability of individuals to encounter each other is the prerequisite for reproduction and thus for the persistence of species and genetic exchange. The m_{eff} is calculated using the formula [4]:

$$m_{eff} = \frac{1}{A_{total}} \sum_{i=1}^{n} A_i^2 \tag{1}$$

Where n is the number of patches, A_i represent the patch size, and A_{total} is the total area of the investigation.

The important adaptation addresses the problem of potential biased assessment of landscape fragmentation. Namely, the boundaries of the reporting units do not have to be the elements of landscape fragmentation. To solve the boundary problem, new calculation procedure that considers complete patches including those parts of the patches that are outside of the reporting unit. This adaptation is known as the cross-boundary connections (CBC) procedure [6]. It is calculated as:

$$m_{eff}^{CBC} = A_{total}^{cmpl} \sum_{i=1}^{n} \left(\frac{A_i}{A_{total}} \frac{A_i^{cmpl}}{A_{total}^{cmpl}} \right) = \frac{1}{A_{total}} \sum_{i=1}^{n} A_i A_i^{cmpl} \tag{2}$$

Where A_i^{cmpl} is the area of the complete patch that A_i is a part of, including the area on the other side of the boundaries of the reporting unit up to the physical barriers of the patch.

Another adaptation addresses the permeability of transport routes. To take into account the barrier strength, an additional term should be embedded in the formula of the effective mesh size, in the following form [7]: $2 \cdot A_i \cdot A_j \cdot (1 - B)$ where A_i and A_j are adjacent patches and B is the strength of the barrier between them and $0 < B < 1$.

Increase in permeability due to crossing structures can also be taken into account by terms in the form of [7]: $2 \cdot A_i \cdot A_j \cdot D \cdot N$,where D is the perforation of the route between patches A_i and A_j as determined by the number of crossing structures and N is the willingness of the species to use crossing structures. These values should be determined from empirical data.

4. AN EXAMPLE OF COMPARATIVE ANALYSIS OF THE CROSSING STRUCTURE LOCATIONS USING m_{eff}

The construction of crossing structures along railroads enables restoration or maintenance connections across the landscapes. Over recent years, efforts have been made to create their design that meets technical and environmental requirements. They should enhance the incorporation of crossing structures into the movement patterns. Due to high construction costs, the location of crossing structures is of importance.

To illustrate the incorporation of the permeability effect into landscape fragmentation metric, a case with two railway routes and three crossing structures is presented. It is assumed that the acceptance of crossing structures is N = 0.95, and a perforation of railway line by one, two and three crossing structures are D_1= 0.4, D_2 = 0.6, D_3 = 0.75 respectively. The crossing structures are located in different ways (Fig. 1).

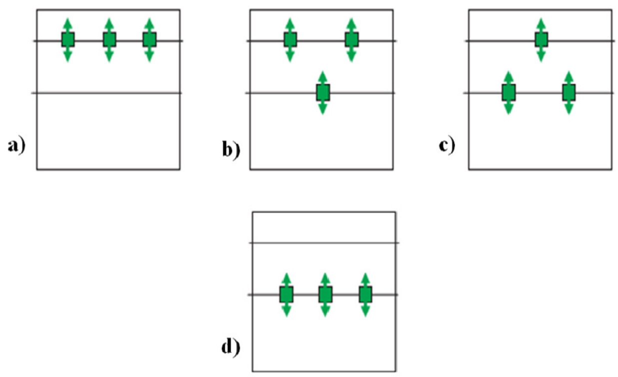


Fig. 1. Different locations of crossing structures on habitat (A_{total}=100 km^2) with tree patches (A_1 = 20 km^2, A_2 = 30 km^2 i A_3=50 km^2)

Effective mesh size is calculated for each case:

$$m_{eff}^{a)} = \frac{1}{A_{total}}(A_1^2 + A_2^2 + A_3^2 + A_1 \cdot A_2 \cdot D_3 \cdot N) = 42{,}27km^2$$

$$m_{eff}^{b)} = \frac{1}{A_{total}}(A_1^2 + A_2^2 + A_3^2 + A_1 \cdot A_2 \cdot D_2 \cdot N + $$
$$+ A_2 \cdot A_3 \cdot D_1 \cdot N) = 47{,}12km^2$$

$$m_{eff}^{c)} = \frac{1}{A_{total}}(A_1^2 + A_2^2 + A_3^2 + A_1 \cdot A_2 \cdot D_1 \cdot N + $$
$$+ A_2 \cdot A_3 \cdot D_2 \cdot N) = 48{,}83km^2$$

$$m_{eff}^{d)} = \frac{1}{A_{total}}(A_1^2 + A_2^2 + A_3^2 + A_2 \cdot A_3 \cdot D_3 \cdot N) = 48{,}69km^2$$

The most preferable case is the one with the highest value for m_{eff} (the case c), i.e. $m_{eff}^{c)}$. This means that the decision-maker should first consider building two crossing structures between larger patches and one towards the smallest patch.

5. CONCLUSION

Contemporary transportation planning and policy interacts with manifold fields, where one of the biggest challenges is the convergence with conservation biology. In this paper we discuss the fragmentation metrics that can help in evaluating the disturbance of wildlife caused by railway and other linear infrastructure. As we emphasized, one of the promising metrics of this kind is the effective mesh size, m_{eff}, which can be upgraded from various perspectives including as to account the issue of permeability. Using a simplified example we illustrated how the location of crossing-structures along railroad affects m_{eff} and thus the level of fragmentation. To test the calculations in real conditions, empirical data on movement patterns should be provided.

ACKNOWLEDGEMENT

This paper is a part of the project “Critical infrastructure management for sustainable development in postal, communication and railway sector of Republic of Serbia”, funded by the Ministry of Education and Science of the Republic of Serbia, Project number: TR36022.

REFERENCES

[1] Leitão, A. B., Miller, J., Ahern, J. and McGarigal, K., Measuring landscapes — A planner's handbook, Island Press, Washington DC, 245 pp. 2006.

[2] Peng, J., Wang, Y., Zhang, Y., Wu, J., Li, W., Li, Y., Evaluating the effectiveness of landscape metrics in quantifying spatial patterns, Ecological indicators, 10, 2010.

[3] Jaeger J.A.G, Madriñán, L.F., Soukup, T., Schwick, C., Kienast, F., Landscape fragmentation in Europe, Joint EEA-FOEN report, EEA report 2, 2011.

[4] Jaeger JAG. Landscape division, splitting index, and effective mesh size: new measures of landscape

fragmentation. Landscape Ecol 2000;15(2):115–30.
[5] ESRI, 2005. ArcGIS 9.1. 2005. Environmental Systems Research Institute, Redlands, CA.
[6] Moser, B., Jaeger, J.A.G., Tappeiner, U., Tasser, E., Eiselt, B., 2007. Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem. Landscape Ecology 22, 447–459.
[7] Jaeger JAG. Effects of the Configuration of Road Networks on Landscape Connectivity. In C. L. Irwin, D. Nelson, K.P. McDermott (Eds.) Proceedings of the 2007 International Conference on Ecology and Transportation (pp. 267-80). Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

IMPROVING QUALITY OF SERIVCE FOR PEOPLE WITH DISABILITIES IN RAILWAY TRANSPORT

Dragan ĐORĐEVIĆ [1]

***Abstract** – Allowing the movement, providing same condition, and services to all people certainly leads to the path of a successful community. To increase the mobility of persons with disabilities as a precondition provide adequate regulations and their application of accessibility to buildings, such as services that can be provided. The main objective of the planning service and installation of such systems to ensure easy traveling of this category of passengers traveling by rail as a part of the public transport system. This paper is devoted to pointing out ways to improve essential services by rail provided which includes a way of providing information, covering the possible routes, timetables, information about the accessibility of stations and trains, etc.. Although the Serbian Railways has made a significant contribution in this area, it is necessary to make further efforts in which the contribution in which direction it is necessary to go to improve the services which they need to provided to persons with disabilities in rail transport.*

Keywords – Quality of service, methodology, railway transport, people with disabilities.

1. INTRODUCTION

Transportation of persons with disabilities requires certain conditions, service, resources and way different from passengers who have not a disability. In developing countries and country with the lower economic development ability to satisfy these services depends first of sufficient financial resources for infrastructure development and provision of sufficient quality staff.

In this paper, the first part was completed by review of the existing ways of monitoring the data of bus and rail transport, considering the problem through policy at the level of the carrier and the national transport strategy, in the second part it is made a review of further steps about procedure that could be applied to monitor the quality of passengers services and at the third section is presented a part of research carried out in connection with the performance of transport by train for persons with disabilities in the City of Belgrade.

2. REVIEW OF LITERATURE

For the observed problem generally is made methodology for analysis and for the data collection is done through a survey.

According to [1] a general approach to data that is collected is divided into four groups: whether the new system will allow greater mobility for the elderly, what kind of behavior the passengers have in their daily activities, what kind of problems they have in achieving the transport services and providing opinions on new service. In the analysis of [2] an analysis of passenger data regarding the distributions of origin places, the distributions of destination locations, access, travel and trasffer time, costs and behavior. In a survey [3] conducted a survey accessibility of heavy rail services where more attention was given to qualitative research rather than of quantitative. One of the most comprehensive document [4] which examines the satisfactions user of the rail service, at the request of the European Commission, Directorate-General Mobility and transport provides a unique overview of a large number of data perceived two major sections: Rail passenger satisfaction and accesibility of railway stations.

In a study [1] were analyzed ways to improve planning service bus transportation for seniors with an overview of the behavior of passengers, the social aspect of relations between the problems of the transport system and mobility, improving transport policy. The focus of research [2] contained data on the frequency of use of the vehicle, socio-economic character of the passengers, the difficulty in achieving the transport of passengers and their satisfaction service. The survey [3] compared to the previous two methods carried out a survey among companies

[1] Dragan ĐORĐEVIĆ, MSc. Traff. Eng. Institute of transportation CIP, 6/IV Nemanjina St., Beograd, Srbija, dragandjordjevic@hotmail.com

engaged in transportation of passengers with the aim of understanding the current trends in relation to persons with reduced mobility, identification of the use of different standards and their unification in the field of European countries. The paper [3] have been followed by three parts: legislative framework and policy recommendations in use across Europe, accessing the platform and vehicle and travel information and journey.

Certainly in terms of perception and overcoming the problems of persons with disabilities the transport strategy and also national strategy for people with disabilities or a combination of both in terms of reducing social exclusion and transport have contibution.

A good example of observing the general human development can certainly be smaller percentages of the social exclusion of certain groups in society. Transport and its availability in [5] is seen as one of the links, which is necessary for the exercise of all rights, enabling new capabilities of the individual and society, such as. going to school, to work, carrying out high-quality mental health care and etc. has support of the highest state authorities in England.

Transport strategy are made for a certain period of time with a view to considering all aspects that can bring prosperity to a country in transit.

Survey [7] is set to using certain indicators inspect the progress of the implementation of the National Disability Strategy.

Bearing in mind all the different ways that can be viewed problem of achieving better services, and that by itself it is not an activity that is carried out only for profit but also allowing the general social inclusion of all members of a community.

3. FURTHER STEPS

It is believed that due to the development of the railways it is very important to pay attention to railway staff [8]. In research to be implemented in conjunction with disabled staff assistance is of great importance because a large number of categories of passengers require some kind of assistance. Assisting passengers with disabilities in most cases reflected the physical assistance with entry / exit in buildings and vehicles, providing information and a sense of security. If we pay attention to this type of service we will have certainly contribution of reducing barriers not only the physical nature of the use of railways by people with disabilities.

In the paper [9] are presented a set of indicators that are classified according to criteria related to accuracy, safety, cleanliness, comfort of passengers, passenger service and information. The processed data are quantified and developed multicriteria for their assessment. The aim of this analysis has provided to get a good tool for assessing the quality of service for passengers.

In a study [10] is observed a mark of quality for transportation services in all aspects of passenger transport and is a separated analysis of the assessment of transport services by rail. Data on attitudes were collected through questionnaires and they contained the following questions: relationship trip frequency, travel motivations, attitudes remarks on railways, possible alternatives for transportation and suggestion on how to improve transportation services.

Plan [11] which are carried out in the United Kingdom can be seen that there is a great effort in solving problems of transport people with disabilities by rail. This approach involves all levels of government and all holders of railway transport services in order to allow equal accessibility to all categories of railway passengers.

Considering the problems related to the realization of travel for people with disabilities, it can be seen that it is necessary to carry out continuous monitoring of data to this category of passengers to better social inclusion of all social activities. According to the author believes that monitoring the quality of rail transport on the one hand there is a user with the requirements and on the other side service provider. In order to measure the impact beatwen each other it is necessary to measure the quality of service. Measuring the quality of services must be carried out with studies wich contain data shown in Fig. 1.

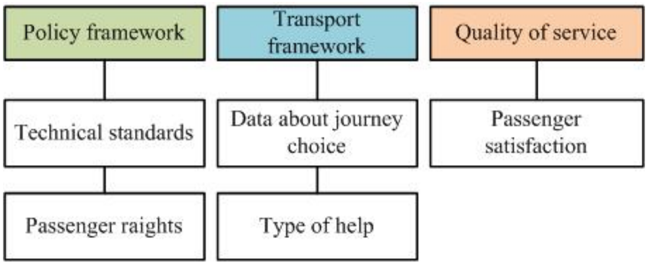


Fig. 1. The parameters for measuring the quality of providing rail transport services for passengers with disabilities

The diagram is classified in various areas, and they need to determine the following:

- In the policy framework it is necessary to determine whether the observed all the necessary technical standards for passengers and their raigts in transport are satisfied,
- In the transport framework is necessary to determine information about destinations and types of travel and essential assistance in achiving the same,
- In the quality of service it is necessary to determine the level with direct surveys of customer satisfaction in terms of availability, timetables, information, ticket price, safety, reliability, staff behavior, cleanliness etc.

4. RESEARCH RESULTS

During the first half of 2014., In the area of Belgrade was carried out qualitative research with particular associations of people with disabilities in order to determine the level of satisfaction and the use of railways as a public transport. Unlike the test of the quantitative data provided in detail, considering the qualitative examination of a smaller number of questions. Quantitative analysis has been made as brief overview of how people with disabilities use the railroad and what kind of attitude have about it.

This research looked at the problems and observations of two groups of persons with disabilities as follows: motor dsability (muscular dystrophy, and cerebral palsy, multiple sclerosis, paraplegia) and sensory impairments (blind and visually impaired persons).

Although not considered all groups of persons with disabilities can be said that information obtained from given data can give a very good picture of what problems people with disabilities can meet or encounter when using the train as a means of transportation.

Structure issues in research for this report in relation to the known number of users and the main reasons for the use or non-use of railways as a means of transportation. Figure 2 shows the reasons for use or non-use of railways.

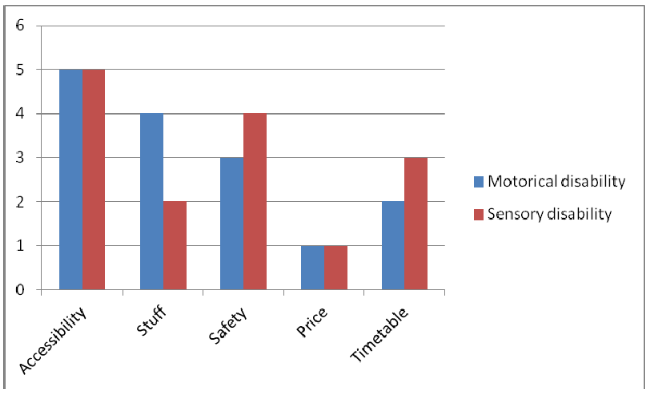


Fig. 2. The survey results (1 the most favorable, 5 the least favorable rating)

In both groups of persons with disabilities in a larger number of persons is needed companion in the movement. For all groups as well as the accessibility is the problem number one. Depending on the level of assistance that can be provided by staff persons with mobility impairments play a very important role. From the standpoint of an independent movement for people with sensory disabilities is very important security impact. In further analysis, it was noted that the timetable and ticket price may not be of significance if presdnog are sustainable because in some cases there is the possibility of donating some different trips that are not included in the regular discounts for persons with disabilities.

5. CONCLUSION

In determining the required level of service that can provide travelers must take into account all categories of travelers.

Serbian Railways [12] in the provision of certain services to people with disabilities perform as best as they can in accordance with their capabilities in terms of rolling stock and infrastructure and the types of services that are provided are realized to the fullest extent possible. The level of provision of these services is not satisfactory because it does not provide sufficient quality. Serbia as a future member of the European Union will have to do much more on this field because they will expect it to participate equally in the provision of transport services to all citizens at the same level.

As a next step in order to achieve a certain level of service in transport by train, with the assumption that there are adopted infrastructure and rolling stock, is proposed on the one hand approval of new methodologies for monitoring and research of the service provider that offers travelers (satisfaction monitoring transport and types of accidents that are occurred in travelers with disabilities), and on the other hand, setting up and implementation of new services that are directly related to passengers with disabilities. Time-based method of data collection make the legality of the observation of certain phenomena related to particular group of passengers. Overview of services provided by the railways in the form of new information (to perform certain types of train travel) must be available in all types of media, especially with the wide range of filtering data over the Internet [13], placing additional forms to aid in the performance of the railway transportation of persons with disabilities [14]. In addition to the information must include better training of railway personnel.

Number of persons with disabilities in a huge number of forms from category of passengers that can certainly contribute a lot in increasing the revenues of the railways, on the other hand, as a public carrier is required to provide equal use of transport for all passengers. Given these circumstances, rail traffic can be certainly one of service that in the futuret can count people with disabilities.

REFERENCES

[1] Yasutusugu. N., Gunseop D.: Special bus service planning for improving mobility of elderly people considering travel effort, Journal of the Eastern Asia Society for Transportation Studies, Vol 2, No. 5, Autumn, 1997

[2] Siti N. AB. K., John P., Masria M.: Passenger Travel Profiles through Origin-Destination (OD) Surveys for Malayan Railways Limited. Proccedings of the Eastern

Asia Society for Transportation Studies, Vol 9, 2013
[3] European Metropolitan Transport Authorities: Survey about accessibility of heavy rail services, Berlin November 2011
[4] Flash Eurobarometar 382a: European's satisfaction with rail services, december 2013
[5] Social Exclusion Unit: Making the connections (Final report on transport and Social Exclusion), London, February 2003
[6] Social Exclusion Unit: Making the connections (Final report on transport and Social Exclusion), London, February 2003
[7] Susan C.: Survey on national Disability Strategy Indicators 2011, Prepared for national Disability Authority
[8] http://actionforrail.org/what-does-the-future-of-railway-staffing-mean-for-disabled-and-older-passengers/
[9] Eftihia N.: Measuring the quality of service for passengers on the hellenci railways, Transportation Research Part A 42 (2008) 48-66
[10] Olga C. i dr.: Istraživanje komponenti kvaliteta prevoznih usluga u cilju definisanja mera za povećanje kvaliteta usluga u železničkom putničkom saobraćaju, Saobraćajni institut CIP, Beograd, 1992.
[11] Railways for All, The plan to Make Great Britain's Railways More Accessible, Department of Transport UK, 2006
[12] http://www.zeleznicesrbije.com
[13] http://www.nationalrail.co.uk /stations_destinations/disabled_passengers.aspx
[14]] http://www.disabledpersons-railcard.co.uk

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

DATA DRIVEN MODEL FOR PREDICTION OF RAIL TRAFFIC

Luka LAZAREVIĆ [1]
Miloš KOVAČEVIĆ [2]
Zdenka POPOVIĆ [3]

Abstract *– The rail system, as a system with high capacity, the least air and water pollution, solvable noise and vibration emission problem and the least space usage, is competitive with other modes of transportation. In addition, European transport policy supports shift from road to rail and waterborne transport. It is expected that changes in rail traffic volume be followed by changes in certain economic parameters. On the other hand, changes in economy influence rail traffic volume. The aim of this paper is creation of the data driven models for prediction of rail traffic volume in different economic contexts, using world development indicators, defined by the World Bank, as input parameters.*

Keywords – Rail traffic, data driven model, prediction, World Bank, development indicators.

1. INTRODUCTION

European transport policies were at first directed at the development of the road network. Fast increase in number of vehicles resulted in higher road congestion, and thus the increase of air pollution and the number of traffic accidents. It was obvious that road development has limited potential, especially in densely populated areas.

Although construction costs for roads are, in general, lower than construction costs for railways, for high traffic volumes external cots are significantly lower on railways. Therefore, the rail system as a high capacity system with the least air and water pollution, solvable noise and vibration emission problem and the least space usage became competitive with other modes of transportation.

The European Union (EU) defined a common transportation policy in its White Paper entitled "Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system" [1]. This policy defines 10 goals for reaching a competitive and resource efficient transport system. Four of these goals are directed towards the use of rail transport:

- to shift 30% of road freight over 300 km to rail or waterborne transport by 2030, and more than 50% by 2050,
- to complete European high-speed rail network by 2050, triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States,
- to complete a fully functional and EU-wide multimodal Trans-European Transport Network (TEN-T) by 2030, with a high quality and capacity network by 2050 and a corresponding set of information services, and
- to connect by 2050 all network airports to the rail network, preferably high-speed, and to ensure that all seaports are sufficiently connected to the rail freight and, where possible, inland waterway system [1].

It is expected that achievement of these goals will be followed by certain economic changes. On the other hand, economic changes can influence the changes in rail traffic volume.

The aim of this paper is creation of a data driven model for prediction of changes in rail traffic volume based on the changes in economic parameters. Two countries were chosen for the creation of the model, Serbia and Austria since they have similar area, population and population density [2]. For both countries, it was separately analysed freight and passenger traffic.

As economic parameters, there were used world development indicators defined by the World Bank [3]. The models were developed using software Weka 3, a collection of machine learning algorithms for data mining tasks, developed at the University of Waikato [4,5].

[1] Luka LAZAREVIĆ, master inž.građ., University of Belgrade, Faculty of Civil Engineering, llazarevic@grf.bg.ac.rs
[2] Miloš KOVAČEVIĆ, dipl.inž.elektr., University of Belgrade, Faculty of Civil Engineering, milos@grf.bg.ac.rs
[3] Zdenka POPOVIĆ, dipl.građ.inž., University of Belgrade, Faculty of Civil Engineering, zdenka@grf.bg.ac.rs

2. DATA REPRESENTATION

The first task was to choose the appropriate data representation and prepare a dataset that will be used for building and validation of the proposed prediction model. As it was stated above, world development indicators were chosen as economic parameters to represent the predictors of the traffic for each year in both countries. World Bank (WB) divides these indicators into ten groups: education, environment, economic policy and debt, financial sector, health, infrastructure, social protection and labor, poverty, private sector and trade, and public sector [3]. Two of the infrastructure indicators are data about freight and passenger rail traffic. WB databank provides rail traffic data from 1980 to 2012, therefore this time range was chosen to build the proposed models.

Since the indicators have different orders of magnitude and measure units, their values were replaced with relative changes (changes in percentage comparing to the previous year). The same processing was applied on the rail traffic data. Both modifications on the dataset ensured the model aim - establishing the correlation between economic changes and changes in rail traffic.

From the aspect of machine learning, relative changes of world development indicators represent numerical attributes. On the other hand, relative changes of rail traffic were represented as nominal values (classes):

- decrease in rail traffic was denoted as N (relative change is negative), and
- increase in rail traffic was denoted as P (relative change is positive).

Introduction of two classes transformed the problem of prediction of rail traffic into a simple classification task. The prediction model was built from the data to classify the change in rail traffic whether as positive or negative based on the relative changes of world development indicators in the related country.

	attributes					classes	
	A_1	A_2	...	A_{n-1}	A_n	FT	PT
1981	$\delta_{1,1}$	$\delta_{1,2}$	...	$\delta_{1,n-1}$	$\delta_{1,n}$	$\delta_{1,f}$	$\delta_{1,p}$
1982	$\delta_{2,1}$	$\delta_{2,2}$	...	$\delta_{2,n-1}$	$\delta_{2,n}$	$\delta_{2,f}$	$\delta_{2,p}$
...							
2011	$\delta_{31,1}$	$\delta_{31,2}$	...	$\delta_{31,n-1}$	$\delta_{31,n}$	$\delta_{31,f}$	$\delta_{31,p}$
2012	$\delta_{32,1}$	$\delta_{32,2}$	...	$\delta_{32,n-1}$	$\delta_{32,n}$	$\delta_{32,f}$	$\delta_{32,p}$
						freight transport	passenger transport

$\delta_{i,j}$ [%] - relative change of attribute *j* in year *i* comparing to year *i-1*

$\delta_{i,f}/\delta_{i,p}$ - relative change of rail traffic in year *i* comparing to year *i-1* {N,P}

Fig.1. The proposed data representation

The last step in data preparation was to eliminate attributes that have more than 50% of missing values. Therefore, number of attributes (n) was not the same for Serbia and Austria, since it depends on availability of data. Fig.1 shows the data representation (dataset) used to build the model.

3. PREPARATION OF TRAINING AND TEST SETS

After the representation is defined and the entire data set is prepared, it is necessary to divide it into disjoint subsets for building (training set) and validating (test set) the model.

Since it is expected that freight and passenger transport do not depend on the same indicators, separate models were developed for these two traffic types.

Using the software-implemented filter in Weka, the dataset was divided into five non-overlapping folds for the purpose of cross validation. This filter divided dataset on training and test sets in five different ways (each train-test split consisted of 80% of data for training and 20% of data for testing the model).

The next problem to be solved considered the fact that the number of attributes (world development indicators) was significantly higher than the number of examples, or j>>i according to Fig.1. Therefore, the number of attributes needed to be reduced. The reduction was achieved using correlation feature subset (CFS) filter. This filter created a subset of attributes that are highly correlated with the class (N or P in this case), while having low intercorrelation. The filter was applied on each of the five train-test splits.

4. MODEL VALIDATION AND OBTAINED RESULTS

According to the previous, four groups of data each containing five train-test splits were created to build and validate four models: for freight and passenger traffic in Serbia, and for freight and passenger traffic in Austria. After learning the mapping from attributes to classes using common machine learning techniques, three classifiers were built for each model:

- Naive Bayes (NB) - a probabilistic classifier based on Bayes theorem and the assumption of mutual independence of attributes [6],
- Decision Tree (DT) - a classifier which successively tests attribute values in each internal node until it is possible to deduce about the item`s target value (class) [7],
- Multilayer Perceptron (MLP) - feed-forward neural network that maps sets of input data onto a set of appropriate outputs, trained using back-propagation algorithm [8].

After applying classifiers on each train-test split generated in a 5-fold cross validation procedure, five confusion matrices were obtained. Confusion matrix for the model is obtained by simple addition of separate matrices:

$$\begin{bmatrix} \sum_{i=1}^{k} TP_i & \sum_{i=1}^{k} FN_i \\ \sum_{i=1}^{k} FP_i & \sum_{i=1}^{k} TN_i \end{bmatrix} = \begin{bmatrix} TP & FN \\ FP & TN \end{bmatrix} \quad (1)$$

where k is number of folds, and:
- TP (true positive) - the number of instances that are correctly classified as positive,
- TN (true negative) - the number of instances that are correctly classified as negative,
- FN (false negative) - the number of instances that are incorrectly classified as negative, and
- FP (false positive) - the number of instances that are incorrectly classified as positive.

Using data from the confusion matrix, three pieces of information related to both classes (P, N) were derived for each model: precision (π), recall (ρ) and F-measure.

$$\pi_P = \frac{TP}{TP+FP} \qquad \pi_N = \frac{TN}{TN+FN} \quad (2)$$

$$\rho_P = \frac{TP}{TP+FN} \qquad \rho_N = \frac{TN}{TN+FP} \quad (3)$$

$$F_P = 2 \cdot \frac{\rho_P \cdot \pi_P}{\rho_P + \pi_P} \qquad F_N = 2 \cdot \frac{\rho_N \cdot \pi_N}{\rho_N + \pi_N} \quad (4)$$

$$F = \frac{TP+FN}{TP+TN+FN+FP} F_P + \frac{TN+FP}{TP+TN+FN+FP} F_N \quad (5)$$

All the obtained model results using equations (2)-(5) are presented in Tab.1. Models that provided the largest F-measure are marked with gray colour in Tab.1.

Tab. 1. Final results of the prediction models

Classifier	Model	F_P	F_N	F
NB	SF	0.632	0.462	0.558
	SP	0.560	0.718	0.659
	AF	0.696	0.222	0.563
	AP	0.766	0.353	0.624
DT	SF	0.529	0.467	0.502
	SP	0.500	0.700	0.625
	AF	0.708	0.125	0.544
	AP	0.632	0.462	0.568
MLP	SF	0.579	0.385	0.494
	SP	0.583	0.750	0.687
	AF	0.571	0.182	0.462
	AP	0.732	0.522	0.653
SF , SP - freight and passenger traffic in Serbia AF , AP - freight and passenger traffic in Austria				

Micro weighted F-measure of the developed models ranged from 0.56 to 0.69, depending on the country and traffic type. The main reasons for this performance are:
- small dataset,
- unequal number of examples of one class comparing to other, except in the case of freight traffic in Serbia where class split was almost 50%, and
- the fact that each train-test split consisted of 80% of data for training and 20% of data for testing.

According to the values from Tab. 1, NB provided better results for freight traffic and MLP provided better results for passenger traffic. In addition, predicting the passenger traffic for both countries appeared to be the easier task than predicting the freight traffic. Predicting the decrease of freight traffic in Austria was the most difficult task according to the low F_N value.

5. INFLUENCE OF THE WORLD DEVELOPMENT INDICATORS

As it was mentioned before, number of attributes (world development indicators) in the dataset was reduced using the CFS filter. According to the definition of CFS filter, there were actually created subsets of world development indicators that are mostly correlated with the rail traffic.

After the analysis of selected WD indicators, it was noted that rail traffic mostly depends on indicators belonging to the two groups: environment and economic policy and debt. Fig.2 shows the distribution of selected WD indicators over the four significant groups.

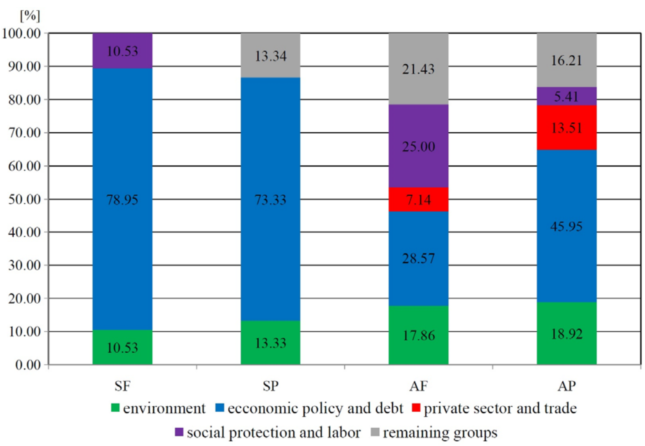


Fig.2. Distribution of selected WD indicators over the four significant groups

For example, from the environment group, as informative indicators it can be considered parameters related to the CO_2 emission and water pollution (that often repeated in data subsets). In particular, it was determined that the increase of rail traffic in Autria was followed by decrease of *CO_2 emission from liquid* *fuel consumption* and CO_2 *intensity* (in 70% of examples). Although this complies with the expected effects of the shift to rail transport, this type of analysis should also consider many other aspects of economy.

From the economic policy and debt group, as informative indicators it can be considered gross national income and gross national expenditure.

In addition, several WD indicators could not be set in the context of the model, although they were selected by the CFS filter. For example, several indicators originated from the health and education groups.

However, application of CFS filter showed which groups of indicators are mostly correlated with rail traffic and which indicators can be used for prediction of rail traffic.

6. CONCLUSION

In general, it is considered that countries with strong industry and economy have fully organized and functional railway transport. The main reason is high capacity, efficiency and safety of railways. That is why European transport policies are directed towards the shift to rail transport.

The shift to rail transport will be followed by certain economic changes. On the other hand, economic changes can influence the changes in rail traffic volume in countries that strongly rely on rail transport.

The research presented in this paper was directed towards development of the model for prediction of changes in rail traffic based on changes of world development indicators defined by the World Bank. Models were developed for two countries, Serbia and Austria, in order to provide sound basis for model comparisons.

Relevant indicators were chosen according to their correlation with traffic changes. In most cases, selected relevant indicators were CO_2 emission, water pollution, gross national income and gross national expenditure.

Micro weighted F-measure of the developed models ranged from 0.56 to 0.69, depending on the country and traffic type. The main reason for such performance is a small dataset and large difference between the number of positive examples (increase of rail traffic) and the number of negative examples (decrease of rail traffic). However, the research proved that changes in rail traffic are followed by changes in many aspects of country`s economy.

ACKNOWLEDGEMENT

This work was supported by the Ministry of Science and Technological Development of the Republic of Serbia through the research project No. 36012: „Research of technical-technological, staff and organizational capacity of Serbian Railways, from the viewpoint of current and future EU requirements”.

REFERENCES

[1] European Commission, *White Paper - Roadmap to a single European transport area - Towards a competitive and resource efficient transport system*, Commission communication COM (2011) 144, Brussels, 2011.

[2] Popović, Z., Lazarević, L., Ižvolt, L., *Potential of the railway infrastructure in Serbia*, Railway transport and logistics, Vol. 3, 2013.

[3] http://data.worldbank.org/

[4] Hall, M., Frank, E., Holmes, G., Pfahringer, B., Reutemann, M., Witten, I.H., *The WEKA Data Mining Software: An Update*, SIGKDD Explorations, Volume 11, Issue 1, 2009.

[5] http://www.cs.waikato.ac.nz/ml/weka/

[6] Mitchel, T., *Machine Learning*, McGraw Hill, Columbus, Ohio, 1997.

[7] Quinlan, J.R., *Induction of Decision Trees*, Kluwer Academic Publishers, Boston, 1986.

[8] Haykin, S., *Neural Networks: A Comprehensive Foundation*, Prentice Hall, New Jersey, 1998.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

HOW TO EVALUATE BODIES FOR RAILWAY MARKET REGULATION

Branislav BOŠKOVIĆ [1]
Danijela ĐORIĆ [2]
Nataša CEROVIĆ [3]

Abstract *– Opening railway market in the EU requires establishment of new bodies. Among them is the most important regulatory body, which is the public body (governmental or parliamentary agency) responsible for railway market regulation. Establishment and operation of regulatory bodies primarily intended to help creation and development of market in the railway infrastructure and promotion of competition in it in order to increase the efficiency of participants and increase the quality of services. To fulfill this role it is necessary for regulatory body to continuously improve the operation and to increase its authority and efficiency. Therefore, it is necessary to periodically carry out the evaluation of the regulator and the efficiency of its drawbacks. In this intent we should not forget that this is a difficult task, because the railway is a typical example of a natural monopoly that is kept up to date since its inception in the 19th century and where on one network appear only one company predominantly owned by the state. The paper discusses and suggests an approach and methodology to the evaluation of the regulatory body based on previous experience and literature.*

***Keywords* – Regulatory body, evaluation, efficiency.**

1. INTRODUCTION

The European Union (EU) has started the processes of liberalization of the railway market, privatization and restructuring of the railway sector in order to stop the trend of growing non-profitability in the sector. Its main cause is the decline of competitiveness of railways additionally deteriorated by the decrease of use of railway transport service. The main principles related to these processes have been given in, the so-called, first and second package of railway directives, namely: clear separation of roles of the state (Government), on one hand, and infrastructure manager and operator, on the other hand; ensuring fair and non discriminatory network access in the conditions of natural monopoly and ensuring that non profitable passenger lines are allocated by a public tender procedure through Public Service Obligation, instead of using legally defined monopoly of national operators owed by the state (Beria P. at all, 2012).

Market liberalization required introduction of several new bodies for its regulation, among which the most important is the Regulatory Body whose task is to enable fair and non-discriminatory access to railway infrastructure. There are several forms of regulation. This paper deals only with economic regulation[1], which is the most usually treated as the process that should contribute to elimination of all market imperfections and establishing of a competitive market. It usually has a sectoral character, meaning that it is introduced in the field of activities showing monopolistic tendencies. In the railway sector, the regulation has the most usually two directions: (i) towards the monopoly, with the objective to prevent the abuse of market power of a monopolist and (ii) towards providing an equal access to infrastructure and creating non discriminatory business conditions (Bošković B. at all, 2014). Regulation is not a new term for railways since the Government has always had the control over infrastructure companies, especially when they are completely state owed, which is the case in Europe. The problem was that it was concentrated in one

[1] *Railways are also concerned by technical regulation, safety regulation, ecological regulation.*

[1] Branislav BOŠKOVIĆ, PhD, University of Belgrade - Faculty of Transport and Traffic Engineering, Serbia b.boskovic@sf.bg.ac.rs
[2] Danijela ĐORIĆ, Serbia, danijeladjoric@gmail.com
[3] Nataša CEROVIĆ, Directorate for Railways, Belgrade, Serbia, natasa.cerovic@raildir.gov.rs

place, the competent Ministry, and without enough transparency. However, the appearance of new entrants in the railway market, especially private companies, requires new regulation mechanisms including the necessary level of independence of regulatory bodies and their authority.

2. REGULATORY SYSTEM

The regulatory system can be defined as a combination of institutions, laws and processes. The regulatory system consists of two basic dimensions, namely: regulatory governance and regulatory substance. Regulatory governance relates to institutional and legal design, that is, the framework of decision-making. Regulatory governance is defined as answer to the question "how" to regulate, while regulatory substance is the subject of regulation and it can be defined as answer to the question "what" is regulated.

Regulatory governance involves decisions about the following: Independence and accountability of the regulator; Relationship between the regulator and policymaker(s); Autonomy of the regulator; Processes, formal and informal, by which decisions are made; Transparency of decision-making by the regulator or other entities making regulatory decisions; Predictability of regulatory decision-making; Accessibility of regulatory decision-making; Organizational structure and resources available to the regulator (Brown, A.C. at all, 2006).

Regulatory substance typically involves decisions about the following: Tariff levels; Tariff structures; Automatic and nonautomatic cost pass-through mechanisms; Quality-of-service standards; Handling of consumer complaints; Investment or connection obligations and reviews; Network access conditions for new and existing customers; Accounting systems; Periodic reporting requirements; Social obligations (Brown A.C. at all, 2006).

If we know what should be the purpose of regulatory bodies, then we can ask the following practical question: Do they work well, that is, are they used for the purpose they have been established for? Do their decisions contribute to increase/decrease of competition and profit or they do not influence the market? We must also know what is the meaning of the notion "work well", and finally, how to evaluate a regulatory body in that sense. This paper deals exactly with this subject. The paper is mostly based on the results of a large study done by the World Bank (WB): *Handbook for Evaluating Infrastructure Regulatory Systems by the four authors:* Ashley C. Brown, Jon Stern, Bernard Tenenbaum and Defne Gencer. The study concerns all infrastructure systems, but it has been mostly developed by working on regulation of energetic systems.

3. EVALUATION METHODS

Although this has not been said, the above-mentioned study of the WB is based on the *meta-analysis* method. The meta-analysis represents a statistic and analytic method combining and synthesizing different studies independent from each other and integrating their results in a common, unique result. The use of meta-analysis to sum up, integrate and analyze a great number of independent studies dealing with the same subject and finally obtain a common result, allows the researcher to make relevant, objective and precise conclusions, if the procedure has been carefully prepared and controlled by the researcher[2]. It can be applied only to studies having empirical research results and not to theoretical papers. It cannot synthesize and integrate theoretical results published in qualitative and not quantitative form, which means that the processed studies must use measuring quantitative variables. Besides that, it is very important that these results can be reasonably analyzed and combined. That means that researches entering into a common analysis must deal with the same structures and connections and their results must be in a similar statistical form (Hartung J. at all, 2008).

The World Bank (Brown A.C. at all, 2006) has established three evaluation methods related to efficiency of regulatory systems, that is, regulatory bodies, by summing up all evaluations of regulatory bodies from different economic sectors which have been done so far, namely:

- cross-country statistical analyses,
- cross-country descriptive analyses,
- single-country structured case studies.

3.1 Cross-Country Statistical Analyses

Cross-country statistical analyses method uses different statistical techniques, primarily econometric techniques based on variants of regression analysis, in order to find out if different formal or informal characteristics of a regulatory system, that is, a regulatory body, have produced positive or negative effects on economic performances of the sector. The data for these methods are usually obtained through published information and questionnaires sent to the regulatory bodies in different countries.

The studies applying this method are used to find out whether certain characteristics or combinations of characteristics of a regulatory system, that is, a

[2] *Since the last several years the statistic experts have become more and more interested in the meta-analysis and the real expansion has been made in the field of biomedical sciences where clinical research of a certain problem do not always provide compatible results (Hartung J. at all, 2008).*

regulatory body (such as institutional independence, existence of a regulatory statute or a sort of system establishing tariffs) produce positive or negative effects on different dimensions of performances in the sector (such as investment levels and capacity use).

3.2 Cross-Country Descreptive Analyses

Cross-country descriptive analyses method is applied in studies intended to compare formal characteristics of regulatory systems in different countries. It is focused on legally defined governance elements, such as procedures of appointing and suspension of responsible persons, financing sources, complaints on regulatory decisions and distribution of responsibility between the regulator and other parts of the Government.

The result of studies applying this method has been published as a report containing different tables designed to facilitate comparison between the countries. The general objective of such studies is to provide benchmarking of regulatory systems, unlike cross-country statistical analyses measuring positive or negative effects on system performances.

3.3 Single-Country Structed Case Studies

The third approach is the single-country analysis usually used to analyze the current regulatory system of a sector (for example energy, telecommunication) for a one country. They normally have the form of *structured case studies* focused on regulatory governance.

Depending on the available resources, the evaluation can be limited to testing of formal-legal and institutional aspects of a regulatory system or it can be further examined to show how the formal elements have been included.

Depending on the available resources, the case studies can consist of:

- Quick evaluation,
- Mid-level evaluation, or
- In-depth evaluation.

4. BENCHMARKS OF REGULATORY GOVERNANCE: KEY PRINCIPLE AND CRITICAL STANDARDS

Every evaluation requires certain benchmarks. Without benchmarks, the evaluation of a regulatory system will lack coherence, discipline and meaning. More specifically, in this case, the evaluation is in fact a set of key principles and critical standards represented in the more efficient versions of independent regulator model.

Efficiency of a regulator depends on (evaluation) two key aspects (Brown A.C. at all, 2006):

- the quality of regulatory governance; and
- the quality of regulatory decisions.

4.1 Quality of Regulatory Governance

The most important aspect of the quality of regulatory governance is independence of the regulatory body, taking into account that "independence" here means: organizational independence (organizationally separated from the ministry and departments), financial independence (dedicated, safe and adequate source of financing) and independent governance (autonomy above internal administration and protection against lay-off of employees without reason).

The best practice of regulatory governance contains three main elements (Brown A.C. at all, 2006):

- Three regulatory meta-principles;
- Ten key principles; and
- Full list of critical standards for regulation.

Taken together, these three elements represent benchmarks for evaluation of efficiency of regulatory governance.

Three regulatory meta-principles are (Brown A.C. at all, 2006):

- Meta-Principle 1: Credibility – Investor must trust that regulatory system will fulfill its obligations.
- Meta-Principle 2: Legitimacy – Users must be sure that the regulatory system will protect them from the monopoly of the Government, either regarding high prices or bad services or both.
- Meta-Principle 3: Transparency – Regulatory system must work transparently so that investors and users know what the conditions of an agreement are or what the rules of the game are.

Meta-principles represent the highest level and they must be satisfied so as for the regulatory system to be efficient and sustainable.

Meta-principles are followed by the principles related to specific models of regulatory governance, that is, the principles designed to implement meta-principles. Ten key principles are: independence; accountability; transparency and public participation; predictability; clarity of roles; completeness and clarity in rules; proportionality in application; requisite powers; appropriate institutional characteristics; integrity of conduct (Brown A.C., at all, 2006).

Finally, we reach the implementation of ten key principles realized through critical standards. In other words, the principles represent the objective of general governance and tasks for an independent regulatory model, while standards are designed so as for the principles to become operational. Critical standards are: Critical standards include a variety of elements listed under the following headings: legal framework; legal powers; property and contract rights; clarity of roles in regulation and policy; clarity and comprehension of regulatory decisions; predictability and flexibility; consumer rights; proportionality; financing of regulatory agencies; regulatory independence; regulatory accountability; regulatory processes and transparency; public participation; and ethics (Stern, J., 2006).

4.2 Quality of Regulatory Decisions

A good regulatory system gives good economic results, through making *good decisions*. Good decisions are decision improving economic performances and ensuring benefits for users (including future users) and investors. Besides that, good regulatory decisions are also decision helping to achieve certain objective of transport policy of a country or other objectives of the Government.

When state objectives are explicitly indicated and published, regulators should try to achieve them – provided if they are not contrary to other legal obligations they can have towards users and investors. However, the state has multiple objectives which are often in conflict with each other. The most common case and problems are that the state has the objectives requiring important investments in railways (or some other industrial sector), and it is not willing to allow the prices that cover the expenses. These problems are usually solved by subventions, which is also the case of railway transport.

Eight parameters influenced by regulatory decisions in economics have been defined: output and consumption; efficiency; quality of supply; financial performance; capacity, investment and maintenance; prices; competition; social indicators.

If there are good decisions there are also bad decisions. Bad decisions can be divided into (Stern, J. 2006):

- Decisions containing sins of "omission" of a RB; and
- Decisions containing sins of commission of a RB.

Sins of „omission" are decisions or actions that should have been made or done by a regulatory body, but had not been made or done, such as: omission to search or understand the structure of costs before defining tariffs; omission to introduce an appropriate quality of service indicators; failure to define regulatory methodologies, etc.

Sins of commission are decisions or actions made or done by regulatory bodies by mistake, such as: establishing unreasonable benchmarks; enabling increasing discrepancies between costs and prices; establishing low fines for criminal offences, etc.

After defining which benchmarks describe the quality of regulatory governance, as well as quality of a regulatory decision, it is necessary to make different types of questionnaires, make interviews with key participants on the railway market, etc. The World Bank has made Guidelines and Questions, that is a document showing how to make a selection of candidates for interview, which type of questions should be asked according to the above defined benchmarks, in order to successfully analyze whether a railway regulatory system is in accordance with the define benchmarks. Therefore, we can evaluate the quality of regulatory governance and quality of regulatory decisions of the concerned regulatory body comparing it with the good practice defined by efficient regulatory systems.

5. CONCLUSIONS

Development of railway market requires also development of regulatory arrangements and frameworks where the focus is on the regulatory body. The WB has particularly worked on evaluation of infrastructural regulatory bodies by engaging well-known scientists and experts. Specificities and case studies related to railways have not been treated yet but they are expected to be in the near future. Experience and methods applied within the regulation of other infrastructure systems can also be applied on railways. Therefore, methods and experiences in evaluation of regulatory bodies of other infrastructure systems, presented in this paper, will be precious for evaluation of railway regulatory bodies.

REFERENCES

[1] Beria, P., Quinet, E., de Rus, G. and Schulz, C. *A comparison of rail liberalization levels across four European countries*, Research in transport Economics, 36 (1), pp. 110-120, 2012

[2] Bošković B., Bugarinović M., Petrović-Vujačić J. and Kaplanović S., *Forms and Instruments of the Market Regulation of Railway Infrastructure,* Tehnika, No2, 2014

[3] Brown, A. C., Stern, J., Tenenbaum, B. and Gencer, D., *Handbook for Evaluating Infrastructure Regulatory Systems*, World Bank, Washington D.C. 2006

[4] Hartung J., Knapp G., Sinha B.K., *Statistical Meta-Analysis with Applications,* John Wiley & Sons, Ltd. 2008

[5] Kaufmann D., Kraay A. A. and Mastruzzi, M., *Governance Matters III: Governance Indicators for 1996–2002*, Washington D.C., World Bank, 2004, http://www.worldbank.org/wbi/governance/govdata/

[6] Stern, J., The *Evaluation of Regulatory Agencies*, CCRP Working Paper No16, City University London, 2010, Downloadable from: http://www.city.ac.uk/ _data/assets/pdf_file/0020/81029/stern_evaluation_regulatory_agencies

[7] Stern, J., *Evaluating Infrastructure Regulators Developing - UK and International Practice*, CRI Occasional Lecture, No17, The University of Bath, 2007, Downloadable from: http://www.bath.ac.uk/ management/cri/pubpdf/ Occasional_Lectures/17_ster

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

GROUP DECISION MAKING APPROACH IN RANKING MODELS OF SUSTAINABLE RAILWAYS RESTRUCTURING

Boban ĐORĐEVIĆ [1]
Tanja PAREZANOVIĆ [2]
Snežana PEJČIĆ TARLE [3]
Nena TOMOVIĆ [4]
Nikola PETROVIĆ [5]

Abstract *– As an environmentally friendly mode of transport, rail is a key pillar of Europe's efforts to encourage sustainable transport and mobility through increasing market share of restructured and modernized rail. The paper highlights the potentials of the multi criteria group decision making approach as a tool for evaluation various restructuring models when different stakeholders' preferences exist. The complexity of this issue is demonstrated within an illustrative example.*

Keywords – railway restructuring, sustainability, group decision making, AHP.

1. INTRODUCTION

Despite a number of strengths relating to the concept of sustainable transport, "there is still a certain lack of dynamism, reliability, flexibility and customer orientation on the part of railway undertakings. At times the political influence on the railway business is too strong, while there is still insufficient interoperability between national rail systems as well as insufficient - and decreasing - investment. In addition, rail is often hamstrung by outdated business and operational practices, by the presence of too much ageing infrastructure and rolling stock and by a financial situation that is often weak. Rail's relatively small share of the overall transport market is another threat that has to be addressed" [1]. Making rail more customer-oriented with good quality of service and meeting customers' expectations should help to increase the share of rail transport in relation to other modes. To be "green" and market oriented in same time, is a general goal for railways restructuring. The aim of this paper is to indicate the possibility of obtaining more objective multi criteria group decision making approach in ranking methods of sustainable railways restructuring, by including stakeholders in an initial phase of rail reforming process. The proposed approach is based on Analytical Hierarchy Process (AHP), a recognized decision support tool for individual and group decision making (GAHP), without any suggestions that GAHP is superior to the other methods in all aspects.

2. RAILWAYS RESTRUCTURING AND SUSTAINABILITY

Based on a numerous relevant international organizations, it is possible to define sustainable transport system as one that "allows the basic access and development needs of people to be met safely and promotes equity within and between successive generations" (*social dimension*), "is affordable within the limits imposed by internalization of external costs, operates fairly and efficiently, and fosters a balanced regional development" (*economic dimension*), "limits emissions of air pollution and GHGs as well as waste and minimises the impact on the use of land and the generation of noise (*environmental dimension*), and "is designed in a participatory process, which involves

[1] Boban ĐORĐEVIĆ, Faculty of Transport and Traffic Engeneering, University of Belgrade, Vojvode Stepe 305, Beograd, bbn.djordjevic@gmail.com
[2] Tanja PAREZANOVIĆ, Faculty of Transport and Traffic Engeneering, University of Belgrade, Vojvode Stepe 305, Beograd t.parezanovic@sf.bg.ac.rs
[3] Snežana PEJČIĆ TARLE, Faculty of Transport and Traffic Engeneering, University of Belgrade, Vojvode Stepe 305, Beograd s.tarle@sf.bg.ac.rs
[4] Nena TOMOVIĆ, Serbian Railways, Beograd , tomovicnena@gmail.com
[5] Nikola PETROVIĆ, Faculty of Mechanical Engineering, University of Niš, Aleksandra Medvedeva 14, Niš, petrovic.nikola@masfak.ni.ac.rs

relevant stakeholders in all parts of the society (*degree of participation*)[1]. Work on sustainable transport is well in progress, both in the research field and in policy-oriented studies, suggesting common core indicators for monitoring and measuring sustainability on global, local, industry sectors and company level as well [2] [3].

Despite this, comprehensive review of the literature reveals that application of one model of a railway company restructuring may be successful in one country, but it does not guarantee success in another country. In order to observe influential factors and find the appropriate railway company restructuring method on time, it is necessary to start with survey of changes could be happen in the environment, and how they influence railway companies and their activities. Additionally, it is very important to specify the power of railway resources in terms of these changes, and stakeholders[2] influence on position of railway including their attitudes towards restructuring [4] [5].

According to experiences of railway companies worldwide, all restructuring methods differ along three main features to be analyzed in detail: "how are access and infrastructure and multimodal competition considered, what is the extent of vertical separation introduced after the change, and what is the amount of private participation allowed in the industry after the reform" [5]. In practice, the restructuring models differ depending on: the degree of vertical integration/separation, the degree of open access to competition and the amount of private participation.

The approach of vertically organized railway companies offers three different structuring options: (1) vertical integration, (2) competition access, (3) vertical separation. While total vertical integration is the traditional model of monopolistic railway companies where one body controls all the infrastructural facilities, as well as operations and administrative functions, the open competition access, although characterized by the existence of an integrated operator, offers advantages in terms of higher income from better quality of services, lower cost per product unit and adaptability to changing market conditions [6]. The most attractive model within approach of vertically organized railway, is the vertical separation - the railway infrastructure, still characterized by the natural monopoly terms, is separated from the transport services. Advantages of this model are: reduction of unit cost, stimulating competition, promotion of commercial and management focus on services and setting the railway transport in the same position with the road transport in terms of tariff system and infrastructure planning. Separating the railway infrastructure from transportation also enables planning and implementing concept of critical infrastructure, whereas services may be provided by private or public authorities [4] [5].

Regarding the approach with high degree of open competition, practices indicate that beside significant savings which could be achieved through competition, this is an important mechanism in limiting the monopolists and maximizing the benefit for transport services users [7].

The amount of private participation is approach which covers different situations in world rail industry: enterprise fully controlled and financed by the government, public enterprise, reformed and commercialized public enterprise, mixed forms of cooperation between private and public capital[3], and full private ownership [8].

3. AHP GROUP DECISION MAKING: APPROACH AND ILUSTRATIVE EXAMPLE TABLES

For evaluation and ranking of the railway company organizational models in the process or railway restructuring is very important to select the appropriate evaluation approach which should include multidimensionality, uncertainty, qualitative data and possibility to reconcile stakeholders different positions, priorities and preferences. When the selection of the best alternative depends on several decision makers (stakeholders), the GAHP is considered appropriate. Two most frequently used methods of aggregation of ratings in the group decision-making are the aggregation of individual judgments (AIJ) and aggregation of individual priorities (AIP) [9] [10]. For both these methods, the arithmetic or geometric mean for aggregation of ratings of decision makers may be used. According to advantages of geometric mean for aggregation of ratings of multiple decision, presented by Forman and Penivati [10], for illustrative example was used the geometric mean for aggregation of expert ratings.

Use of GAHP technique may be described by the following steps: (1) Selection of sum of alternatives and criteria; (2) Selection of team of experts/decision makers (DM) determining the significance of criteria and alternatives; (3) Defining the problem and hierarchical problem structuring; (4) Constructing the matrix of comparison by pairs (values $n \times n$) for each problem level and for each decision maker; (5) Collection and aggregation of ratings obtained from decision makers based on the equation:

[1] *Adapted from "Defining Sustainable Transportation", Centre for Sustainable Transportation (CST), Canada 2005*

[2] *Government, local authorities, tax payers, service users, ecologists, private stakeholders, labour unions*

[3] *Service and management contracts with private sector, leasing and concessions, joint ventures*

$$X'_{ij} = \left(\prod_{I=1}^{k} X'_{ij} \right)^{1/k} \quad (1)$$

$$i, j = 1, 2, \ldots n.; I = 1, 2, \ldots k.; i \neq j$$

where *I* is the number assigned to a decision maker, *k* is the total number of decision makers, (*i,j*) are criteria and alternatives being compared. For determining the significance of criteria and alternatives, the decision makers use values defined by Saaty scale (Table 1) [11]; (6) Calculating of matrix of aggregated ratings and establishing of consistency of comparison by pairs. For matrices that are fully consistent, maximal eigenvalue of matrix equals to matrix order (λ_{max}= n).

Tab.1. Scale of measurement for AHP

Definition	**Significance**
Equal importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9
Intermediate values	2,4,6,8

Consistency index (CI) is defined in the following manner:

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \quad (2)$$

where λ_{max} is the maximal eigenvalue of matrix A, and *n* is the number of matrix order. Then, the consistency ratio (CR) is calculated in the following way:

$$CR = \frac{CI}{RI} \quad (3)$$

where RI is the random index of consistency, the values of which are presented in Table 2 (*n*, matrix size).

Tab.2. The Random Consistency Index (RI)

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41

If the is CR ≤ 0.10 the consistency of the matrix is considered as acceptable, otherwise the evaluation procedure has to be repeated to improve consistency [12]. The consistency ratio is frequently higher than 0.10, and yet the selected alternative could be adopted as the best one [13].

For an illustrative example, based on literature review criteria and alternatives of railway companies restructuring models are identified [2][4][5]. Selected alternatives - A1 to A8 are: (A1) Vertical integration in the state property; (A2) Vertical integration with a commercialized public company; (A3) Vertical separation with a commercialized public company; (A4) Access of competition with concessions; (A5) Vertical separation with concessions; (A6) Vertical integration with privatization; (A7) Access of competition with privatization, and (A8) Vertical separation with privatization.

The selected criteria – K1 to K8 are: (*K1*) Maximising income from railway restructuring; (*K2*) Operational and cost efficiency; (*K3*) Better allocation of resources and external efficiency; (*K4*) Innovation, market development and dynamic efficiency; (*K5*) Social equity; (*K6*) Environmental protection through intermodal transport; (*K7*) Risk minimizing; (*K8*) Infrastructural management. In order to find the best alternative, ratings by the expert team, made of five decision makers: DM1, DM2, DM3, DM4 and DM5, respectively, have been collected.

After the ratings had been collected, the procedure of calculation by GAHP technique was performed according to the steps described in the previous part of the paper. The results is shown that Consistency Ratio (CR) for all individual decision makers and for all criterias, have values >0,1 (Table 3).

Calculation of priority vectors for all decision makers is shown that there was not agreement regarding final ranking of alternatives. Therefore, after excluding DM4, in next stage ranking was repeated. After aggregating the individual evaluations for all alternatives and criteria, the best ranking alternative is A3 - Vertical separation with a commercialized public company (Table 4). Vertical separation is often advocated in network industries generally, because it is assumed to be necessary to eliminate discrimination in gaining access to infrastructure and therefore helpful to the development of competition [14].

Tab.3. Consistency Ratio (CR) values for all experts and criterias

	Consistency Ratio (CR)							
	K1	**K2**	**K3**	**K4**	**K5**	**K6**	**K7**	**K8**
DM1	0.113630	0.122277	0.117759	0.107766	0.125825	0.134253	0.131376	0.132556
DM2	0.146726	0.173097	0.150162	0.120582	0.146041	0.162755	0.148861	0.177186
DM3	0.130717	0.175993	0.155117	0.143733	0.158387	0.175633	0.154310	0.180079
DM4	0.184652	0.193496	0.174849	0.204158	0.170736	0.186827	0.173362	0.198160
DM5	0.166782	0.134212	0.158390	0.135893	0.100071	0.104971	0.118411	0.170907

Tab. 4. Comparison matrix of aggregated ratings

	K1	K2	K3	K4	K5	K6	K7	K8
A1	0,144	0,144	0,142	0,144	0,141	0,145	0,147	0,142
A2	0,160	0,169	0,171	0,168	0,167	0,168	0,168	0,166
A3	0,193	0,193	0,191	0,191	0,192	0,187	0,190	0,191
A4	0,131	0,127	0,128	0,127	0,129	0,131	0,125	0,127
A5	0,112	0,110	0,110	0,111	0,113	0,111	0,109	0,110
A6	0,099	0,098	0,098	0,097	0,098	0,098	0,100	0,098
A7	0,087	0,084	0,085	0,086	0,085	0,085	0,085	0,087
A8	0,072	0,071	0,071	0,073	0,071	0,071	0,071	0,074
∑Wc	1	1	1	1	1	1	1	1

4. CONCLUSION

In scope of contemporary European Union transport policy, rail is recognized as backbone of sustainable transport, particularly considering its green credentials. Increasing rail's share of passengers and freight will substantially reduce the transport sector's carbon emissions while also decongesting the highways and facilitating trade throughout the single market. Despite a number of strengths relating to the concept of sustainable transport, railway should be more customer-oriented with better quality of service, what could be achieved through restructuring traditionally monopolistic rail companies. For evaluation and ranking of the railway company organizational models in the process or railway restructuring is very important to select the appropriate evaluation approach which should include multidimensionality, uncertainty, qualitative data and possibility to reconcile stakeholder's priorities and preferences. When the selection of the best alternative depends on several decision makers/stakeholders, and in same time should be evaluated according to sustainability objectives and criteria, GAHP as support tool for multi criteria group decision making could considered appropriate. Presented case example is hypothetical but still semi-realistic. The proposed approach could be apply to a real modeling session where the interactions of the DMs and their preferences and priorities will determinated via additioanly research instruments and methods.

ACKNOWLEDGEMENT

This paper is a part of the project "Critical infrastructure management for sustainable development in postal, communication and railway sector of Republic of Serbia", funded by the Ministry of Education and Science of the Republic of Serbia, Project number: TR36022.

REFERENCES

[1] Ostermayer U.: Marketing of Green Mobility - EcoPassenger and EcoTransIT World, XI UIC Sustainable Conference, Madrid, 2010.

[2] Eurostat: Sustainable development in the European Union, 2013 monitoring report of the EU sustainable development strategy, EC 2013. 197-215.

[3] Bojković N., Macura D., Pejčić Tarle S., Bojović N.:A Comparative Assessment of Transport-Sustainability in Central and Eastern European Countries with a Brief Reference to the Republic of Serbia, International Journal of Sustainable Transportation, 5(6), 2011, 319-344.

[4] Kopicki, R., Thompson, L.S.: Best Methods of Railway Restructuring and Privatization, CFS Discussion Paper Series, Number 111, The World Bank, 1995.

[5] Cantos, P.,Campos, J.: Recent changes in the global rail industry: facing the challenge of increased flexibility, Europen Transport, Vol.29, 2005, 1-21.

[6] Jensen, A.: Competition in railway monopolies, Logistics and Transport Review, Vol.34, 1998, 267-287.

[7] Beesley, M. E.: Privatisation, Regulation and Deregulation. Routledge. London, 1997.

[8] Galenson, A., Thompson, L.S.: Forms of Private Sector Participation in Railways, TWU Papers, No.9, The World Bank, Washington DC, 1993.

[9] Ramanathan, Z., Ganesh, L. S.: Group preference aggregation methods eployed in AHP. European Journal of Operational Reserch, 79, 1994, 249-265.

[10] Forman, E., Peniwati, K.: Aggregating individual judgments and priorities eith the AHP. European Journal of Operational Research, 108, 1988, 165-169.

[11] Saaty, T.L.: The Analytic Hierarchy Process, McGraw Hill, New York, 1980.

[12] Srdevic, Z., Blagojevic, B.,Srdevic, B.: AHP based group decision making in ranking loan applicants for purchasing irrigation equipment: a case study, Bulgarian Journal of Agricultural Science, 17(No4) 2011, 531-543.

[13] Taleai, M., Mansourian, A: Using Delphi-AHP Method to Survey Major Factors Causing Urban Plan Implementation failure, Journal of Applied Sciences 8(15), 2008, 2746-2751.

[14] Drew, J. Nash, C.A.:Vertical separation of railway infrastructure - does it always make sense? Institute for Transport Studies, University of Leeds, WP 594, 2011.

SELECTION OF THE LOCOMOTIVE SERIES FOR MODERNIZATION, BASED ON MULTI-CRITERIA ANALYSIS

Oleg KRASTEV [1]
Kiril VELKOV [2]
Mario KRASTEV [3]

Abstract *– In the paper is presented one different approach than traditionally used for choosing the suitable for modernization locomotives. It is based on well-known multi-criteria optimization methods and specially build software system. This approach is useful when one of several similar looking alternatives should be chosen and allows extracting necessary data for specific purpose. It is demonstrated with example from practice, solving an optimization task based on real data.*

Keywords – Decision making, locomotives, modernization, multi-criteria.

1. INTRODUCTION

Nowadays renewal of locomotive fleet is a serious challenge for each country nevertheless how developed is it. This comes from the fact that prices of new locomotives is relatively high - varies in range 6 to 12 million € and it is multiplied by their quantity for different series.

That is why and due to economic crisis many companies are interested in prolonging the exploitation term of locomotives with modernization and recycling.

This paper presents a different view for selecting the locomotives suitable for modernization. The approach is based on several optimization and multi-criterial decision support methods, which are embedded in specialized software system [1].

The goal of proposed approach is to overcome difficulties, which are facing when you have to choose one of several similar looking locomotives suitable for modernization. Software system analyses big amount of data and based on multiple-criteria theory provide support for decision-making process. It is not a replacement of expert rating but it is additional source for decision-support by extracting the valuable information for systems.

2. SOFTWARE SYSTEM

Specially build software system is used for solving the issues with finding the expedient locomotive for modernization. It is founded on several popular multi-criteria decision support methods, which arranged several equivalent alternatives. Software system is developed by usage of popular programming languages and well-known models and could help people in process of solving different multi-variant problems. Although it is primary used for choosing the correct locomotive for modernization, it could be easily adapted and applied for supporting decision-making in various areas of technics, economics, business and natural science.

2.1 Theoretical methods

Developed Software system bases on well-known methods and the main purpose is to provide suggestions for dominating alternative. In future releases could be incorporated some other theoretical models. For evaluation of different alternative are used four methods:

- Method **PROMETHEE** (Preference Ranking Organization METHod for Enrichment Evaluations)

Allows ranking of alternatives based on several preference functions. Method could be used for pointing out potential solution between parties with apparently incompatible objectives.

- Method **AHP** (Analytic-Hierarchy Process)

This method ranks all criteria according to

[1] Oleg KRASTEV,Ph.D, Assoc. Professor, Department of Railway Engineering, Faculty of Transport, Technical University of Sofia, e-mail: okrastev@tu-sofia.bg
[2] Kiril VELKOV, Ph.D, Assoc. Professor, Department of Railway Engineering, Faculty of Transport, Technical University of Sofia, e-mail: khvel@tu-sofia.bg
[3] Mario KRASTEV, M.Sc. Ph.D student, Faculty of Telecommunications, Technical University of Sofia, e-mail: krastev.mario@gmail.com

quantitative values pre-defined by user. Its goal is to reduce subjective evaluation in decision-making process.

- Method **SAW** (Simple Additive Weighting)

The SAW method is based on the weighted average. An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by decision maker followed by summing of the products for all criteria. This method is one of the oldest and most studied multi-criteria decision support techniques. It is used for quick assessment of alternatives due to its simple calculation.

- Method **TOPSIS** (Technique for Order Preference by Similarity to Ideal Solution)

This method arranges the alternatives according to preferences that are close to ideal solution. The algorithm evaluates and ranks user-defined alternatives using quantitative definition of weight. In TOPIS is defined a proximity index for each alternative which is numerical representation of difference between best and worst solution.

2.2 Software realization

Contemporary programming tools and methods are used for realization of software application. The main purpose is to provide simple, convenient and intuitive user interface. There are possibilities for future extension of the product with adding new algorithms and modules for evaluation and decision-support.

Source information is imported by using simple and easily understanding electronic tables based on MS Excel. There are provided intuitive pre-defined templates matching the needed input information for different methods and criteria. This approach eliminates need of manual inserting the necessary source information in dialog-based interface. Additionally placed are several checks for input sheet to secure accuracy of calculations.

Method PROMETHEE requires most parameters to set to precede evaluations. Electronic table should include the following source information:

- Criteria for evaluation of alternatives;
- Different alternatives;
- Weights of different criteria;
- What is the target value of each criteria – minimum or maximum;
- Only in PROMTHEE method is required to be predefined the preference function for each criteria. The method uses six preference functions (Fig. 1):

1 – Usual criterion – simple criteria, do not require additional parameters to be set;

2 – Quasy-criterion (U-shape) – need to be set additionally level of preference (q);

3 – Criterion with linear preference (V-shape) – also should be set preference value (p);

4 – Level criterion – requires two additional parameters – p and q, which defines zones for strong preference and zone of indifference.

5 – U-share criterion with linear preference and indifference zone – same requirement like Level criterion but the function of preference is linear in indifference zone;

6 – Gaussian criterion – it is based on Gaussian normal distribution functions and needs to be set the standard deviation σ.

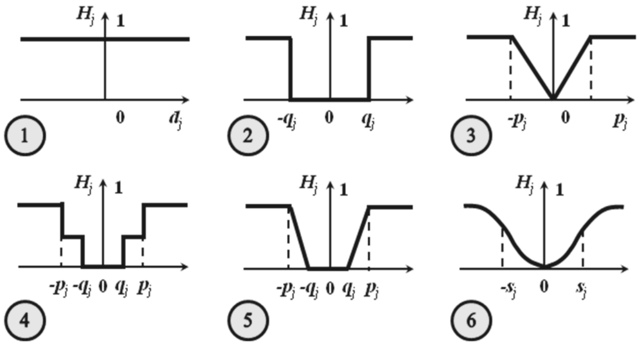


Fig. 1. PROMETHEE preference functions

Received results are also presented in electronic table format. The program provides in one view ranking of alternatives based on all different methods and presents results for weighted values from each method. This allows in convenient way to be juxtaposed final data from each method.

3. DEFINITION OF THE PROBLEM AND SOURCE DATA

Problem for selection of appropriate locomotive for modernizations could be divided in two separate tasks. First task is to define proper series of locomotives for modernization series and the second task is to select the most suitable of them.

Criteria for evaluation are quite difficult and depend on both economic reasons and technical conditions and amortization of the vehicles. Correct choice of each criterion and its relative weight is quite important for right calculation and obtaining realistic results. Selection of criteria is made after analysis of big amount of data from operation of vehicles during years. It also grounds on international experience in respective area and possibilities of selected companies in providing technical refresh of locomotives.

In present example the selection of series of locomotives for modernization based on six different criteria and usage of software system for decision-making support are illustrated. The selected criteria are:

- Relative market share – it represents what portion of trains in organization are served by locomotive from specific series [%];

- Forecasted average price for modernization of single locomotive [million BGN];
- Ratio between forecasted average price for modernization and average market price of new locomotive [%];
- Return of investments period in case of modernization of locomotives [years];
- Experience of companies providing modernization service. This criterion is based on expert assessment and provides values from 1 (bad) to 6 (excellent). Such assessment additionally could be ranked by using the same software system in one more iteration with respective criteria;
- Percentage of potential energy saving after modernization [%].

Input data is used for calculations and ranking the alternative with methods – PROMETHEE, SAW and TOPSIS. In Table 1 is presented extract of electronic table with source information. There are evaluated six different series of locomotives and quantitative equivalent for each criterion with respective values.

Table 1. Source data for methods: PROMETHEE, SAW and TOPSIS

Series	Market share	Price	Price / Price of new one	Return of investment period	Experience of the company	Energy saving
06-000	6	2	30	10	3	5
07-000	5	2	30	10	4	7
55-000	8	1.5	25	13	2	9
44-000	36	3	40	6	5	15
45-000	31	3	40	7	5	15
46-000	14	3	35	8	4	14
Relative weight	3	2	1	2	1	1
min(0); max(1)	1	0	1	0	1	1
Function	1	1	1	1	1	1
p						
q						
s						

Analyses with AHP method need different approach of input data. It uses hierarchical structures of data, and user defined preferences on each criterion against the other. There are used the same six criteria and six series of locomotives like shown in table 2. Data is entered in electronic table but in dialog interface, dominating preferences for each couple of locomotives are ranked. It is used nine-degree scale for arranging the preferences. This method requires more user interaction and strictly clear view and knowledge about domination of one series over other based on specific criteria. Additional should be determined the relative importance of one criterion compared to the others.

After performing the calculations the normalized quantitative assessments of individual attributes and general machinery are obtained, which is shown in Table 3.

Tab. 2. Source data for AHP method

Attr 1	Attr 2	Alter 3
Series	Market share	06-000
	Price	07-000
	Price / Price of new one	55-000
	Return of investment period	44-000
	Experience of the company	45-000
	Energy saving	46-000

Table 3. Normalized quantitative rankings for attributes and machines based on AHP method

Series	Market share	Price	Price / Price of new one	Return of investment period	Experience of the company	Energy saving
06-000	0,2977	0,0741	0,0239	0,2708	0,0400	0,0596
44-000	0,0726	0,0816	0,0465	0,0372	0,1285	0,1448
46-000	0,1248	0,0465	0,4381	0,1307	0,0921	0,1443
07-000	0,0252	0,5648	0,0886	0,4021	0,5271	0,4757
45-000	0,0509	0,1890	0,0981	0,1352	0,1884	0,1443
55-000	0,4286	0,0439	0,3046	0,0240	0,0232	0,0315

These results show that according source data and user defined preferences and parameters the most appropriate for modernization are locomotives from 44-000 series.

The second iteration of the software program is to point out the most suitable locomotives for modernization from selected series. For this task are used the following optimization criteria:

- Mileage [thousands km];
- Condition of the frame and the body of the locomotive [expert assessment for 6 (very good) to 1 (bad)];
- Condition of running gear [expert assessment for 6 (very good) to 1 (bad)];
- Condition of breaking system [expert assessment for 6 (very good) to 1 (bad)];
- Number of accidental repairs during last 5 years;
- Period form the last planned maintenance [days];

In the presented example are evaluated ten locomotives from series 44-000. Input data tables are similar with these used for evaluation of the most suitable series for modernization are not shown here due to limited space for publication. Additional improvement of decision-supporting system could be done by replacing all expert assessment with another iteration of the presented software system.

4. RESULTS

Results from ranking locomotive's series suitable for modernization are shown in fig.2. Classification of each locomotive from selected series 44-000 according to different methods and appropriateness for modernization is presented in fig.3.

AHP Altern	AHP Priori	PROMETHEE Alt\Alt	PROMETHEE netfl	SAW F1	SAW Priori	TOPSIS F1	TOPSIS Priori
44-000	0.26844	44-000	6.2	44-000	800	44-000	0.80243
45-000	0.21518	45-000	4.2	45-000	723.041	45-000	0.74556
46-000	0.14823	46-000	0.19999	46-000	453.287	46-000	0.36145
06-000	0.14266	55-000	-2.8	07-000	339.047	55-000	0.22989
07-000	0.12042	06-000	-3.8	06-000	295.391	07-000	0.20070
55-000	0.10503	07-000	-4	55-000	269.032	06-000	0.19136

Fig. 2. Result for ranking suitable series locomotive for modernization

AHP Altern	AHP Priori	PROMETHEE Alt\Alt	PROMETHEE netfl	SAW F1	SAW Priori	TOPSIS F1	TOPSIS Priori
44-001	0.14288	44-006	6	44-006	776.449	44-002	0.77387
44-003	0.11487	44-002	4	44-002	747.891	44-006	0.72063
44-006	0.10964	44-010	2.22222	44-010	668.802	44-010	0.59554
44-002	0.10370	44-008	1	44-004	595.547	44-004	0.54558
44-005	0.10226	44-004	0.44444	44-008	546.899	44-008	0.52132
44-004	0.09757	44-007	-0.66666	44-007	519.304	44-007	0.47137
44-007	0.09567	44-009	-1.77777	44-009	453.829	44-005	0.44838
44-009	0.08631	44-001	-2.88888	44-001	389.036	44-009	0.39136
44-008	0.08534	44-005	-3.11111	44-005	352.340	44-003	0.36837
44-010	0.06170	44-003	-5.22222	44-003	244.528	44-001	0.36198

Fig. 3. Results for ranking suitable locomotives for modernization from selected series 44-000

5. CONCLUSION

With the help of specially developed software system is demonstrated the possibility for solving one complex multi-criteria decision-making problem for correct selection of locomotives for modernization. It is examined the liaison between several different criteria and results could be easily put in the practice. The system not aims to replace the experts in process for determining the correct solution. Its primarily goal is to support decision-makers for quick assessment and finding the correlation and dependencies between criteria, which are not easily comparable. Proposed software solution is actual and could be used not only for selection of locomotives but could be easily adapted to other area in the economic and engineering field.

Software system used one of the famous multi-criteria decision support methods - PROMETHEE, AHP, SAW and TOPSIS. These methods can be used for a wide spectrum of practical problems. Developed software system is easily adaptable to support large-scale of criteria and alternatives.

Main contribution of this system is possibility to compare results from different methods in one screen. Selection of one alternative depends on the type of problem and the choice is variant regarding the method used. Results show that correct selection of criteria, preference functions and values leads to similar ranking of alternatives by different methods. This significantly facilitates decision-making people and allows them to provide more deep analysis of the data. Additionally software systems give a possibility to be included more criteria for better accuracy and motivation of chosen solution.

REFERENCES

[1] Krastev, O., Velkov, K., Krastev, M. *Software system for multi-criteria evaluation and decision selection in the operation of railway equipment.* International scientific conference BulTrans-2011, Sozopol, 2011. (in Bulgarian)
Кръстев, О., Велков, К., Кръстев, М.. *Софтуерна система за многокритериална оценка и избор на решения при експлоатацията на железопътна техника.* Научна конференция с международно участие – БулТранс-2011.

[2] Kovachev, B. *Modernisation of electric locomotives series 46.* Technique, Sofia, 2003. (in Bulgarian)
Ковачев, Б. *Модернизацията на електрически локомотиви серия 46*. Техника, С., 2003.

[3] Stoyanov, S. *Methods and algorithms for optimisation.* Technique, Sofia, 1990. (in Bulgarian)
Стоянов, С. *Методи и алгоритми за оптимизация*, С. Техника, 1990.

[4] Tsonev, S., Vitliemov, V. Koev, P. *Optimisation methods.* 2nd edition, University of Russe, Russe, 2004. (in Bulgarian)
Цонев, С., В. Витлиемов, П. Коев. *Методи за оптимизация*. 2. изд., Русенски университет, Русе, 2004.

[5] Brans, J-P. Vincke, P., Mareschal B.. *How to select and how to rank projects: The PROMETHEE method.* European Journal of Operational Research, Vol. 24, 1986.

Other Railway aspects

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

RISK MANAGEMEMENT CAPABILITIES IN RAIL TRANSPORT UNDER SEVERE WEATHER CONDITIONS

Dragutin JOVANOVIĆ [1]
Vujadin VEŠOVIĆ [1]
Branko BABIĆ [2]
Nebojša ĆURČIĆ [3]

Abstract *– Due to its technical and exploitation characteristics, railway has the capability of providing transport service in severe conditions, e.g. caused by extreme weather. In such conditions, risk is present and we should try to find organizational and technical solutions for its reduction to the level that it can be controlled and managed. This paper will examine all the necessary resource and processes of resource management, as a prerequisite for successful risk management in railway transport operation in extreme natural disasters. Then the paper defines measures for risk reduction which are the result of not providing required resources and inadequate resource management.*

Keywords – Risks, rail transport, emergency situations.

1. INTRODUCTION

Functioning of the railway in extreme weather conditions (disasters) is followed by a certain level of risk related to exposure to adverse influences which through their acting can lead to undesirable consequences which means a failure to provide adequate transport services. An example of this is the recent blizzards in the windy region of Vojvodina where the railway mobile capacities were covered with snow causing the interruption of the railroad for several days.

When natural disasters occur, such was the blizzard in 2012 in Montenegro and the one in Vojvodina in 2014 as well as severe floods in western Serbia, one is powerless to prevent the occurrence of such risks, but it is possible to be prepared in advance and react timely if such things actually occur.

Although it is not possible to eliminate risk entirely, risk in the operation of railways in poor weather conditions is an opportunity to improve, identify and define the methods and measures for its management if the risk was recognized timely.

In order to meet the expectations of all interested parties concerning operation in conditions of natural disasters, especially in extreme weather conditions, the railway has to have all the necessary resources and to have established processes of resource management. Proper resources and established processes of resource management are the basic prerequisites for successful risk management in railway operations in conditions of extreme natural disasters and therefore provision of quality services of transport in such conditions.

The risk management itself [6] in railway operations in conditions of extreme natural disasters implies the impact analysis, detection of their causes and consequences of failure, especially at the stage of recognizing the risk, risk assessment, and defining measures for reduction of their occurrence, and eliminating the cause, and thus the consequences. Defining corrective and preventive measures to reduce or eliminate the risk consequences would be also a good basis for the planning techniques application of risk management.

[1] Dragutin JOVANOVIĆ, Faculty of Transport, Communications and Logistics, Donje Luge bb, Berane, Montenegro, djovanovic@politehnika.edu.rs
Vujadin VEŠOVIĆ, Faculty of Transport, Communications and Logistics, Donje Luge bb, Berane, Montenegro, vujadin.vesovic@gmail.com
[2] Branko BABIĆ, Technical College of Vocational Studies, Školska 1, Novi Sad, Serbia, babic@vtsns.edu.rs
[3] Nebojša ĆURČIĆ, College of Vocational Studies - Belgrade Polytechnic, Brankova 17, Belgrade, Serbia, ncurcic@politehnika.edu.rs

2. RAILWAY OPERATION IN ADVERSE WEATHER CONDITIONS

Railway as one of the transport branches which apart from its own tasks in social, political and economic system of the country, has a very important function in emergency situations, especially in extreme natural disasters. Because of its importance, it has been appointed by the Government of the Republic of Serbia as a legal entity authorized to act in order to protect and rescue people, as well as material goods and cultural heritage [8].

There are a few terms used for emergency conditions (emergency situation, disaster, danger [5]), which basically means that emergency implies irregular situation, therefore those which differ from the normal state and the established norms of the society or state functioning.

Natural disasters, as a form of emergency peacetime conditions, may occur as a result of various phenomena: earthquakes, fires, floods, strong winds, severe blizzards etc. out of which only 10% refer to earthquakes and volcanos, and 90% refer to blizzards, floods, strong winds, storms etc. (the data were announced by the United Nations according to 30-year-long research, and they informed all the members that the greatest threat to people's lives and property are not wars or the atomic bomb, but natural disasters). All forms of natural disasters, regardless the cause of their creation, have one in common characteristic – they require increased and more complex railway functioning as an element of the country's transportation system.

Railway as a branch of land transports, apart from all the difficulties and constrains, has a permanent mobility which enables it to adapt quickly to new situations. That is an important factor which highlights the importance of railways during the elimination of the emergency situations consequences.

Railway is expected to provide secure and regular railway traffic flow in all weather conditions as well as natural disasters. In such circumstances, it is necessary to provide normal railway operations, railway infrastructure troubleshooting and all the necessary mobile assets.

Railway operations in natural disasters is characterized by the ability to perform the railway transport 24/7 using all the available railway resources and with the maximum of cooperation with other sectors and means of transport.

3. RESOURCES AS A BASE OF RISK REDUCTION IN RAILWAY TRAFFIC OPERATIONS IN TERMS OF NATURAL DISASTERS

Thorough understanding of railway operations in the in conditions of extreme natural disasters is possible to achieve by analysis of the resources required for such an operation.

Standard SRPS ISO 9001:2008 emphasises the human resources, infrastructure and work environment. The resources required for railway operations in extreme natural disasters are: material resources, human resources, work environment, natural resources and information, Fig. 1. Apart from previously mentioned resources there are also knowledge, technologies, suppliers and partners, and financial resources in SRPS ISO 9004:2009.

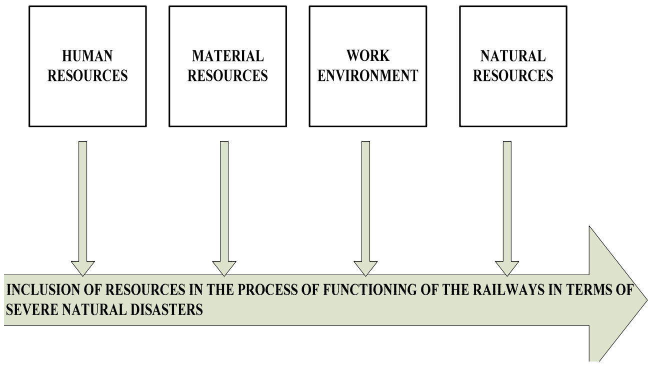


Fig. 1. The resources required for railway operations in extreme natural disasters

In order to meet railway users' expectations in such conditions, it is necessary to identify the resources as well as to organize resource management and coordination [5]. Resource management includes a few processes as it was shown in Fig. 2.

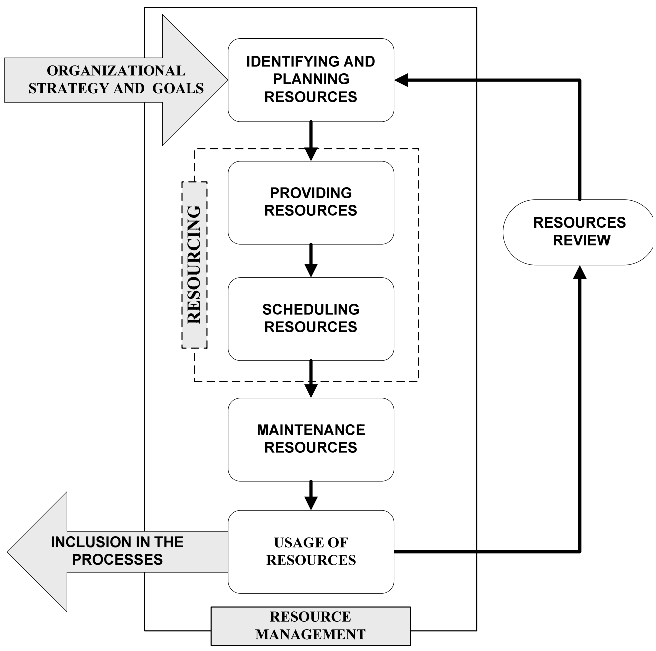


Fig. 2. Resource management processes [3]

The process of resource identifying and planning includes identifying needs and plan of resourcing. Providing resources include the acquisition process and deployment of resources, which are identified as necessary, and whose provision is planned.

The acquisition process should provide resources in sufficient quantities and quality required at the time when they are needed. The process of allocating resources is the preparation phase before the use of resources. The process of resource maintenance should provide resource availability in a state that ensures their timely use in the process and achieve the required outputs from the process.

Resource review should include effectiveness and efficiency issues of resource use, as well as evaluation, optimization, resource development, etc.

Material resources required for railway operations in extreme natural disasters, actually in blizzards are:

- locomotives “cruisers”,
- snow removal equipment,
- special equipment (bulldozers, snow blowers, truck transporters, etc.),
- construction machinery with rubber wheels which has ability of track motion,
- hand tools for snow clearing and removal,
- individual elements of railway infrastructure (tracks, track facilities),
- snow and ice melting chemicals - rock salt or calcium chloride, sand, clay, wood chips, etc.,
- ice and snow melt systems at railroad switches etc.

Human resources required for railway operation in blizzards are:

- officials at a particular section of the railway,
- officials from other organizational units of the railway,
- other institutions’ and companies’ staff working in the field,
- “cruiser” locomotive drivers,
- operators and snow removal machinery drivers and other machinery operators,
- qualified and trained civil protection units’ personnel trained for their own needs [5].

Work environment resources required for railway operations in blizzards are:

- work conditions,
- motivation and personnel satisfaction,
- equipment functioning and achieving the projected parameters of railway transport operations in specific conditions.

Natural resources required for railway transport operation in blizzard conditions are:

- energy,
- environment.

Information resources required for railway transport operations in blizzard conditions are systematized information about:

- weather conditions (snow depth above the upper rail edge, air temperature, snow characteristics, precipitation, wind characteristics (direction, strength)),
- weather forecast for the upcoming period,
- location of vulnerable places,
- level and type of jeopardizing the parts of railway line,
- level and type of jeopardizing the overhead contact system and other aspects of railway electric traction systems,
- necessary resources provided,
- measures taken to eliminate the consequences
- cruisers’ movement and mechanized snow-removal equipment (snow plows, snow removals and snow cleaners),
- cruisers’ effectiveness and resources engaged for mechanized snow removal.

The basic requirement for reducing risk to a level that can be controlled and can be operated with, is to provide all the necessary resources for proper railway functioning in blizzards.

4. MEASURES TO MINIMIZE RISK

Considering the identified resources and the possible risks arising from the failure to provide them and from inadequate resource management, it is possible to define measures to reduce their occurrence, and to eliminate the cause, and thus the consequences. Some of the measures can be:

a) infrastructure preparation

- preparation of rail vehicle undercarriage (pillars of the bridges, tunnels with water that freezes in winter, river embankments, etc.),
- enabling snow removal equipment cross the railroad and run smoothly,
- removing dry grass and bushes which can cause a fire in snow shed areas and wood movable snow sheds,
- construction of new facilities according to needs (snow shed areas, permanent snow sheds and wind fences etc.),
- obtaining the new movable snow sheds, machinery, vehicles, tools and other operating and communication equipmenet etc.,
- preparation of permanent facilities for protection from the snow, avalanches and strong winds,
- preparation of movable snow sheds,
- preparation of facilities for servicing and maintaining the locomotives and railway carriages,
- preparation of machinery, vehicles, tools and other equipment for snow and ice clearing and removing,
- preparation of the forests snow shed areas,
- preparation of water supply installations and other devices for water supply,

- preparation of signalling devices, communication devices, personal protective equipment and their layout,
- overhead contact system preparation,
- preparation of facilities and equipment required for personnel housing in vulnerable places,
- checking the road safety on level crossings,
- cleaning the roads at the crossings,
- removing ice from the railway tracks,
- defining the needs and dynamics of moving snow sheds in winter time
- cleaning of culverts from garbage materials, overgrown grass and bushes,
- cleaning of drainage ditches and canals for faster water drainage during snow melting period
- removal of materials that could cause precipitation of snow on the track and snow drifts,
- providing railroad switches drainage;

b) preparation of mobile capacities

- defining the types of equipment foe mechanized snow removal (snow plows, snow removals and snow cleaners),
- preparation of machinery and vehicles for snow and ice cleaners and removals,
- cleaning machinery and vehicles layout based on carried out assessments,
- choosing type and series of a locomotive "cruiser" based on following parameters: inclination of railway track, length of the route where it operates, snow depth, wind speed, railway jeopardy etc.,
- providing a certain number of locomotives "cruiser", defining the ways of their engagement (with or without a plow, one or two hooked up),
- preparation of railway electric traction;

c) human resources preparation

- task-assignment of the workforce engaged in snow clearing and their housing,
- preparation of the personnel for snow and ice clearing from the following parts of railway infrastructure (tunnels on electrified lines, road crossings, bridges, switches, rail bands and dilatation devices, railway platforms, etc.) as well as from the trains and vehicles covered with snow,
- mobilization of personnel in emergencies,
- constant surveillance in vulnerable places.

d) other preventive measures

- risk assessment of the company [5,6],
- protection and rescue plans sorted by type of risk [6,7],
- training of personnel and measures of personal, mutual and collective protection.

5. CONCLUSION

Regardless the technical characteristics, extreme weather conditions – natural disasters can jeopardize the railway system. Those are the conditions when numerous risks related to railway traffic arise. They refer to the exposure to unfavourable factors which can cause adverse effects, which actually means inability to provide adequate transport service.

Taking into account the technological characteristics and specificities of the railway system it may be necessary to define the resources which consist of material and human resources, as well as working environment resources, natural resources, and information resources.

Among a number of adverse factors which lead to the risk of the railway transport operations, one very important factor is not provided, inadequate and insufficient resources and inadequately established resource management processes. Only appropriate resources and established resource management processes provide an opportunity for successful risk management in railway operation in such conditions.

An important stage in risk management in railway transport operations in extreme natural disasters is defining the measures of risk reducing i.e. eliminating causes and at the same time consequences that may arise due to lack of adequate and sufficient resources, as well as failures in the process of resource management. Important things from the group of measures that have to be taken, are preventive measures to reduce or eliminate the risk consequences. Properly identified and defined preventive measures are a prerequisite for successful risk management planning.

REFERENCES

[1] Vešović, V.: *Menadžment u saobraćaju*, Faculty of Transport and Traffic Engineering, Belgrade, 2008.

[2] Jovanović, D., Eror, S.: *Železnički saobraćaj*, Faculty of Transport, Communications and Logistics, Berane, 2010.

[3] Dželetović, S.: *Uspostavljanje i provera sistema menadžmenta kvalitetom*, Belgrade Polytechnic, Belgrade, 2011.

[4] *The Guidelines on the Provision of Traffic During the Winter*, Official Gazette of the Association of Yugoslav Railways No. 1/2004.

[5] *The Law on Emergency Situations*, Official Gazette of the Republic of Serbia No. 111/2009, 92/2011, 93/2012.

[6] *The Guidelines on the Methodology for the Development of Risk Assessment and Protection and Rescue Plans*, Official Gazette of the Republic of Serbia No. 96/2012.

[7] *The Regulation on the Content and Method of Making Plans for the Protection and Rescue in Emergency Situations*, Official Gazette of the Republic of Serbia No. 8/2011.

[8] *The Decree on Determining the Authorized and Qualified Entities for the Protection and Rescue in the Republic of Serbia,* Official Gazette of the Republic of Serbia No. 36/2011.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

DISCUSSION ON AUCTIONS AND THE POSSIBILITY OF THEIR APPLICATION IN RAILWAYS

Nikola STOJADINOVIĆ [1]
Branislav BOŠKOVIĆ [2]

Abstract *– With the opening of railway markets and the emergence of competition in the rail sector there is a need to change the traditional way of allocation of railway resources. One possible way to allocate resources, whether in terms of facilities or services, are auctions that are increasingly present in other transport modes and economy sectors. Is the use of auction feasible on the railway, which types of auctions are suitable for use, when, in what circumstances and under what conditions are the main issues discussed in this paper. The paper gives a brief overview of previous experience in applying auction railways.*

Keywords – Auctions, railway market, allocation of railway capacities.

1. INTRODUCTION

Due to competition in the railway infrastructure and scarce capacity, a question of allocation of track capacities emerges. The question of allocation of scarce capacity in the busy corridors is especially sensitive. In such situations, infrastructure managers and railway undertakers are confronted with high costs due to scarce capacity and with congestion costs on the railway infrastucture.

The introduction of competition in train paths in public railway infrastructure de facto influences the procedure of allocation of railway infrastructure capacity. While there used to be a single integrated railway company that performed all operations from planning and constructing a railway network to traffic operations, nowadays the responsibilities of infrastrucutre managers in a deregulated railway system are limited mostly to network planning, allocation of capacity and traffic operations.

One of the possible ways for a fair allocation of capacity is the introduction of an auction mechanism for the allocation of scarce capacity. As in other activities where demand is higher than supply, a well-devised and well-organised auction can accomplish the goals stipulated in the directives of the European Commission which refer both to the allocation of capacity and to a fair and non-discriminatory allocation of infrastructure manager costs.

Auctions became known to the broader scientific community after a successful auction sale of the rights to use radio and television frequencies in the US in 1994 (*spectrum auctions*). That year, the Federal Communications Commission (FCC) sold 2,500 rights to use frequencies. Since then, 87 such auctions have been organised in the US up till now, generating a revenue of over $60 billion for the state [1].

Following these auction sales there has been a growing interest in the formulating of new forms of auctions for specific markets, such as the sale of rights to use frequencies for cellular telephony, and the use of auctions for opening new markets such as electric power trade and transport. Regardless of their specific qualities, it is indicative that these markets were monopolistic until recently, which opens up possibilities for the consideration of applying auctions to the railways, which is the topic of this paper.

2. THE BASIC POSTULATES OF AUCTIONS

In economic theory, an auction may refer to any mechanism or set of trading rules for exchange. [1]. An auction may also be seen as a formalised negotiation procedure [2]. The devising of an auction in fact lays down the rules which constitute the framework for conducting the negotiation. Whether an auction will be successful or not depends on the success of defining the rules. There are two aspects that characterise negotiations: the economic good which is being negotiated (this may be an item, a right, a resource or a service) and the negotiation

[1] NikolaSTOJADINOVIĆ, Faculty for Transport and Traffic Engineering, V. Stepe 305, Belgrade, n.stojadinovic@sf.bg.ac.rs
[2] dr Branislav BOŠKOVIĆ, Faculty for Transport and Traffic Engineering, V. Stepe 305, Belgrade, b.boskovic@sf.bg.ac.rs

procedure. An auction may be used as a means of determining the value of resources and services whose value has not yet been determined. An auction is a market mechanism for allocation of resources which independent participants bid for [3]. The auction participants who bid to buy an item or service are called *bidders*, while the seller who offers an item or service up for sale is called an *auctioneer* [1]. Usually there are several bidders who attempt to purchase an item or service. In certain cases there are several sellers (they can be manufacturers or operators) who attempt to sell an item or service to a buyer, offering the lowest possible price. This is called a *reverse auction* [4]. The reason for the majority of auctions is commonly the sale of an item, a good, a service or rights. However, it is often the case that multiple items or services at auctions are simultaneously up for sale.

3. NECESSARY CONDITIONS FOR AUCTION APPLICATION

The most important condition for the implementation of an auction for allocation of any resources is the existence of two or more bidders who are simultaneously bidding for the scarce resource. It is exactly this situation that has been recurring on the congested railway infrastructure[1] where two or more operators demand the use of the capacity on the same part of the network at the same time. On some sections and at certain times, infrastructure managers are faced with a greater number of demands for the train path than the capacity they have at their disposal even with the introduction of a fee for infrastructure use. Consequently, there is a growing number of conflicts between the demands of the operators for the use of the infrastructure.

Another important condition for the implementation of auctions is the existence of a regulated regulatory and institutional system for the implementation of the auction mechanism. According to Directive 2001/14/EC [5], an infrastructure manager, who should be independent from any operator in the decision-making process, allocates the track capacity. It is necessary that there exist a regulatory body that receives complaints from operators which have to do with the capacity distribution process and its results.

Before the railway reform in Europe, the railway infrastructure capacity was allocated following already defined priority rules (such is the example of the primary incorporation of train paths for passenger intercity trains) along with next to no transparency during decision-making. After first organisational changes to vertically integrated railway companies and separation of operators from infrastructure managers, some infrastructure managers published a collection of rules based on which they had made decisions about the allocation of capacity and resolving conflicts. In the competitive market, the infrastructure manager's role is to coordinate the operators' demands for train paths according to available capacity and to resolve conflicts based on the criteria determined in the Network Statement which s/he is obligated to issue.

4. TYPES OF AUCTIONS SUITABLE FOR APPLICATION

The railway system possesses numerous specific qualities pertaining to technology of traffic operations itself, organisation of the railway sector, and complexity of the railway network. The first noticeable characteristic is that this market is imperfectly competitive, because there are only few operators in it. Beside that, the track capacity as a resource has certain specific qualities such as the complexity of the network, the interdependence of train paths, and the inhomogeneity of the timetable [6]. Also, the greatest number of rights are assigned for a longer period of time so that the operator holding the rights be interested in investing significant funds.

It is precisely these characteristics that determine the type of auction which can be applied to a certain segment of the market. Depending on the development stage of the market, auctions can currently be used in two different segments: allocations of train paths in a timetable (drawing up timetables, thereby resolving conflicts between the demands for train paths), and bidding for the right to carry out public service obligation (PSO).

4.1 Allocation of train paths in the timetable

In cases when two or more operators demand train paths which intersect completely or in one of their parts, it is necessary to determine which train path to incorporate into the timetable, i.e. to determine which operator should be granted the right to use the infrastructure on that section at that moment. Then any kind of open or closed price auction for an item may be used. According to research [7] and experience in other fields, an auction for the second highest bid gives the best results because it stimulates the bidder to make bids which are in accordance with his/her honest evaluation of the item on auction.

However, during the drawing up of a timetable, operators often submit requests to an infrastructure manager that contain a package of train paths which are necessary for providing transport service. In situations when several operators are bidding for

[1] "Congested infrastructure" means a section of infrastructure for which demand for infrastructure capacity cannot be fully satisfied during certain periods even after coordination of the different requests for capacity (Directive 2001/14/EC)

several different units (in this case train paths), combinatorial and simultaneous ascending auctions may be used. The use of these auctions can lead to a much more efficient allocation, especially when the train paths being sold are complements, because the value that the bidders give for the package is greater than the simple sum of the values of individual items. On the other hand, determining the optimal bidding strategy can pose a problem to operators, as can be deterimining the winner. However, with the assistance of contemporary software packages, models of combinatorial auctions in which bidders make their offers for packages via computer have been developed, and they determine the winner of the auction.

4.2 Types of auctions for the sale of rights to carry out PSO

One of the common dilemmas that occurs during public procurement in railway traffic in Europe is the choice of operator that will be granted the right to provide public service obligation. The aim of the state in public procurements is to provide this service with the lowest possible fee, but in accordance with the prescribed standards which operators have to meet while providing the service, such as minimal train frequency, train-set capacity, service quality, etc. The bidding of operators is conducted at so-called reverse auctions where operators bid for the lowest possible fee. The winner at a reverse auction is the operator who requested the smallest fee.

5. EXPERIENCE IN AUCTION APPLICATION IN THE RAILWAYS SO FAR

Auction in Europe is currently applied in several European countries where there is a relatively developed railway market. The first application of auctions in the railways was applied in the United Kingdom for the sale of franchises for conducting passenger and freight traffic. Railway operators made sealed bids, and by winning at the auction, the operator purchased a package of jobs which they commited to carry out for a longer period of time. This kind of mechanism has greatly simplified the process of allocation. However, through franchises a monopolistic position was secured by operators who were granted the right to the franchise.

Auctions are used in Germany as a last resort for resolving conflicts between operators who submitted a request for a train path. If during the capacity allocation procedure a solution that satisfies both parties is not found, the infrastructure manager organises a closed price auction for the highest price and calls on railway operators whose demands were involved in the conflict to submit a bid, i.e. a sum of money they are prepared to pay. The offer has to be larger than the amount of the fee the railway operator would pay for the train path without the auction. The demand for a train path of the railway operator that offered the highest price is accepted and the train path is incorporated into the timetable.

Apart from resolving conflicts in a timetable, auctions are applied at public procurements for the sale of rights to carry out PSO on some lines in Germany. Lalive and Schmutzler [8] compared the results of allocations of rights when they were directly negotiated and when more operators bid for the right at an auction in Germany. The authors concluded that through the application of auctions, a 16% higher frequency of trains on the lines of the PSO is acquired, as opposed to when the service is granted through direct negotiations.

In Sweden the application of the auction mechanism has been considered because of growing problems connected to scarce capacity in bigger cities [9]. Unlike the use of auctions in the final stage of elimination, it has been suggested that the auctions for train paths be held during the early stages of timetable negotiations so that the Swedish Transport Administration functioning as the regulatory body could uncover the true preferences of operators through their willingness to pay. According to the authors, the main obstacle to the application of auctions in Swedish railways is the complexity of its railway network, as well as the evaluated decline in social welfare due to the reduction of daily frequency of passenger traffic.

6. EFFECTS OF INTRODUCING AUCTIONS TO ALLOCATION OF CAPACITY IN THE RAILWAYS

Although auctions are used for granting rights to carry out PSO, it is still early to assess the effects, whereas for the allocation of capacity they can be systemised in the following way (figure 1).

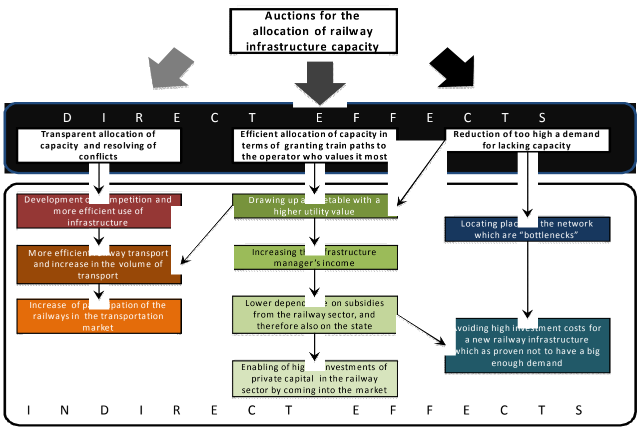


Fig. 1. Schematic representation of direct and accompanying indirect effects of auctions for train path allocation

The introduction of auctions has the primary goal of accomplishing direct effects such as:

- **Transparent allocation of capacity and resolving of conflicts**. The rules of the game such as the amount of the reservation fee, the way in which the bid is submitted, and the price the winner pays are defined by the formation of the auction mechanism. It is precisely these rules that not only help prevent discrimination of operators, but also crucially influence the number of operators who participate in the auction;
- **Efficient allocation of capacity**. Another change which the auction mechanism for capacity allocation introduces refers to infrastructure capacity evaluation . In the use of auctions for the buying of train paths, the initiative is granted to operators rather than to infrastructure managers because operators are susceptible to competition and are familiar with the demands of end-users. The price of a train path is influenced by an infrastructure manager who determines the *reserve price*[2], and by operators bidding for the train path. Which price will be reached depends on the evaluation of a train path and the number of operators bidding for it. Operators giving suggestions for train paths, their bidding and drafting of train paths where the market dominantly decides the price of a train path results in a timetable with the highest value;
- **Reduction of demand for scarce capacity**. It is well known that investements in the railway sector are relatively very high, as well as that they are often unjustified. With the introduction of auctions, the operator who is most ready to pay at that moment is granted the train path for use. This is of particular importance to freight operators who are discriminated in the traditional way of planning timetables, but who are in most cases prepared to pay more for a train path than passenger operators. On the other hand, after the auction it is obvious to an infrastructure manager on which segments of the network a higher demand that surpasses capacity occurs, and s/he will be able to plan its expansion exactly where needed.

Other, indirect effects derive from these direct effects, such as drawing up a timetable of a higher value, a potentially higher income for an infrastructure manager on a congested segment of the network, more efficient railway transport and avoiding high investment costs for a new railway infrastructure which has proven not to have a big enough demand.

[2] In some cases it is optimal for the seller to determine a reserve price, i.e. a minimal price below which s/he is not prepared to sell an item. If there is only one bidder participating at an auction and no reserve price, s/he can make an offer equal to zero and get an item for free. On the other hand, if a seller determines a reserve price too high, s/he risks not selling the item. Therefore, a seller must find the optimum between these two effects (Trifunović, 2012)

7. CONCLUSION

Auctions offer a practical solution for determining train path values and resolving the problem of scarce capacity. Because an infrastructure manager knows the value of train paths after an auction, s/he is then in a position to draw up a timetable which is based on a Pareto efficient allocation. Without auctions, as without fees for use of infrastructure, operators do not have the incentive to consider how their demand impacts the scarcity of capacity. High demand which may occur at an auction could potentially create high prices for some train paths, which would lead to disburdening of the capacity for which there is too great of a demand.

In comparison to the administrative mechanism for allocation of capacity, the auction mechanism is more dominant because it provides a higher efficiency of capacity allocation, a greater transparency of allocation and reduction of too much demand for scarce capacity. The introduction of auctions as an instrument within transport policy has the goal of accomplishing a series of effects, which in a short or longer period of time can bring about certain changes in the functioning of the railway sector, opening of markets, attracting competition, and change of the state policy towards the railway industry.

REFERENCES

[1] Trifunović, D.: *Aukcije*, Ekonomski fakultet u Beogradu, Centar za izdavačku delatnost, 2012.

[2] Borndoerfer, R., Grotschel, M.S., Mitusch, K., Schlechte, T., Schultz, S., Tanner, A.: *An auctioning approach to railway slot allocation*, Konrad-Zuse-Zentrum fur Informationstechnik Berlin, ZIB-Report (45), 2005.

[3] Parkes, D.C., Ungar, L.H.: *Iterative combinatorial auctions: Theory and practice*, 17th National Conference on Artificial Intelligence (AAAI-00), pp. 74-81, 2000.

[4] Klemperer, P.: *Auctions: Theory and practise*, Prinston University Press, New Jersey, 2004.

[5] European Comission, *Directive 2001/14/EC*, Official Journal of the European Communities, Brussels, 2001.

[6] Gibson, S.: *Allocation of capacity in the rail industry*, Utilities Policy 11, pp. 39 – 42, 2003.

[7] Isacsson, G., Nilsson, J.-E.: *An experimental comparison of allocation mechanisms in the railway sector*, Journal of Transport Economics and Policy 37(3), pp. 353-382, 2003.

[8] Lalive, R., Schmutzler, A.: *Auctions vs negotiations in public procurement: Which works better?,* Working Papers Series, Department of Economics, University of Zuerich, No. 23, 2011.

[9] Jansson, K., Lang, H.: *Rail infrastructure charging EU-directive, Swedish concerns and theory*, Research in Transport Economics 39, pp. 285-293, 2013.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

THE UNIVERSITY RAILWAY ENGINEERING EDUCATION

Dušan STAMENKOVIĆ [1]
Dragomir MANDIĆ [2]

Abstract *– New scientific findings, the globalization of the world market and rapid technological developments introduced changes in industry, transport and education. According the technology development, education also introduces new disciplines to form specialists for new challenges. Railways need engineers from different fields such as civil, mechanical, electrical, traffic engineers, computer scientists, etc. Railways experience significant progress in developed countries, but in many less developed countries they are in crisis. Long-term crisis of railways and railway industry in Serbia resulting in a decrease of the interest of students in this area. This paper describes the current state of curricula relating to the railways at Serbian universities, but provides information about EU universities that educate railway engineers. The authors conclude that the development of Serbian railways can provide only qualified engineers.*

Keywords – Railway Engineering, University Education, Serbian Railways, Global Education.

1. INTRODUCTION

Railway engineering is a multi-faceted engineering discipline that includes civil engineering, mechanical engineering, electrical engineering, traffic engineering, computer engineering, production engineering etc.

Considering new scientific discoveries and extremely rapid development of engineering and technology, constant and continuous changes in the education system are necessary. The goals that were set for the engineers fifty year ago were directed to increase productivity and product quality, whereas today these aims, among other things, are oriented towards the requirements of comfort, energy efficiency and ecology.

The system of traditional higher education was established during the twentieth century, but since the signing of the Bologna Declaration in 1999 it has begun changing significantly across Europe. The main goal of the Bologna process is to establish a single European area of higher education [1].

The rail industry is becoming more globally oriented where major players operate in multiple nations and continents. The universities have reduced rail programs over the past several decades. With growing demands, it will be a challenge to find new rail professionals who must understand the system complexities, new information technologies, and the global aspects of today's rail industry that have traditionally not been required.

TUNRail [2] is an on-going two-year project funded under the EU-US Atlantis Program that has bought together faculty from several universities in Europe and the United States to examine railway higher education programs, explore opportunities for knowledge exchange and collaboration, and develop materials for new railroad education and research programs. It is the first known effort to bridge the knowledge in rail higher education and the initial step toward continuous collaboration to strengthen the role of railway education and research in academia. Authors of Handbook for Rail Higher Education [2] think that the higher demand for rail education should be expected in the coming years.

Considering the German railway is very developed, there are few universities with railway engineering programs in Germany [3,4].

Effects of transformation of the railway and the education systems in Poland last years are: lack of specialists, deterioration of personnel resources of railway companies, problem of safety in the rail traffic, problem of managers from outside the branch, not familiar with the subject, who appeared in the railways (domination of economical factors), lack of "railway" specialists among the university teachers, and other [5].

There were a numerous problems in the last thirty

[1] Dušan STAMENKOVIĆ, Faculty of Mechanical Engeneering, University of Niš, Serbia, dusans@masfak.ni.ac.rs
[2] Dragomir MANDIĆ, Faculty of Transport and Traffic Engineering, University of Belgrade, Serbia, drama@sf.bg.ac.rs

years caused by unstable political conditions in the region of South Eastern Europe, the economic crisis and the decline in economic activity in recent years, and the slow transformation of the Serbian Railway. The Law on Higher Education of the Republic of Serbia was adopted in 2005 and since then, numerous activities have been conducted at universities, but a changes in studying programs must be continiously performed in the future [6,7].

The authors in this paper wish to indicate that long-term crisis of railways and railway industry in Serbia influenced to the university education in this area. There are reducing the interest of students for railway engineering education in Serbia.

2. RAILWAY ENGINEERING EDUCATION IN EU

About 1.3 million people are directly employed by railway operators in EU. There are a wide variety of railway transportation and engineering courses available. EU has dozens of railway programs dispersed between the EU nations, with a high percentage of the programs being located in the predominantly German-speaking regions. Even though a multitude of universities exist in the EU with rail education and research related activities, there is no a uniform system of railway higher education. Instead, there are still significant differences between countries. The total number of students receiving rail education in EU is approximately 1000-3000 [2].

Course topics in UE universities are usually: Railway systems, Railway Operations Management, Railway Signalling, Transportation, Urban Transport, Railroad Vehicle Engineering, Operation of Railroad Vehicles and Railway infrastructures.

A significant feature is that there is cooperation between the railway industries and universities. Research and teaching of railways is almost always linked together at the university in the EU. Examples of collaboration with the railway industry are: Railway industry funding, Sponsored research projects, Official partnerships with financial support, Internships, Field trips for classes, Guest speakers / professors from industry and other [2].

As rail transportation industry becomes more globally oriented, it must be considered whether the educational offerings should undertake similar transition. Global education needs the new methodologies and tools in order to achieve the new outcomes.

Basic information of the most common approaches currently used to global education is described in [2]. There are few program formats: traditional international activities, E-learning and E-teaching, Virtual global I-class, Short-term study-abroad programs, Long-term study-abroad programs, Long-term on campus programs, and others.

Traditional international activities include: visiting lectures by foreign visitors, international conference, visiting scholars, foreign culture course, foreign language training, enrolling international students, bilingual teaching.

E-learning and E-teaching imply teaching by foreign universities lecturers through internet-based tools. It is economic way for the students to learn foreign technologies.

Virtual global I-class enables students from different universities study together by using internet-based tools in a virtual global classroom. It is good opportunity for students to learn about global issues.

Short-term study-abroad programs include students traveling to one or several countries and visit companies and/or universities for a tour and/or lectures between one to several weeks under the guidance of a faculty member. It also includes project-based learning and research abroad (students travel to a foreign laboratory and conducts research under the guidance of a faculty member), etc.

There are two forms of Long-term study-abroad programs: Exchange (students from the two universities involved are exchanged for a period and take regular courses in the host university. Degree awarded by their home university); Double degree (students obtain one degree from the home university and another one from the foreign university during a period of study abroad).

On-campus foreign course study is more popular than studying abroad.

Combinations of the previous formats are also possible.

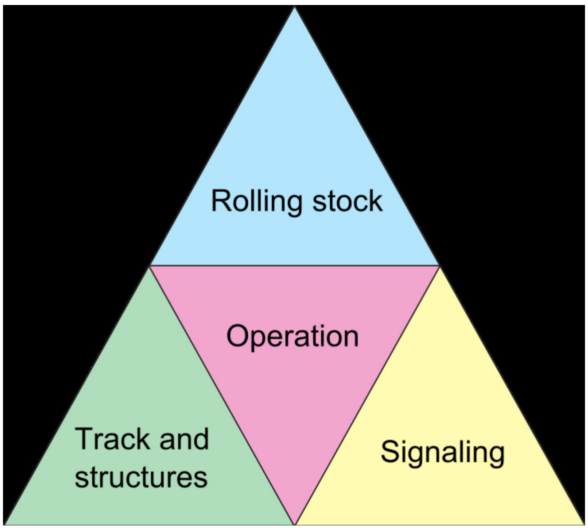


Fig. 1. The railway systems triangle [2]

Innovative teaching methods exist in university railway engineering, but rail higher education has not moved to global education and taken advantage of educational technologies [2]. Railway engineering differs from teaching many other fields of technology, as in the railway system all fields of engineering are interconnected (Figure 1). As a result teaching railway science must follow an interdisciplinary approach where fundamental knowledge of rail related aspects of civil engineering (permanent way, structures), mechanical engineering (rolling stock), electrical engineering (signaling, electric traction), and computer science (signaling, control systems) come together in the process of operation [2].

EU has dozens of railway programs with a high percentage of the programs being located in the predominantly German-speaking regions (Figure 2).

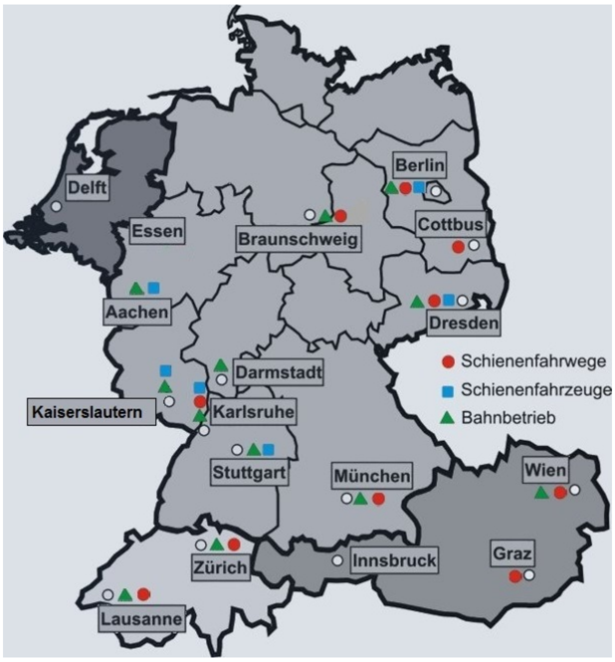


Fig. 2 Universities with railway programs in Germany, Austria and Switzerland [4]

The subjects of railway engineering education are Railway system, Infrastructure and Vehicles. Elements/main researches of Railway system are: system integration, operation management, risk and safety analysis of transportation systems, marketing for passenger and freight transport, urban rail systems, information systems of public transport and automation systems.

Elements/main researches of Infrastructure are: track design; construction and maintenance of tracks, points, bridges, tunnels; new technologies of superstructures; noise protection; construction and assembling management; power supply; railway signalling; telecommunication systems; passenger information systems, and others.

Elements/main researches of Vehicles are: acoustics, safety, energy management, maintenance, dynamics, power technology, life cycle cost, engine, gear and break, bogy, interaction rail wheel, and others.

Principles of education which exist on these universities are:

- interaction of national and international research and teaching
- high valuable laboratories for research and operation enable a strong link to practice and reality
- engineering institutes mostly maintain contracts with customers of in railway enterprise and railway industry; often students are involved to the contracted workload
- graduates are prepared for a large range of professional opportunities.

3. RAILWAY ENGINEERING EDUCATION AT SERBIAN UNIVERSITIES

The Law on Higher Education of the Republic of Serbia was adopted in 2005 and since then, numerous activities have been conducted at universities . The reform of higher education in Serbia should provide more efficient and flexible studying adapted to European quality standards. Today in Serbia there are 18 accredited universities, of which 8 are state-owned and 10 private. Railway engineering education exists only at state universities ie at Belgrade, Novi Sad, Nis and Kragujevac (Kraljevo).

The reorganization of higher education in accordance with the Bologna Declaration was conducted at Serbian universities last 10 years. This process has increased the number of electives that. objects that student self-selecting. Special study programs relating to railways exist only on Belgrade University, Faculty of Mechanical Engineering and Faculty of Transport and Traffic Engineering. At other universities within the general study program, there are groups of subjects that are related to railways.

At Faculty of Mechanical Engineering University of Belgrade, at the undergraduate studies, which last for 3 years, in addition to other subjects, there are three subjects that are directly related to railways. Within two years of master studies there is a separate module called Railway Mechanical Engineering, from a total of 15 items there are 8 compulsory subjects that are directly related to railroad cars. Department of Railway Mechanical Engineering exists at this faculty.

At Faculty of Transport and Traffic Engineering University in Belgrade, at the undergraduate level which is 4 years long and master studies last for one year, there are modules called Railway Traffic and Transport. Module Railway Traffic and Transport at the undergraduate level has a total of 34 subjects, among them 9 are compulsory and 7 electives that are direct related to railways. Module Railway Traffic and Transport on one-year master studies, has total of 14 subjects, of which 9 are related to railways. In this faculty there are two departments that are facing rail transport: Division for Management in Railway, Rolling stock and Traction and Joint Department in Railway Exploitation.

At Faculty of mechanical engineering University of Nis there are 4 elective subjects at undergraduate academic studies which last for 4 years and 2 elective subjects at master academic studies which last for 1 year. These subjects are within the program module Mechanical Constructions, Development and Engineering and program module Traffic Engineering, Transport, And Logistic.

There is a study program Traffic and Transport Engineering at Faculty of Technical Sciences in Novi Sad. At undergraduate academic studies there are one compulsory and three elective courses that are directly related to railway engineering. At master academic studies there are two optional subjects related to rail transport.

At the Faculty of mechanical and civil engineering in Kraljevo, there are two optional courses at undergraduate academic studies and 1 mandatory and 3 elective at master academic studies that are directly related to railroad cars.

The situation is similar at the Faculty of Civil Engineering and Faculty of Electrical Engineering University of Belgrade and at the Faculty of Civil Engineering and Architecture University of Nis.

Reduced students interest in railway engineering programs and railway subjects is evident at all Serbian universities in recent years. The main reason for this is the crisis of Serbian Railways and reduced employment.

The restructuring process of Serbian Railways is performed in the framework of the following activities: legislative framework, organizational structure, rationalization of unprofitable sections of the network, the separation of secondary activities from the company, reducing the number of employees, improving the quality of the relationship between the State and the Railway. Certain aspects of the restructuring (reducing the number of employees, legal framework) are increasingly further away than the other (organizational structure, the relationship between the State and the Railway, etc.) [6].

However, the process of restructuring takes place very slowly and a number of substantive changes are yet to come. This can result in that the railway sector in Serbia remains unprepared for the opening of the market, which will be established by the pressure from EU, by the international financial institutions [7].

Serbian Railways, preoccupied with its own reorganization, neglected relationship to the national industry. Purchase of new vehicles, reconstruction of the old and investment repairs are carried out through tenders. In new construction jobs, because of severe commercial conditions, national industry cannot be employed, except that to a lesser extent, it may possibly be involved as a subcontractor. Unfortunately, in factories for production and repair of railway vehicles privatization was conducted unsuccessfully [6].

The last 5-6 years Serbian Railways did not hire graduates of mechanical, civil, electrical and traffic engineers. This is the main reason that fewer young people decide to study at the "very difficult faculties." That is absurd. Fewer students are enrolled or complete college and those who complete studying looking for a job many years.

4. CONCLUSION

Only qualified engineers can conduct the development of the railway. Capable engineers are formed on the good study programs on the one hand, and in industrial practice on the other hand, which implies the overall good functioning of railways and industry.

In order to ensure a better future for Serbian Railways, it is essential that university educate engineers who will be able to conduct business goals of railways and industry. Railway department units only exist at the Faculty of Mechanical Engineering and Faculty of Transport and Traffic Engineering of the University of Belgrade. It is certain that at the moment and the situation of the railway sector in Serbia is irrational to propose the creation of new. But even these should be retained. On the other Universities (Niš, Novi Sad, Kragujevac) should maintain and update the railway related subjects.

Rail industry has become globally oriented and it should be expected that railway engineering education undertake similar transition in next time. Universities should provide experts who are able to continuously communicate, to constantly upgrade their knowledge, to dedicate their professional skills to contemporary issues and to use modern IT tools.

REFERENCES

[1] M.Manić, D.Stamenković: Perspektive univerzitetske nastave i uloga univerziteta u razvoju železnice, XI naučno-stručna konferencija o železnici "ŽELKON '04", Niš 2004.

[2] P. Lautala, W. Sproule, R. Macário, V. Reis, R. Edwards, C. Barkan, J. Pachl, M. Marinov: Handbook for Rail Higher Education, TUNRAIL 2011.

[3] J. Trinckauf: German railway engineering education, Technische Universitat Dresden 2014.

[4] http://eisenbahnlehre.org/index.html

[5] A. Chudzikiewicz, Education of the technical personnel for railways in Poland, presentation for InfraCare conference, Warsaw, March 2013.

[6] D. Stamenković, M. Milošević: From Meeting on Railway Engineering 1984 to Railcon Conference 2012, Proceedings of the 15th International Scientific-Expert Conference on Railways - RAILCON 2012, Niš 2012.

[7] Mandić, D.: Restrukturiranje železničkog sektora Srbije, dostignuća i izazovi, XIV Naučno-stručna konferencija o železnici "ŽELKON '10", pp. XVII-XIX, Niš, 2010.

ROLE AND COMPETENCES OF THE REGULATORY BODY ACCORDING TO THE LAW ON RAILWAYS

Branka NEDELJKOVIĆ [1]
Zorica RADOVIĆ [2]

Abstract *– Recognizing significance of the railway transport, European Union has been very active in restructuring the European rail transport market and establishing a single European railway area. In that context, special attention is paid to the role and importance of the regulatory body for the establishing and functioning of the railway market. Among the most important novelties introduced in the national railway legislation by the new Law on Railways ("Official Gazette of RS", no. 45/13), there are provisions that define competencies of the regulatory body in the railway sector, following the European legislation in this area. The topic of this paper is to present the Directorate of Railways as a regulatory body, with reference to case study.*

Key words – Market, regulatory body, infrastructure access.

1. INTRODUCTION

In the context of the 130th anniversary of Serbian Railways, the introduction of this paper includes a short overview of the development of railways, since their beginnings until the current restructuring phase of the railway sector, requiring the establishment of a sectoral ***regulatory body***.

Besides that, having in mind that the restructuring of the railway sector in Serbia is being realized within the process of the accession to the European Union, the introduction also gives a summary on the development of the ***regulatory body*** in the EU and establishment of the appropriate body in Serbia.

1.1 Development of railways – from monopoly to the open market

Ever since the invention of railways in the 19th century, railway traffic has been rapidly developing due to the need of a mass transport mode dictated by the industrial development and, therefore, it has soon become dominant compared to other inland transport modes. However, the circumstances at the transport service ***market*** have considerably changed, especially with the development of road transport and since railways were not ready to adapt to the new conditions and requirements of transport service users and, therefore, railway traffic started to lose its positions already in the first half of the 20th century.

In the European Union, after the II World War, the railways have been constantly losing their importance, until their passenger and freight transport was reduced to a very small share at the end of the 20th century. The Commission has analyzed the reasons for such a situation and concluded that there are several reasons for decline of railway traffic and that, besides the development of road traffic, one of the important reasons is the relationship between the railways and the Government.

As stated in the White Paper – A strategy for revitalizing the Community's railways from 1996, railways have been largely isolated from the ***market*** law and the governments have been influencing their management by imposing obligations without full compensation of costs. Moreover, the governments have never set clear financial objectives to railways, but they have been covering the losses by subsidies and leaving the debts to accumulate. Besides that, the White Paper points out the need for a different kind of railways, that would be able to do business at the open ***market***. This would require a clear distinction between the responsibilities of the government and responsibilities of railways and the government would have to relieve the railways from debts, release them from the burden of the past and thus improve their financial situation. The Commission has estimated that railways should be more efficient, customer oriented, less expensive and that they should require smaller subsidies.

Since 1991, when the Directive on the Development of the Community's Railways (91/440/EEC) was adopted, the European Union has adopted a number of acts in the field of railway law,

[1] Branka NEDELJKOVIĆ, Directorate for Railways, Belgrade, Nemanjina 6, branka.nedeljkovic@raildir.gov.rs
[2] Zorica RADOVIĆ, Directorate for Railways, Belgrade, Nemanjina 6, zorica.radovic@raildir.gov.rs

in order to improve the efficiency of the railway system. to promote competition at the rail transport ***market***, in the interest of customers, and to establish a "fair" competition among the different transport modes, which means to increase the ***market*** share of railways compared to other transport modes. This Directive created grounds for establishing of the European railway ***market*** and the beginning of the process of fundamental reforms in the field of railway traffic, based on separation of infrastructure management and railway undertakings using that infrastructure for passenger and freight transport.

Having in mind the specificity of railway transport, related to the use of national railway networks, which has developed different technical specifications for infrastructure, track gauges, electrification standards, safety and signaling systems, the establishment of the European railway ***market*** represents a very complex process.

In the European Union, international and domestic freight, as well as international passenger transport ***market,*** have been opened so far, while opening of national railway passenger ***markets*** has been provided for by an EU regulation within the 4th Railway Package which is in the process of adoption.

1.2 Regulatory Body in the EU

A freely functioning rail service ***market*** in the EU requires the establishment of an independent body, whose main task would be to ensure a fair and non-discriminatory ***access to railway infrastructure***.

The obligation of the member states to give railway undertakings a possibility of appeal before an independent body against the decision on the allocation of railway infrastructure capacity or charging of fees has for the first time been provided for in 1995 by the Directive 95/19/EC.

The concept of the ***regulatory body*** has appeared for the first time in 2001, when the EU regulations within the 1st Railway Package laid down an obligation to establish such a body in the EU member states. The competences of the ***regulatory body*** have been changing depending on the development and needs of the ***market***, as well as the level of their independence from the other actors in the railway sector. The competences of the ***regulatory body*** are actually defined by the Directive 2012/34/EU establishing a single European railway area. This directive has amended and repealed all the earlier acts regulating opening of the ***market*** and ***access*** to railway infrastructure. One of the key issues regulated by this Directive is reinforcement of national ***regulatory bodies*** by:

- extending their competencies to rail-related services);
- higher level of independence;
- reinforcing of competences regarding sanctions, supervision, ex-officio actions, etc.

The amendments of this Directive within the 4th Railway Package are in the process of adoption.

1.3 Regulatory body in Serbia

In the Republic of Serbia, the first step towards the harmonization of the national railway legislation with the Acquis communautaire related to the railway sector has been done by the adoption of the Law on Railways ("Official Journal of the RS", No 18/05) which was in force until May 2013.

This law has established a legal framework for the opening of the rail service ***market*** and ***access*** and use of the public railway infrastructure for all interested undertakings that meet the conditions provided for by the law, under the same conditions. It also defines the competence to decide upon appeals against a refused or amended offer for a contract on the use of railway infrastructure.

Activities in the field of rail service ***market*** regulation are defined by the new Law on Railways ("Official Journal of the RS", No 45/2013), making a clear difference between the competences of a ***regulatory body***, national safety body and licensing body, which are to be established according to the EU railway legislation.

2. DIRECTORATE FOR RAILWAYS

Directorate for Railways (hereinafter referred to as: Directorate) is a special organization having a capacity of a legal person, founded by the Law on Railways from 2005. Until the entering into force of the new Law on Railways on 30 May 2013, the Directorate had only one ***regulatory*** competence, that is, to decide upon appeals against a refused or amended offer for conclusion of a contract on the use of railway infrastructure.

The Law on Railways in force regulates, for the first time, the activities of the Directorate in the field of regulation of the rail service ***market***, which is a result of further harmonization of the national legislation in the field of railway sector with the relevant EU legislation.

According to the Law on Railways, the Directorate for Railways adopted, in December 2013, a new Act on Internal Organization and Systematization, providing for special organizational units for each of the established competences of the Directorate, as a ***regulatory body***, a body in charge of safety and a body issuing licenses. In April 2014, this act was amended to comply with the provisions of the Railway Safety and Interoperability Law.

2.1 Competences of the directorate for railways as a regulatory body

According to the Article 93 of the Law on

Railways, the Directorate for Railways shall perform the following activities in the field of the regulation of the rail service ***market***:

- decide upon appeals of applicants for train path allocation, particularly having in mind possible unfair conduct or discrimination by the infrastructure manager or railway undertakings in relation to the following:
  (1) Network Statement,
  (2) criteria determined in the Network Statement,
  (3) train path allocation procedure and its outcome,
  (4) manner of determination of the ***infrastructure access*** charges,
  (5) level or structure of the ***infrastructure access*** charges;
- monitor and analyze the conditions of the competitors on the rail service ***market*** and review, at its own initiative, the procedures and documents mentioned under the previous indent in order to prevent discrimination among the applicants for the train path allocation. The Directorate shall particularly check whether the Network Statement contains the causes or provides for discretionary rights of the infrastructure manager that could be used for discrimination of the applicants for the train path allocation;
- control the independence of the infrastructure manager in relation to other entities in the rail service ***market***;
- ensure that the charges determined by the infrastructure manager are non-discriminatory and in compliance with this Law;
- ensure that the infrastructure manager provides ***access*** and use of the railway infrastructures on non-discriminatory basis and in compliance with this Law;
- control the access and use of the structures and fixed installations not managed by the infrastructure manager, which are regulated by the contract concluded between the person providing the service and the railway undertaking;
- monitor railway ***market*** in order to analyze the competition between the different traffic modes;
- control the quality of the railway services provided by the railway undertakings and infrastructure managers, including accessibility for disabled persons;
- cooperate with the body in charge of the competition protection, give expert opinions an analysis, provide technical assistance regarding the issues which are not regulated by this Law and relate to the limitation, prevention or disturbance of the ***market*** competition;
- perform other activities determined by this Law.

Execution of these competences of the Directorate as a ***regulatory body*** depends on the consistent enforcement of the provisions of the Law on Railways, restructuring of the railway sector in Serbia and establishment of rail service ***market*** in the railway traffic, that is, on the possibility of the interested railway undertakings to ***access railway infrastructure***.

2.2 Situation on the rail service market

In Serbia, rail service ***market*** has not been established yet and, therefore, interested railway undertaking meeting the conditions laid down by the law do not have ***access*** to the public railway infrastructure.

The company Serbian Railways ad, which performs both freight and passenger transport, manages railway infrastructure and is still the exclusive user of the public railway infrastructure.

According to the Article 17 of the Law on Railways, railway infrastructure may be used by a railway undertaking and railway undertaking performing transport activities for its own purposes, provided that they hold the following:

1) transport license,
2) safety certificate and
3) contract on use of rail infrastructure.

At the moment, five railway undertakings hold a valid transport license and safety certificate. According to the data known to the Directorate, so far, one railway undertaking has twice submitted an application for train path allocation to Serbian Railways.

Serbian Railways ad are explaining their refusal to conclude a contract on use of railway infrastructure with the applicant for train path allocation by stating that the company for rail infrastructure management has not been established yet as a separate legal entity. Therefore, according to the Serbian Railways ad, the conditions for the use of the public infrastructure by railway undertakings other than Serbian Railways ad have not been met and that is why Serbian Railways do not have a legal authority to decide on the application for train path allocation.

2.3 Former practice

Since the adoption of the Law from 2005, establishing a legal framework for opening of the rail service ***market*** and ***access*** and use of the public railway infrastructure, one railway undertaking has contacted the Directorate concerning the actions of Serbian Railways ad related to two applications for train path allocation, namely:

- due to the refusal of an application for train path allocation and
- due to the refusal to act upon its application for train path allocation.

In the case concerning the refusal of the application for train path allocation submitted by the railway undertaking, the Directorate has issued decisions asking Serbian Railways ad to decide on the concerned application according to the Law on Railways. However, Serbian Railways have refused to act according the above-mentioned decisions. This case has ended by cancellation of the procedure since the applicant, who did not have any further interest to continue the procedure, has decided to withdraw the appeal.

In the procedure conducted against Serbian Railways ad that have refused to act upon the application of the railway undertaking for train path allocation, the Directorate, acting in accordance with its competences, has issued a Decision ordering Serbian Railways ad to decide on the concerned application for train path allocation within 10 days from the reception of the Decision. Since they have not acted upon the Decision, the Directorate has made a request for initiation of offence proceedings against Serbian Railways ad.

One of the originalities of the Law on Railways is providing for responsibility for offence in case of not acting upon the decisions of the Directorate. Thus, Article 107, paragraph 1, point 56) of the Law on Railways provides for a fine amounting from 500.000 to 2.000.000 dinars for a company or legal entity in case that they do not act in accordance with a decision of the Directorate (Article 95. par. 5. and 6). Paragraph 4 of the same article lays down that a responsible person of the company or other legal entity shall also be punished for offence from paragraph 1 of this article by a fine amounting from 30.000 to 100.000 dinars.

In December 2013, the Commission for Protection of Competition initiated an ex officio procedure against Serbian Railways ad in order to investigate violation of competition and abuse of the dominant position in terms of Article 16 of the Law on Protection of Competition. This procedure is still in progress.

3. CONCLUSION

In order for the Directorate to function in its full capacity and realize its competences within an open rail service ***market***, it is necessary to implement the provisions of the Law on Railways, especially those regarding legal obligations of the public rail infrastructure manager.

The final objective of restructuring of the railway sector in Serbia is to establish a fair competition at the rail service ***market.*** This would increase the quality of passenger and freight transport services, as well as competitiveness of railway transport comparing to other transport modes, taking into account the advantages of railway traffic, especially from the point of view of protection of the environment.

Changes in the railway sector are inevitable, both from the point of view of revitalization of the railway transport and from the point of view of accession to the EU, that is, entering the Single European Railway Area.

REFERENCES

[1] White paper – A strategy for revitalizing the Community’s railways since 1996, COM(96) 421 final

[2] Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways, Official Journal L 237 , 24/08/1991.

[3] Directive 2012/34/EU of 21 November 2012 establishing a single European railway area (recast), Official Journal of the European Union L 343/32, 14.12.2012

[4] Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/34/EU of 21 November 2012 establishing a single European railway area, as regards the opening of the market for domestic passenger transport services by rail and the governance of the railway infrastructure COM(2013) 29 final

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

CURRENT PROBLEMS OF CROSSING THE RAILWAY DURING THE CONSTRUCTION AND OPERATION OF THE HIGHWAYS ON CORRIDOR 10

Aleksandar NAUMOVIĆ [1]
Sinisa MARIĆ [2]
Predrag ATANASKOVIĆ [3]

***Abstract** – European Transport Corridor 10 through Serbia is spatially defined by the railway and highway lines in the same infrastructure corridor. Actual locations of level crossings are consistent with the existing conditions of road traffic in the area of railway lines. During the construction of highways was observed that the designers did not take sufficient account of the need for level crossings, underpasses and overpasses. This caused a serious problem in terms of access to the site due to the impossibility of crossing the railway lines at the appropriate locations. Aditional problem is the intensive use of the existing level crossings which are not intended for construction site machinery. Another problem is when the highway is planned between the railway and the river (e.g. the South Morava on Highway E75, or the Nišava on Highway E80), but it is not designed underpass or overpass from the existing level crossing to the area between the highway and the river, which is causing additional construction of level crossings at a new location. Consequences of aditional designing.*

Keywords – *infrastructure corridor, highway, railway, level crossing, Investor, Contractor.*

1. INTRODUCTION

Transport Corridor 10 through the Republic of Serbia is spatially defined by the railway and highway lines in the same infrastructure corridor. This is a consequence that the main road and rail lines followed the route of the ancient Roman roads, laid in the valleys of major rivers (for example, the VIA MILITARIS road on Belgrade - Niš - Preševo - State border and Niš - Dimitrovgrad - State border road and railway lines).

The development of transport infrastructure in Serbia, as well as in other parts of Europe, was such that the railway network was completed first. The construction of highways was begun abuot a century later. The result is that the railway lines in Corridor 10 got the best position from the point of the physical conditions, so the highway lines have to comply the railway lines. This can be a significant problem in terms of spatial constrains [1].

Such position between road and railway line, in combination with the relief and the position of the river, resulting in serious problems in terms of crossing the railway line due to construction and operation of the highway.

2. PROBLEMS CAUSED BY THE EXISTING AND FUTURE LOCATIONS OF LEVEL CROSSINGS, UNDERPASSES AND OVERPASSES

During the construction of highways on Corridor 10 was observed that the designers did not take sufficient account of the need for level crossings, underpasses and overpasses. This caused a serious problem in terms of access to the site due to the impossibility of crossing the railway lines at the appropriate locations, especially in river valleys (e.g. the South Morava river on Highway E75, or the Nišava river on Highway E80).

2.1 Problems during construction of the bridges over the railway line

The most common problems occur during

[1] Aleksandar NAUMOVIĆ, MSc, Civ.Eng, "Corridors of Serbia", Belgrade, 21 Kralja Petra Street, a.naumovic@koridorisrbije.rs
[2] Sinisa MARIĆ, MSc, Transp.Eng, "Serbian Railways", Belgrade, 6 Nemanjina Street, sinisa.maric@srbrail.rs
[3] Predrag ATANASKOVIĆ, PhD, Transp.Eng , Faculty of Technical Sciences, Novi Sad, 6 Dositej Obradovic Square, pedja.atanaskovic@yahoo.com

construction of the bridges (overpasses) over the railway line. Usually in the area of the location of the planned overpass is no possibility for communication between the left and right side of the railway line.

Due to unfavorable differences in elevation between the road and the railway, and in terms of the steep terrain and narrow river valley, it happens that it is impossible to build a level crossing in a convenient location, but the site has access bypass roads or construction of a temporary bridge across the river, which adversely affects the amount of unforeseen construction costs of highway.

Fig. 1 presents the location of the first overpass on the E80 Highway (Niš - Dimitrovgrad - Bulgarian Border), between Niška Banja and Prosek where the Contractor abandoned the construction of a level crossing and instead built a pontoon bridge across the river Nišava near this location.

Fig.1. Location of the first overpass on the E80 Highway (Niš - Dimitrovgrad - Bulgarian Border), between Niška Banja and Prosek (photo by Aleksandar Naumović)

If terrain conditions are favorable for the construction of a new level crossing, there may occur other problems, such as insufficient distance to adjacent level crossings, or the lack of transparency which is resulting in the need for installing a expensive automatic safety device on a level crossing.

According to the Law on Railways [2], the minimum distance between two adjacent level crossings is 2,000 meters. This distance could exceptionally be reduced to 1,500 meters, but often it is not enough distance for opening new level crossing. So it can happen that there are no legal preconditions for the opening of a new level crossing at the required location.

If there is a need for installation a expensive automatic safety device on a level crossing, the costs will be significantly increased (approximately by about 100,000 euros), which could also jeopardize the possibility of opening a level crossing.

2.2 Problems that occur when the highway is planed between the railway line and the river

Another problem occures when the highway is planned between the railway line and the river but it is not designed underpass or overpass from the existing level crossing to the area between the highway and the river, which is causing additional construction of crossings at a new location. If it is possible to build a new crossing (level crossing, overpass or underpass), the problem will be solved by increasing the cost of the highway, but if it is not possible to build a new crossing (level crossing, overpass or underpass) must be expropriated all the land between the highway and the river. In this way, in addition to an increase in costs due to expropriation, there is also a serious problem in terms of extending the period of construction of the highway. Land between the highway and a river is usually a fertile land, so it is a serious loss for agriculture, also.

Fig. 2 presents the location near Grdelica, where the E75 Highway (Belgrade - Niš - Preševo - FYRM Border) is planed between the railway line and Južna Morava. Existing level crossing will be closed, no underpass is planned, so there will be no access to the large area between the highway and the river

Fig.2. Location near Grdelica, where the E75 Highway (Belgrade - Niš - Preševo - FYRM Border) is planed between the railway line and Južna Morava. (photo by Aleksandar Naumović)

2.3 Problems caused by when the intensive use of the existing level crossings

Aditional problem is the intensive use of the existing level crossings which are not intended for construction site machinery. Locations of construction sites, deposite areas or borrow pits are usually conencted with the State road network by local roads. Those local roads were intended for agriculture machinery. Width of those local roads is usually only 3-4 meters, so the level crossings couldn't be used for transport of construction site machinery without proper reconstruction. Unfortunately, the contractors generally used those level crossings without reconstruction, which caused rapid destruction of level crossings.

This usually happened on the Belgrade - Mladenovac - Niš - Preševo - State border (Tabanovci) railway line (level crossings near Grdelica, Predeyane, Vranjska Banja, etc).

The cotractors abuse the fact that these level crossings are open to public traffic. According to Law on Railways [2], maintenance of level crossings costs the Serbian Railways and the local government authorities, but not the contractors.

Fig. 3 presents the location of the existing level crossing of Belgrade - Mladenovac - Niš - Preševo - State border (Tabanovci) railway line near Predeyane, on the local road to the deposite area. Level crossing was not intended for construction site machinery, so it was ruined in only few months.

Fig.3. Belgrade - Mladenovac - Niš - Preševo - State border (Tabanovci) railway line, location of the existing level crossing near Predeyane (photo by Aleksandar Naumović)

The Corridors of Serbia used its authority to force the contractors to still bear the costs of rehabilitation of ruined level crossings, so in this way the problem could be solved. The problem is that the Corridors of Serbia can react when the level crossing is already damaged. The reason for this is that contractors practically used levell crossings covertly, in order to save time and money.

2.4 Problems that occur after the expiration of the term for the operating of the level crossing

Level crossings that are built for the for the construction of highways have no permanent character, but their use is limited to the period of construction of the highway. But, in addition to thecontractors, temporary level crossing are also used by the local population. This results that the local people acquire the habit of using a temporary level crossing, so it could be in opposition to closing the level crossing after the expiration of the term for the operating.

A particular problem may occur if the Main design of highway envisages the closing of the existing level crossing, but for the purpose of construction of a highway the level crossing have to relocated to a new location. In this case, it is reasonable to expect protests of the local residents due to the closure of level crossing.

However, practice in Serbia has shown that, in the case of changing the existing level crossings with new underpasses or overpasses (practically on the same location), the local residents always try do keep the level crossing in operation. Such situation could occur serious problems with the local government.

In that case, the Railways of Serbia could have the serious problem, because they could permanently stay on the maintenance of the level crossing that was supposed to be temporary. For instance, every level crossing is constant potentially dangerous place on the railway line.

3. CONSEQUENCES OF ADITIONAL DESIGNING

Regardless of whether the additional designing is need of investors or contractors, it creates substantive and formal problems.

3.1 Problems with additional designing for the purpose of Investor

Changing the Main design of highway - additional designing of level crossings, access roads and underpasses or overpasses is a serious problem for Investor. This includes, in addition to the additional costs of design, and an additional expropriation and substantial unanticipated costs of the investment. In addition, extension of time for completion of construction due to the additional design gives contractors the option for claims. In this way, the apparent savings during creation of the Main design of the highway can cause significant damage to the Investor.

3.2 Problems with additional designing for puprose of Contractor

Construction of access roads to the site is the obligation of the Contractor. However, in practice it is still different.

Opening a new level crossing takes time from 4 to 6 months at least. Steps to open the level crossing are as follows:

- Technical conditions from the Serbian Railways,
- Main design for the level crossing,
- Agreement from the Serbian Railways,
- Buliding permition of the Ministry of construction, traffic and infrastructure,

- Construction of the level crossing,
- Tehnical approval of the level crossing,
- Conclusion of appropriate contract with Serbian Railways and Local governments,
- Starting the operation.

Usually, the contractor has no idea that the opening of the level crossing takes so much time, and putting pressure on Investor to find a way to speed up the process or to make changes in the Main design for highway. In addition, a slowdown in the pace of construction works may adversely affect the relationship between the Investor and the Bank providing the loan for the construction of the highway.

4. CONCLUSION

Transport Corridor 10 through the Republic of Serbia is spatially defined by the railway and highway lines in the same infrastructure corridor.

Such position between road and railway line, in combination with the relief and the position of the river, resulting in serious problems in terms of crossing the railway line due to construction and operation of the highway:

- Problems during construction of the bridges over the railway line
- Problems that occur when the highway is planed between the railway line and the river
- Problems caused by when the intensive use of the existing level crossings
- Problems that occur after the expiration of the term for the operating of the level crossing

Solving the above problems is usually implemented with additional designing, which is the source of other problems.

It would be ideal if the designers og Main designs of highway took care of the needs of the local population and the needs of contractors from the point to possibility of undisturbed communication on both sides of the railway line during the construction and operation of highway.

REFERENCES

[1] Aleksandar NAUMOVIC, Sinisa MARIC, *Current Probelems Of Using The Railway Land For the Construction And Operation of the Highways in Serbia,* XV Scientific-Expert Conference on Railways RAILCON'12, Serbia, Niš, 2012.

[2] Law on Railways, Official Gazette of Republic of Serbia No 45/2013, Belgrade, 2013.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

IMPORTANCE OF PASSENGER RAILWAY TRAFFIC IN DEFINING CRITERIA TRANSPORT ACCESSIBILITY OF THE AREAS OF DANUBE DISTRICTS

Ana VULEVIĆ [1]
Dragan ĐORĐEVIĆ [2]

Abstract *– A crucial role in enabling the direction of the Danube and intensifying of transport on the Danube waterway has a systematic regulation of all forms of transport infrastructure in the region. Particularly significant is the improvement of rail transport. The paper considers the indicators of equipment the area railway infrastructure, as well as its implementation possibilities in the concept of accessibility, the area of Corridor VII, i.e. Districts that are directly linked to Danube. Criteria have included following data about the density and length of the railway network and a variable - travel time and frequency of passenger trains. The selected indicators are aligned with the established indicators for monitoring the European area which is being developed within the program of ESPON (European Spatial Planning Observatory Network). Analyzed indicators of equipment the area transportation infrastructure can be used in defining the model the availability of any corridor or region in Serbia in accordance with the statistical monitoring of these areas of research.*

Keywords – Passenger railroad traffic, accessibility by rail, Danube District.

1. INTRODUCTION

More effective utilisation of Serbia's geostrategic position on the wider area of "crossing" of Pan-European corridors - Danube (water) VII and (road-railroad) X – should be one of the basic principles of spatial development in transport domain. That demands coherent development of all transport means – completition of existing and construction of new secondary networks, more intensive development of railroads and services, up to the developed level of road network. Emphasizing the fact that accessibility is one of the basic indicators of spatial aspects of transport infrastructural systems, this paper analyzes some of the indicators of the railroad infrastructure supply indicators, which can be applied in models for assessing the accessibility of the area from the aspect railroad transport, in the future.

2. INDICATORS OF TRANSPORT INFRASTRUCTURE SUPPLY AS INDICATORS OF RAILROAD ACCESSIBILITY

"The concept of accessibility depends, therefore, on the existence of opportunities and the options provided by the transport system to reach them. One of the more suitable definitions of accessibility is the following: "Accessibility indicators describe the location of an area with respect to opportunities, activities or resources that exist in other areas or in the same area, where the term "area" can be a country, a city or a corridor". [3]

This paper gives a very brief overview which kind of supply railroads indicators are used in relevant documents and studies should be treated more and in more detailed way during the process of preparation, drafting and implementation of plans and technical documentation, which would certainly have true effects to making decisions about their realisation and implementation.

Transport infrastructure supply indicators - endowment indicators consider the transport infrastructure in an area expressed by such measures as total length of motorways or number of railway stations. Infrastructure endowment indicators are represented by accessibillity to rail stations and terminals. Travel cost indicators are represented by travel times by railroad to larger cities. Daily

[1] Ana VULEVIĆ, Ph.D. in Spatial planning, Institute of Transportation CIP, Nemanjina 6/IV, 11 000 Belgrade, Serbia, vulevica@sicip.co.rs
[2] Dragan ĐORĐEVIĆ, M.Sc. in Traffic Eng., Institute of Transportation CIP, Nemanjina 6/IV, 11 000 Belgrade, Serbia, djordjevicd@sicip.co.rs

accessibility indicators are represented by travel times between the large cities.

Indicators do range from transport infrastructure and service supply via their use in form of traffic volume and flow indicators towards territorial indicators in form of accessibility indicators. Existing indicators can roughly be classified into two groups:

- Indicators derived from published statistics,
- Indicators derived from modeling. [1]

The two indicator groups are very different with respect to data availability. Indicators derived from published statistics are in most cases not available at the regional level required in ESPON. Here, many indicators are obtainable only at the national level. On the other hand, indicators derived from modeling work haven been already or can easily be calculated for the desired district level or for links or nodes.

3. DEMOSTRATION OF EXISTING INDICATORS IN DANUBE CORRIDOR

In Danube corridor, in Serbia, there are three categories of railroads: international, regional and local. The density of international railroads is the highest in the Belgrade District. There are, however, districts through which international railroads do not pass (Srednjebanatski, Branicevski and Borski).

Tab. 1. Railroad network's length (km) and density (km/km^2) the district level in 2008

District	Lenght (km)	Density (km/km^2)
Srednjebanatski	170.644	0.05
Podunavski	111.804	0.09
Juznobanatski	256.535	0.06
Zapadnobacki	223.227	0.09
Juznobacki	307.405	0.08
Sremski	182.608	0.05
Belgrade	307.010	0.10
Branicevski	98.679	0.03
Borski	104.544	0.03
Source: Statistical Office of the Republic of Serbia – Traffic		

Tab. 2. Number of passengers at Danube Distrct in 2008

District	Number of passenger
City of Belgrade	624,037
Srednjebanatski	117,926
Juznobanatski	32,892
Zapadnobacki	294,965
Juznobacki	730,773
Sremski	420,784
Podunavski	170,798
Branicevski	69,725
Borski	125,798
Source: Statistical Office of the Republic of Serbia – Traffic	

Total number of passengers in the Danube area was 2,587,698 in 2008. The highest number of passengers was recorded in Juznobacki district (730,773).

For further analysis of parameters were selected some data about railways, stations and stops, the frequency of trains travel times between the centers of the district.

Over the observed area which has been classified by districts, it is monitored only on lines through which the passenger traffic, according to numbers (Table 3).

Tab. 3. Review of railroad of passenger traffic by districts

District	Railroad
City of Belgrade	1, 3, 4, 5, 6, 8, 28, 31
Juzno-backi	2, 33, 42, 43, 72
Juzno-banatski	6, 46, 88,
Podunavski	4, 36, 54
Sremski	2, 5, 19, 52, 57
Zapadno-backi	26, 33, 42
Srednje-banatski	32, 43, 45, 46, 88
Braničevski	36

Railroad by ordinal numbers: 1 (Resnik - Vrbnica - Podgorica - Bar), 2 (Stara Pazova - Indjija - Subotica – The State border), 3 (Beograd - Mladenovac - Niš - Preševo - The State border), 4 (Rakovica - Rasputnica "K1" - Jajinci - Mala Krsna - Velika Plana), 5 (Beograd - Sid – The State border), 6 (Beograd center – Pancevo Varos - Vrsac – The State border), 8 (Beograd center - Rasputnica "G"), 19 (Indjija - Golubinci), 26 (Subotica - Bogojevo – The State border), 28 (Topcider - Blok Sava obala – Mesto prelaza - Beograd Dunav – Junctions Pancevacki bridge), 31 (Rasputnica Karadjordjev park – Rasputnica Dedinje), 32 (Banatsko Milosevo - Subotica), 33 (Becej - Sombor), 36 (Mala Krsna - Bor -Rasputnica 2), 38 (Crveni krst - Zaječar – Prahovo port), 42 (Novi Sad – Sajlovo junctions 2), 43 (Sajlovo junctions – Rimski Sancevi – Orlovat stajlište), 45 (Orlovat – Junctions 3a), 46 (Pancevo glavna - Zrenjanin - Kikinda – The State border), 52 (Ruma - Sabac – Junctions Donja Borina – The State border), 54 (Smederevo - Mala Krsna), 57 (Šid – Sremska Rača Nova – The State border), 58 (Junctions 1 - Junctions 3), 72 (Rimski Sancevi - Senta - Horgos), 88 (Zrenjanin - Vrsac - BelaCrkva).

The largest number of railroad is located in the City of Belgrade, followed by Districts (Juzno Backi, Sremski, Srednje – Banatski), (Juzno-banatski, Podunavski, Zapadno-backi, Borski) and Branicevski.

Table 2 is represented by the number of stations which are open for passenger traffic by districts.

Tab. 4. Number of stations by District within Danube Corridor

Number of stations and stops by district	District
54	City of Belgrade
39	Juzno-backi
36	Juzno-banatski
28	Podunavski
27	Sremski
31	Zapadno-backi
23	Srednje-banatski
28	Branicevski
27	Borski District

The number of stations and stops for passengers receiving districts gives results for the City of Belgrade - far ahead of the others, followed by other districts Juzno-backi, Juzno-banatski, Zapadno-backi, Podunavski, Branicevski, Sremski, Borski i Srednje-Banatski.

Frequency of trains

Daily frequency of passenger trains per district was taken according to the planned timetable for 2013/2014.godinu. Table 3 gives an overview of the planned number of trains per district.

According to the number of trains on a daily level the City of Belgrade is far ahead of the others, followed by other District Juzno-banatski, Juzno-backi, Podunavski and the Sremski, Zapadno-backi, Srednje-banatski, Branicevski and Borski District. There is insufficient exploitation of rail road infrastructure endowments in some district, by relation to the number of trains that is planned across of certain districts and the number of railroad stations.

Tab. 5. Number of trains on a daily level by Districts

Number of trains on a daily level	Region
213	City of Belgrade
116	Juzno-backi
52	Juzno-banatski
43	Podunavski
40	Sremski
30	Zapadno-backi
26	Srednje-banatski
19	Branicevski
18	Borski

Travel time by rail

Table 4 shows the travel time between the centers of the district by railroad.

Travel times were taken from the terms at passenger train and timetable 2013/2014 year.

Tab. 6. Travel times between centers of District

Travel times (min)	1*	2	3	4	5	6	7	8	9
1*	-	122	36	144	87	287	160	141	372
2		-	219	237	89	205	204	263	494
3			-	174	123	424	124	177	408
4				-	225	465	298	49	280
5					-	294	293	230	459
6						-	409	468	699
7							-	494	532
8								-	231
9									-

*1 – City of Belgrade, 2 - Juzno-backi District, 3 - Juzno-banatski District, 4 - Podunavski District, 5 - Sremski District, 6 - Zapadno-backi District, 7 - Srednje-banatski District, 8 - Branicevski District and 9 - Borski District.

4. CONCLUSION

This paper gives review indicators of railroad infrastructure endowments from the aspect of passenger railroad transport. They can be implemented together with indicators of accessibility for other modes of transport (road, water, air) and their combination opens up new possibilities of measuring (accessibility of the district, so discovering the missing transport links, with the aim of balanced development all forms of transport. The further researches should go to this direction.

REFERENCES

[1] ESPON 1.2.1, 2006. Transport Services and Networks: Territorial Trends and Basic Supply of Infrastructure for Territorial Cohesion. First interim report by Alain L'hostis, Philippe Mathis, Christian Reynaud, Klaus Spiekermann, Andreu Ulied, Michael WegenerAuthor, 1., Author, 2., Author, 3., Paper title, Proceedings, Conference, Place, Year.

[2] DONAUREGIONEN+, 2011. The Spatial Development Concept of Interregional Cooperation in the Danube Space. WP4 - Transport and tehnical infrastrukture, 2011, 66-67

[3] Wegener, M., Eskelinnen, H., Fürst, F., Schürmann, C., Spiekermann, K., 2000. Indicators of Geographical Position. Final Report of the Working Group "Geographical Position" of the Study.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

ACTIONS TAKEN ON RAILWAYS IN STIMULATING OF TRANSPORT OF PASSENGERS WITH SPECIAL NEEDS

Zoran PAVLOVIĆ [1]

Abstract *– Despite the difficulties with which our railways in the past faced, efforts were made to retrieve the position and role of these sectors in total passenger traffic. In addition to the modernization of railways, rail facilities, driving and towing capacity, railways constantly strives to enrich the passenger transport service. As one of the most difficult categories of vulnerable people are disabled people in wheelchairs, who need assistance and blind people, they are categories of users of transport where a lot invested in recent years by the railway line and services for the care of such persons. At the end of 2006. Serbian Railways have introduced the international access special wagon designed for disabled persons, which are fully adapted for people with disabilities and its needs. To the first cars of this type, not only in our country but also in the region and is involved in international train Avala, then the Belgrade- Budapest- Vienna. In fact, it is a reconstructed Avaline coach who, with the current climate, has extended entrance, seats and toilets, as well as space to accommodate wheelchairs and other assistive devices. Entering the train, the platform is provided with a special cranes.*

Keywords – Transportation, incentives, disabled and blind persons, special offers.

1. INTRODUCTION

The Convention on the Rights of Persons with Disabilities provides independent participation of the same in all spheres of life. In our case, it's a ride. Railways is a signatory to the Convention and must satisfy and remove obstacles and barriers to access for persons with special needs, which include the following:

- Access to facilities and services that are available to the public, access roads, transportation and other indoor and outdoor space and
- Information required for communication (signals in Braille)

2. TRANSPORTATION SEGMENT OF HANDICAPPED PERSONS

As one of the most serious category of vulnerable persons are handicapped in wheelchairs who need other people's help. They are categories of users of transport where a lot invested in recent years by the railway line and services for the care of such persons.

To increase the quality of transport services for the specified category of passengers, Railways have to provide easier access, which can be seen taking measures to enter or exit the platform to the vestibule, to purchase tickets, and other needs of the cell area.

Railways must ensure that people in wheelchairs within the transport service as follows:

- Parking spaces for road vehicles in front of the station used by persons with disabilities and which are clearly marked,
- Driveway without stairs to enter the vestibule,
- Output from the vestibule to the platform, and free movement of the passenger cars that are designed for passengers with special needs,
- Special mobile cranes that lift people in wheelchairs to enter a coach and from the coach,
- pictograms, arrows and labels.

2.1. Technical organization transportation services handicapped persons

Coaches must be adapted to the needs and are reflected in the following:

- In the section to accommodate persons with disabilities in wheelchairs provided space for binding
- Equipment and space toilet was adapted for use.

[1] MSc Zoran PAVLOVIC of Organizational Sciences, Milan MUŠKATIROVIĆ 20,11000 Belgrade, zoran.g.pavlovic@gmail.com

Mobile cranes are used for lifting a person in a wheelchair to the platform to the floor the car and vice versa when landing in cases where the level of the platform and the car not on the same level.

When the cashier up a passenger with a wheelchair or a person who is a companion, the treasurer must assign a place that is already provided and to notify the employee in charge of handling the mobile crane at the departure and destination station, in order to timely prepare for use.

2.1.1 Providing information about rights and opportunities transportation

In order to service this group of passengers at the time provided, it is necessary to operate the additional structure of the company and have been in this part of the work includes the following services for contact with the media; 'Media center', 'call center, management of sales in the sector of passenger traffic, as well as qualified persons to operate with a special crane.

2.1.2 Care disposal of handicapped persons at the entrance to the train and his output from train

I previously mentioned that the safety of disabled people worry a special team of people with the accompanying funds to help this category of passengers.

The interior is tailored to the needs of all disabled people, the approach to toilet, as well as the entrance to a pre-defined and reserved for a person in a wheelchair and a place to store wheelchairs and related items passengers.

The interior is adapted to all the needs of the disabled, the access toilet, as well as the entrance to a pre-defined and reserved for a person in a wheelchair and a place to store wheelchairs and related items passengers. Persons with disabilities (disability) benefit from a transport of 75% with the card with your personal data or under special certificates, which must correspond with the ID and the identity of the person with personal data (identity card). The discount applies to all types of trains and all grades - class to the carriage with seats and in cars with beds and sleeper cars. A mitigating circumstance is that all users of transport can make reservations via the Internet, thus reducing the stress and uncertainty for the map and thus the safety of travel.

Media Center is very important in providing information and agency in the implementation of decisions of users of services, as through contacts internally, advertising and promotion, as well as internet and multimedia presentations.

It is estimated that there are between 700 and 800 thousand disabled people as of 7 - 10% of the population.

3. INNOVATION FOR IMPROVEMENT OF HANDICAPPED PERSONS INVALIDS AND BLIND PEOPLES

People in wheelchairs helped a lot of innovation in special wagons for their needs, but in the program to enable the same conditions on the south and southeast of international traffic.

As for blind persons are important investments invested in equipping cells with substrates and panels for orientation of blind people, a station equipped with these substrates are: Belgrade, Novi Sad, Nis, Of Kraljevo, Cacak and Subotica.

Blind person is transported to the internal and international traffic (with states parties to the agreement, as well as border neighboring countries), with the card, so I paid the full amount of the ticket while his companion carried free of charge (or companion dog if allowed conditions carriage on the train). Benefits for a companion is valid only if they are traveling together in the same train and category-class.

4. ACTION RAILWAYS IN STIMULATING TRANSPORT

Despite the difficulties with which our railways in the past faced, efforts were made to repair the place and role of this industry.

In addition to the modernization of railways, rail facilities, driving and towing capacity, railways constantly strives to enrich the service.

Here are some of the ways:

- The introduction of new international train traffic for travelers who live and work abroad and that have something for our country
- For travelers who are employed or are in need of some personal reasons for the rapid transport of introduced business trains, which are now replaced by the tag IC for European standards.
- The time of the event, as well as significant sporting event, concert or rally, railways out all its available capacity to meet the passengers.
- The obligatory seat reservation to take advantage of all the available seating capacity
- Due to the great interest of passengers, made a large sales network to a traveler timely supplied the ticket.
- How would the passengers were better informed about the new railway transport, in addition to media and advertising materials used and other ways complaint and notice. Excerpts schedules, bulletin boards,

billboards, railway poster ...

- Also the price is one of the very important elements influencing the traveler chooses the railways. Price policy shall be strong incentive travelers.

4.1. Legal privileges

The right to legal privileges have the following categories of passengers:

- National heroes and bearers of "Partisan Medal in 1941"

National heroes are entitled to a rebate of 75% of the regular price for an unlimited number of trips, as well as four free trips per year in the first grade of all kinds of trains. Concession drive is used on the book The Order of National Hero, a free ride with the card for a free ride. Period of validity of free travel is one month from the date of stamping of free tickets.

National heroes if they are disabled and groups have the right to free transport of wheelchair and companion, whether you use a privileged or a free ride. National heroes before starting a journey in legitimizing the "Map for a free ride" should enroll in relation to the intended journey and submit the ticket office for stamping and issuing a ticket on the basis that the railway realized recourse.

- War and peacetime veterans invalids

Wartime and peacetime veterans are entitled to a rebate of 75% of the regular price. Preferential and free transportation by rail of war and peacetime veterans and their family members shall be exercised under the provisions of the Ordinance on the realization and utilization of the rights of disabled war veterans a free and privileged ride, which provides Ministrants of Labor and Social Policy.

Disclosure of privileged and free travel issued by the competent department of the municipality on the basis of the said Ordinance. Publication valid for 60 days from the date of issue of the relevant municipal authority. In exceptional cases the period may be longer if indicated in the publication if it is certified by the competent authorities of the municipality. The validity of the ticket for free travel is at ticket issued by RVC.

- A blind person

Members of the Association of the Blind of Serbia are entitled to a rebate of 75% of the regular price of six trips per year (12 rides). Discount can be used on the book drive Serbian Association of the Blind, which is issued by the Organization of the Association of the Blind of Serbia. Booklet for the privileged driving blind person includes:

- Number,
- Photo of the user,
- Name of blind persons,
- Address,
- The name of the relevant organizations of the League of the Blind,
- Record number booklet,
- Signature or a facsimile of the user and
- Stamp and signature of the authorized issuer.

History of privileged directions of the blind shall be valid for five calendar years, provided that the importance of each subsequent year, certified by the competent authorities of the Alliance of the Blind of Serbia.

Companion of a blind person is free of charge on the basis of revelation which is an integral part of these books. When a companion traveling with the blind face declaration is valid for the class and type of train used by a blind person.

Companion of a blind person can use in order to write out the blind person or to return as escorted a blind person. The provisions apply to blind people and people suffering from muscular dystrophy and related muscle and neuromuscular diseases, plebian, cerebral palsy and polio and multiple sclerosis.

4.2. A special edition of "Transportation of blind persons and their companions"

The holder of a national identification card for a blind person and a person who accompanies the possessors of these deals. Companion may be the dog for guiding a blind person.

In case you are traveling a child under the age of four years, which are free and no ticket, is not entitled to free transport companion. To transport blind people apply regular train price or possibly decreased. Companion (dog or person) is free of charge. For use in the car bed with bed, sleep in the car for some trains will be charged in addition to the full amount. On trains, the market prices are granted special flat rates for a companion for a blind person.

Tickets for international traffic, shall be issued manually or electronically to leave and return. Issuance of tickets is exclusively selling point of the country, where the legitimacy of the Blind issued. Deon coupons for travel departing and returning to estimate railways publication may be issued for the terminal and end the relationship as a supplement to the basic direct coupon.

When manually issue a ticket for a companion must be supplemented by the following remarks:

- Under "preferences" enter "100%"
- in the section "basis" enter "blind follower faces" or "dog blind person" in the national language or in one of UIC Languages and identification number of blind persons.

The car of the same class blind person and his companion must travel together. When control of a blind person must show ID card to establish their identity. If the companion of a blind person traveling alone and at the request of the controlling persons show a ticket on which the note is "companion blind person" shall be considered as a deadhead.

5. CONCLUSION

The expected results of the research have contributed to the definition of the strategy, with emphasis on pricing policy. In addition to the data collected and analyzed, we took some basic information about the railway. As you already know, competition is at an advantage as far as speed, developed infrastructure, and they have large investments to achieve its strategy and operating successfully.

REFERENCES

[1] Vukadinovic, R. (1998): Exploitation of Railways, Zelinda, Belgrade

[2] Dr Sreten Glibetić, Application passenger tariffs, higher schools train Belgrade, 2008

[3] Dr Sreten Glibetić, technology and organization of transport on the railway, railroad Higher School of Belgrade, in 1991

[4] Dr Sreten Glibetić, railway tariffs, higher schools train Belgrade 2001

[5] "Serbian Railways" 161 Instructions for passengers, http://www.zeleznicesrbije.com

[6] Zoran Pavlovic (2011) Defining marketing strategies tourism offer railways, Master work FON

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

JAPANESE HIGH-SPEED MAGLEV TRAIN

Jelena DIMITRIJEVIĆ [1]
Dušan PETKOVIĆ [2]

Abstract – *Japan was the leading country in inventing of high-speed trains in 1960s. Magnetic levitation (MAGLEV) is a technology in which magnetic forces lift, propel, and guide a vehicle over a, usually, elevated guideway, while classic rail does not exist or any type of fastening system. MAGLEV high-speed trains move with magnetic levitation. There are three types of MAGLEV trains, depending on the magnets applied, such as Electromagnetic Suspension (EMS), Electrodynamic Suspension (EDS) and Inductrack. In this paper, a short review of MAGLEV development, specific infrastructure and vehicles is presented.*

Keywords – Railway line, Japanese high-speed train, MAGLEV, EDS.

1. INTRODUCTION

Modern life style and industry require a quick and efficient transport connection between the cities. In general, the transportation vehicle connecting from city to city is required to meet the following conditions: high-speed transportation, bulk volume transportation, safe and comfortable transportation with less air pollution and noise, highly reliable transportation with low cost and maintenance, and so on. The high-speed railway train can be one of the alternatives to meet these requirements. The most famous high-speed railway trains are German Inter City Express (ICE), Japanese Shinkansen, and French Train de Grande Vitesse (TGV). Systematic work is highly needed to understand both aerodynamics of high-speed railway train and infrastructure requirements. Additional researches also are necessary to improve the existing conventional railway trains and to develop a new generation of high-speed train system [1].

Japan's railways are the first railways in the world, projected for high speeds. It was noticed, a few decades ago, that this type of traffic is being a main way for carriage of peoples and goods in the future. In 1964, a railway 516 km long was built in order to connect Tokyo and Osaka. Projected speed was 260 km/h, but real speed was about 210 km/h. Later, railway 562 km of length was built as connection between Osaka-Hakata with train speed about 210 km/h. There were a lot of railway objects, such as tunnels and bridges, which had to be built as straight as possible in order to accomplish projected high-speed of train [2, 3].

Japanese railway map is shown in Fig. 1, where the green line presents direct high-speed train lines (Shinkansen) and blue ones notice the local rail connections [4].

Fig.1. Railway lines in Japan

During the early 1970s it was pointed out the idea of lightweight tracked vehicles running at speeds up to 500 km/h and supported by a contactless suspension. It was argued that for stage lengths up to 500 miles these vehicles would operate competitively with air travel [5].

Magnetic levitation (MAGLEV) technology has researched and developed since the 1960s, especially

[1] Jelena DIMITRIJEVIĆ, University of Niš, Faculty of Civil Engineering, A. Medvedeva 14, 18000 Niš, Serbia, jelena.dimitrijevic@gaf.ni.ac.rs
[2] Dušan PETKOVIĆ, University of Niš, Faculty of Mechanical Engineering, A. Medvedeva 14, Niš, Serbia, dulep@masfak.ni.ac.rs

in Japan and Germany. Japanese Railway Technical Research Institute's MLU-series system has a design based on superconducting magnets in an electro-dynamic repulsive system and set a speed record of 581 km/h in December 2003 [6].

MAGLEV is a technology in which magnetic forces lift, propel, and guide a vehicle over a, usually, elevated guideway. Utilising electric power and control systems one eliminates physical contact between vehicle and guideway permiting cruising speeds over 400 km/h, somewhat higher than conventional high-speed rail. In terms of speed, this makes it competitive with automobile and air transportation within the 60–1000 mile travel markets [7].

2. JAPAN MAGLEV TRAIN DEVELOPMENT

Since 1962, Japanese National Railways (JNR) began investigations into the railway system to succeed Shinkansen. In 1968, a project team started to explore the possibility of speeding up the narrow gauge lines increasing the speed of Shinkasen, and developing some new form of ultra high-speed train [8]. In 1987, the development of superconducting MAGLEV has taken over by the Railway Technical Research Institute when the JNR privatized [9-10].

In recent several decades, the MAGLEV train technology has achieved significant progress around the world. The commercial operation of the Shanghai high-speed MAGLEV line, as well as the Tubo-Kyuryo Line (TKL) in Japan symbols the Electromagnetic Suspension (EMS) system is stepping in to commercial implementation stage [11]. The EMS MAGLEV train utilizes electromagnetic forces to neutralize the weight of the vehicle, which, however, may cause continuous oscillations between the track and electro-magnet due to the flexibility of the track [12].

At present, there are mainly two types of high temperature superconducting magnetic levitation rails: the permanent magnetic levitation rail and electromagnetic levitation rail. An electromagnetic levitation has two sets of power supply system, a DC power supply system for levitation system, and a set of non-DC (AC or pulse) power supply system for driving. The power supply system is complex, and there is line loss. These limit the application of electromagnetic suspension system.

EMS is based on the magnetic attraction force between a guideway and electromagnets. EMS uses attractive force of magnets beneath a guideway to lift it up. The train caches guideway from the bottom and sides [13].

The latest generation of MAGLEV trains based on electrodynamic suspension (EDS) aspires to replace fast bullet trains. Train with EDS system does not use steel wheels on a steel rail. Classic rail road does not exist or any type of fastening system. There are very good experiences with EMS system, but EDS gives more reasons to believe that is more promising than EMS [9].

The third type of magnetic levitation system beside EMS and EDS is Inductrack. Inductrack maximizes levitation forces by a combination of two elements. The permanent magnets on the vehicle are arranged in a magnet configuration that optimally produces a periodic magnetic field below the array, while canceling the field above the array and the track is made up of close packed shorted electrical circuits [14].

The latest MAGLEV train with EDS is Lo prototype, Linear motor vehicle series, with maximum realized speed of 500 km/h. It is designed to carry even 1000 passengers. This prototype is going to start with commercial use in 2027, if environmental impact study goes well [15].

Test vehicle MLX01 achieved very good results, with highest speed. Like a test vehicle it managed speed of 581 km/h. This is a speed record for Japan MAGLEV trains.

Before this impressive, there were a few also very good test vehicles like:

- ML-500 with maximal speed of 517 km/h, in 1979 year;
- MLU001 with maximal speed of 400 km/h, in 1987 year;
- MLU002N with maximal speed of 431 km/h, in1994 year.

It is important to mention that these cars are used only for testing, and they have never been in commercial use so far.

3. ELECTRODYNAMIC SUSPENSION SYSTEM IN MAGLEV TRAIN

EDS (electrodynamic suspension) system, based on repelling force of superconductive magnets, uses the idea of electromagnetic induction. EDS levitates the train by repulsive forces from the induced currents in the conductive guideway. Superconductivity means zero electrical resistance of material, when temperature falls below a characteristic level. When an electric current is applied to a coil of such material in a superconductive state, it continues to flow permanently because of zero resistance. Result is a very powerful magnetic force. Because of the both high strength of the superconducting magnets and propulsion system, which does not rely on adhesion, these trains can achieve very high speeds with rapid acceleration [9].

Superconducting magnets attached to the bottom of the train induce current in the coils and the train moves. The lower half of the coil has the same pole as the superconducting magnets. The upper half has the opposite one. Two halves alternately combined gives upward magnetic force of the superconducting magnets, making the train levitate, shown in Fig. 2 [14].

There are three classes of superconductors. The first class is the metallic low temperatures superconductors, such as all pure metals or metal alloys. The second one - iron based superconductors, and the third class consists cooper oxide superconductors [13].

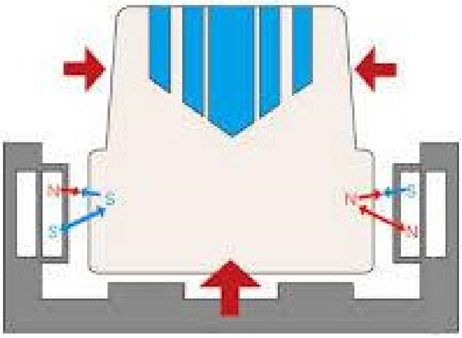


Fig.2. Vehicle and magnet's position in guide way, front view

4. MAGLEV INFRASTRUCTURE

Manufacturing cost of MAGLEV rail account for 60–80 % of the whole investment for the magnetic levitation train system. Therefore, reducing manufacturing cost of MAGLEV rail is one of the key issues for MAGLEV application [16]. Taking into account this fact, the infrastructure and outbuildings have to be carefully designed in order to avoid potential additional costs.

4.1 Site plan and railway

Major limiting factors to the speed-up of train result from many different sources. Technical factors are associated with train/rails systems, while geographical factors are related to the tunnel and bridge systems. For instance, in Japan, the portion of the tunnel to the total railway line amounts to about 60 % [1].

When it known the wanted speed, the first thing should be checked is radius of curvature. Because of geometry, curvature can allow maximum speed. According to this, design engineer must determine which speed they want to come at, and after that to imagine appropriate curvature.

Second condition for higher speed is to make route, as horizontal as it is possible, and/or a route with a as small as possible grade [17].

4.2 Rails and fastening systems

EDS is based on a repulsion of magnets. The magnetic levitation force balances the weight of the vehicle at a stable position. The vehicle does not use steel wheels on a steel rail. Classic rail does not exist or any type of fastening system. MAGLEV EDS trains float over a guideline using basic principles of magnets.

The track along which the train moves is called the guideway. MAGLEV trains levitate in a U-concrete guideway as shown in Fig. 3. The guideway envelopes the vehicles preventing derailments. There are electromagnetic coils placed along the track, while super-cooled superconducting magnets are placed on the train cars. When the train gets close to the coils, a current is induced which allows the train to levitate about 8-10 cm and center itself in the middle of guide way. The second set of coils is placed along the guidance coils and after the train reaches approximately 100 km/h the propulsion coils are activated [18].

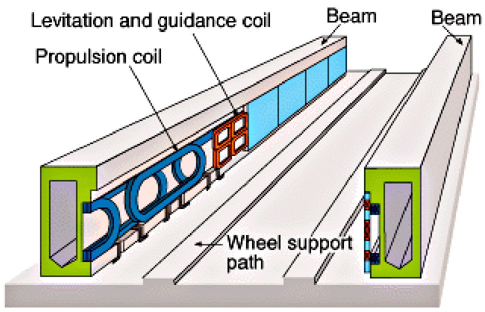


Fig.3. Position of propulsion and guidance coils in guideway

The electric current that is constantly changing allows for a change in polarity of the electromagnets which is turn pushes and pulls the superconducting magnets of the passing train to allocate movement. When the train is pulled off center to either side, an electric current is induced in to the loop, generating an attractive force which exerted on the further side combined with a repulsive force exerted on the nearer side [19] On that way train is securely kept in the center of the guideway. Super cooled and superconducting electromagnets are prone to conduct current even if there is no power supply. [20].

MAGLEV guideway design gives next several conveniences such as increasing of ride quality due to minimize level of passenger acceleration, minimize guideway mass, minimize dynamics stresses as well as static deflections.

5. VEHICLES

Vehicles are one of the most important factor for contemporary railway. New and improved vehicles, give faster but safer and comfortably drive at the same time. Magnetic levitation vehicles are suspended by magnetic forces and therefore do not have physical contact with a roadway. Suspension eliminates mechanical friction with roadway. There is still a friction force from the air, so front side of the vehicle is unusually shaped. Streamlined front side reduces wind drag. Cars from latest series are 28 m long [21].

The latest magnetic levitation vehiche with EDS is Lo prototype. MAGLEV trains with EDS system do not need engines, like conventional trains. The power to propel the train is provided by magnetic fields created by the electric coils kept in the guidance tracks which are added together to provide huge power. For force transmission is used linear motor. [22] The ground coils for propulsion (PNCs) installed on the sidewalls of the guideway and the on-board superconducting magnets for propulsion/suspension constitute a linear synchronous motor. The on-ground power-supply installation supplies an alternating current to the PNCs, thus generating a shifting magnetic field in the PNCs and propelling the vehicle. The running speed of the MAGLEV vehicle is controlled by varying the amplitude and the frequency of the supplied alternating current.

Fig.4. Test vehicle MLX01

6. CONCLUSION

MAGLEV trains with EDS system got ahead of conventional types of railway transoportation systems. This type of rail traffic, based on magnetic levitation with electrodynamic suspension system made a big shift in area of railway transportation. Present transport systems are indispensible to the communities they serve, but are now becoming overburdened with problem such as pollution, manpower, time, space and recourses. Speed was manage airplane, but the train is much safer and chipper transportation than air transport. MAGLEV accomplishes economical types of transportation with electricity as the energy source. The requirements for future inter-city passenger transport are as follows: high speed, possibility of mass transport, safety and comfort, high reliability and punctuality, profitability, no pollution, convenience and ease of maintenance, etc.

This transportation type is not commercial yet. There are still a lot of items to be investigate, in the area of pollution, noise level and influences on people health etc.

REFERENCES

[1] Raghunathana, R.S., Kimb, H.D., Setoguchic, T., *Aerodynamics of high-speed railway train*, Progress in Aerospace Sciences 38 (2002) 469–514.

[2] Tomičić-Torlaković, M.,*Gornji stroj železnica*, Građevinski fakultet Beograd, Beograd, 1996.

[3] Đuričić, M., *Osnovne eksploataciono-ekonomske karakteristike pruga za velike brzine*, Železnice, Beograd, 1985.

[4] Fukushima, S., *Transpotration and urban development in the Chubu Region*, City Planning Institute of Japan (CPIJ), No.32. Japan, 2010.

[5] Howell, J.P., *Aerodynamic response of MAGLEV train models to a crosswind gust*, Journal of Wind Engineering and Industrial Aerodynamics 22 (1986) 206-213.

[6] Chen, X., et al., *High-speed maglev noise impacts on residents: A case study in Shanghai*, Transportation Research Part D 12 (2007) 437–448.

[7] US Federal Railroad Administration. *High-speed Ground Transportation Noise and Vibration Impact Assessment*. USDOT, Washington, DC, 1998.

[8] Kyotani, Y., *Development of superconducting levitated trains in Japan*, Cryogenics, 1975.

[9] Money, L., *The saga of MAGLEV*, Transpa.Res.-A 18A(4) (1984) 333-341.

[10] Takeda, H., *Japanese Superconducting maglev:present state and future perspective*, Physica B 164 (1990) 229-235.

[11] Yan, LG., *Development and application of the maglev transportation system*, IEEE Trans.Appl.Supercond. 18(2) (2008) 92–99.

[12] Zhou D., et al., *Amplitude control of the track-induced self-excited vibration for a maglev system*, ISA Transactions, (2014) article in progress.

[13] Jayavant, B.V., *Electromagnetic suspension and levitation*, Rep.Prog.Phys.44 (1981).

[14] Post, R.F., Ryutov, D., *Inductrack concept: a new approach to magnetic levitation*, National Technical Information Service, Alexandria USA, 1995.

[15] Moon F.C., *Superconducting levitation*, New York 1994.

[16] F. Guo, F., et al., *Structural parameter optimization design for Halbach permanent maglev rail*, Physica C 470 (2010) 1787–1790.

[17] Bajić, D., *Osnovi projektovanja železničkih pruga*, Beograd, 1978.

[18] Suzuki, E., *Heating phenomena in the superconducting magnet of a MAGLEV vehicle caused by electromagnetic vibration*, Cryogenics 37(1997) 363-370.

[19] Cai, Y., Rote, D.M., *A review of dynamic stabillity of repulsive force maglev suspension systems*,Yamanashi, Japan, 1998.

[20] Higashi, K., et al., *Damping Mehanism of Superconducting Electrodynamic Suspension System*, IOS Press,1996.

[21] Kato, Y., *A preliminary study of magnetic fields on railway vehicles*, Railway Technology Newsletter No.46 (2014) 276.

[22] Stephan, R.M., et al., *A superconducting levitation vehiche prototype*, Physica C 408–410 (2004) 932–934

REMOVING OF RELEASING PROBLEM OF FREIGHT CARS OPERATING IN SS REGIME WITH INSTALLING OF BY/PASS

Erdinč RAKIPOVSKI [1]
Dragan MILČIĆ [2]

Abstract – *This paper presents an application of the by-pass of Brake system who is installing in the Triple-valve in freight wagon. For overcoming this problem it is necessary to foresee (install) an additional parallel system (by-pass) for charging of the auxiliary reservoir. This kind of auxiliary reservoir charge is applied on the brake of passenger wagons.In the equipment for by-pass charging it is necessary to install one isolating cock and one non-return valve with filter (between brake pipe and auxiliary reservoir). By-pass charging does not disturb normal triple valve function in any stage*

Keywords– Brake system, Triple valve, Releasing, By-pass, Freight car.

1. INTRODUCTION

Freight wagons are main transport means used to provide railway transport of goods and realize main income of each railway administration. The railway success depends on their mobility (validity and contemporariness) and massive commercialization, so it is not surprising that the Railway Administration through International union of railways deals with issues of modernization, standardization and unification of wagons preventively, and in the program of their own development. One of the components of freight wagons that conditions their application in exploitation of domestic and international traffic, while also represents an essential factor for their safe travel, are the brakes.

In order to achieve the main objective, i.e. carry higher amount of goods, the tendency is placed on longer trains in terms of number of axles, larger capacity of individual wagons, as well as higher transport speed. It is clear that from this arise increased requirements in terms of brake equipment characteristics.

This, above all, refers to safe function in service, increased efficiency in terms of braking distance, increased level of unification for the purpose of interchangeability, regardless of the administration of wagon owners, reducing the role of man in terms of handling with brake force changeover devices, release mechanisms.

Having in mind the tendency of cargo transport development (increased capacity, speed and length of trains, reducing the role of man in brake manipulation), in recent years a considerable development of brake equipment occurred, which meets the requirements and criteria, and does not represent nowadays a restriction in terms of required characteristics for contemporary freight railway traffic.

There are 3 concepts for brake equipment of freight wagons:

a) classical brake of freight wagons regime "S",

b) brake with automatic changeover device "empty-loaded" regime "S", and

c) brake with automatic continuous variable brake-force regime "S" and "SS".

2. BRAKE OF FREIGHT CARS IN REGIME "S" AND "SS"

Under classical brake regime "S" is meant an automatic air brake with compressed air which fully complies with the terms of the UIC 540 to 545, which means it is approved for international traffic. The basic downside of the design of brakes with changeover devices P-T, regardless whether a manual or automatic position changing is in the following:

- In changeover position P - empty wagon, brake force is maximum (120%),
- In position P - wagon loaded till changeover mass, brake force is minimal (55%),
- In position T - wagon loaded at changeover mass, brake force is maximum (120%),

[1] mr. Erdinč RAKIPOVSKI, Skopje, Macedonia, erdincrakip@gmail.com
[2] Prof. dr Dragan MILČIĆ, Faculty of Mechanical Engineering University of Niš, A. Medvedeva 14, Niš, milcic@masfak.ni.ac.rs

- In position T – wagon maximally loaded, brake force is minimal (65%),

In order to provide higher brake force without these oscillations, instead of mechanical changeover device P - T, which ensures only two brake forces, can apply continuous brake force change in two ways:

- Either change of brake cylinder pressure to continuously follow increase of wagon load (larger load - higher pressure);
- Or that the transfer ratio changes in the function of wagon load.

The concept of brake with automatic continuous brake force change is also applicable for "S" and "SS" regime. The difference is in the power of brakes. For "S" regime must provide a minimum of 70% of the brake weight. That is why only one brake cylinder is sufficient for "S" regime, while as two for the "SS" regime. During recent years successively are developed devices and solutions for the brake in terms of improving its characteristics, such as:

Distributor valve as main device is equipped with an automatic releaser, as well as a maximum pressure limiter. The introduction of the automatic release mechanism simplified the handling with the release mechanism by railway staff, so it is now sufficient just to pull the release handle and discharge of overcharged air installations is performed automatically, based on differences of pressure in brake pipe and operating chamber. So the worker is free from long lasting holding of brake release device handle, which is a considerable saving for longer trains. By fitment of **brake cylinder pressure limiter (HBG)** in the distributor valve it is achieved that despite of increased pressure in brake pipe, operating chambers and auxiliary reservoir, brake cylinder will always gain nominal operating pressure, so the brake force does not exceed calculated value. In the opposite case, increased pressure achieves higher brake force, which has the effect of blocking the wheels, creating flat spots or other damages on wheels. Size of **brake cylinder** for 4-axle car is increased from 14" to 16" and is unified for all types of wagons. This should provide brake force for car of 20 tons per axle, with transfer ratio of the brake rigging system below 12. Rubber packing cups are replaced by leather ones, and the cylinder received a condensate drainage orifice in the bottom portion. The **main brake pipe** seamless steel tubes are increased from 1 "to 5/4" in order to provide prescribed breakdown speed of the train set. **Middle rigging system (cylinder)** is improved in design. Holes for bolts, ie. bushes gained corresponding gaps, according to UIC 542 regulations, by heat treatment of bushes and bolts favorable surface strength and hardness are obtained, which significantly increased the level of mechanical efficiency. Length of middle rigging system is increased onto 960mm to facilitate the installation of brake cylinder with increased dimensions.

Slack adjuster is changed in design in respect to water entry protection, protection from corrosion (phosphatizing of elements), and, as most significant, the spindle with knurled screw threads is replaced by spindle with rolled screw threads.

End cocks are re-designed according to the new demands for international traffic and conformed to most reliable European variants in terms of fixation in end positions by spring force. Figure 1 shows the layout of major brake devices of freight cars in regime "S", with brake G-P. According to UIC 543 regulations, the brake must provide a minimum 65% of the brake weight for all loads.

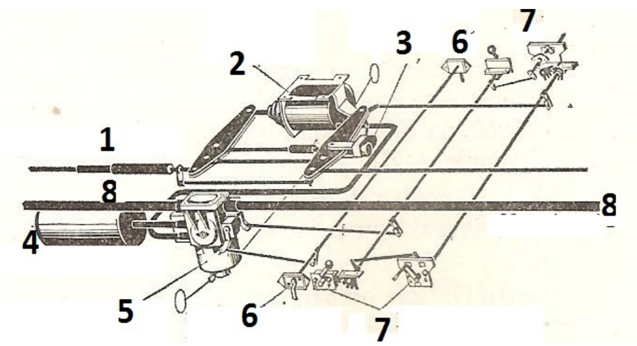


Figure 1. Layout of brake units of freight wagon with brake G-P
(1-Slack adjuster;2-Brake cylinder; 3-Changeover device; 4-Auxiliary reservoir; 5-Distributor valve; 6-Changeover device "ON-OFF";7-Changeover device "P-T"& "G-P"; 8-Brake pipe)

For freight wagons with classical air brake type G-P a distributor valve MZT - Oerlikon EST3f is fitted. Basic features of this distributor valve are provided on Tab 1.

Tab. 1 Basic features of this distributor valve

Pressure drop in brake pipe at full brake application ΔP_B	5 bar.
Maximum cylinder pressure Pz max	3,7 — 3,9 bar
The lowest degree of brake application and releasing ΔPz	0,05 bar
Max.permitted duration of high pressure surge	t_L+10s
Breakdown speed along train length	273-285 m/s
Operating pressure in brake pipe p_B	5 bar
Sensitivity of pressure drop in brake pipe	0,06 bar for 0,7s
Insensitivity	0,5 bar in 60s

3. REMOVING THE PROBLEM WITH RELEASING IN REGIME "SS"

For freight wagons with SS type of brake (with brake shoe P10 and brake cylinders 16"), problem with releasing occurs, which in most cases leads to appearance of flat spots and wheel damage on freight wagons. The standard time for charging auxiliary reservoir is 140-165 sec. according to UIC standards. For "SS" wagon type that time is 200-250sec., depending whether reservoirs of 250 or 300 liters are fitted. This time is permitted by UIC standards for brakes, but they have not taken into consideration the possibility of consequences due to that change.

For removing these problems it is necessary to install an additional parallel system BY-PASS for charging auxiliary reservoir. Such system is applied in the brake system of passenger wagons.

In the BY-PASS equipment need to fit one isolating cock and non-return valve with filter (between brake pipe and auxiliary reservoir). BY-PASS system does not disrupt normal function of distributor valves in any function.

Diagram of Sgnss wagon brake testing is presented on Figure 2.

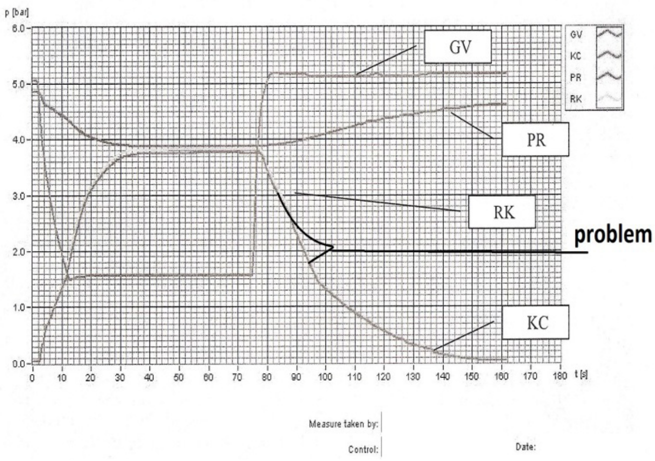


Figure 2. Diagram of testing Sgnss wagon brake (GV-brake pipe pressure, KC – brake cylinder pressure, PR- auxiliary reservoir pressure, RK-operating chamber pressure)

It can be best seen on the diagram when the releasing process is performed and instead of the curve being normal "protrusions" are shown, which is written and reported as a problem This mostly occurs in the period of 20 sec. after releasing in regime "P" (empty wagon) on the brake cylinder (when pressure in brake cylinder drops).

Problems with "SS" wagon types are obvious when in the train are:

- Involved wagons with different types of brake KNORR-BREMSE, SAB WABCO, DAKO, Wabtec MZT (MZT HEPOS);
- Involved wagons with same type of brake, but different wagon manufacturers;
- Insufficient training of railway personnel who operate the brakes.

4. CONCLUSION

Wagon brakes have extremely vital role in traffic safety. In the last years many railway offices worldwide implement high speed passenger and freight trains, which trend has to be followed by development and implementation of efficient and safe brakes. This paper presents a new design solution for brake for removing occurrence of flat spots and wheel damage on freight wagons by fitment of additional parallel system BY-PASS for auxiliary reservoir charge. Such system is mostly applied on brake systems of passenger trains. while nowadays also on freight wagons, against norms and requirements of European railways.

REFERENCES

[1] J. Švagel, *Kočnice na železničkim vozilima*, Beograd, 1962

[2] D. Pajić, Kočnice i sistemi uredžaja za zbijeni vazduh na železničkim vozilima, Beograd 1970.

[3] V. Vainhal, *Kočnice i kočenje vozova*, Beograd 1982

[4] UIC 540 "Brakes-Air brakes for freight and passenger trains" 4th edition, June 2002

[5] UIC 543 "Brake – Regulations govering the equipment of trailing stock", 12th edition, June 2003

[6] UIC 544-1 "*Brake-Braking power*", 4th edition, Octobar 2004

[7] Inž A. Popov,inž. N. Stojkov, *Osnovi na sopiračkata i sopiračkite sistemi*, (MZT HEPOS AD Skopje – kniga za interna upotreba), Skopje Oktomvri 2006,

[8] UDK/UDC 629.463.087, Savremeni pristup seriskim ispitivanjima kočnice teretnih vagon

ANALYSIS OF LIFE CYCLE COSTS AND PROFITS OF TRAMS IN SLOVAKIA

František RUMAN [1]
Juraj GRENČÍK [2]

Abstract *– It is a well-known fact that modern trams are designed and manufactured on much higher standard than older trams, many of them of obsolete concepts. On the other hand, nowadays tram designs are more complex and require much higher investment costs. Efforts to minimise costs and demonstrate the economic advantages of these new technologies and designs, throughout the life cycle (LC), launched a process of economic analysis called life-cycle cost analysis and life-cycle profit analysis (LCC and LCP). Life-cycle cost analysis is the process of economic analysis that focuses on the assessment of the total cost of acquisition and ownership, as well as the disposal of a product. This analysis provides important inputs to the decision-making process at the stages of design, development, use and disposal of a product.*

The paper deals with the analysis of currently the most widely used methods for calculating the costs and profits of the life cycle of trams. Example calculation of the costs and profits of life-cycle of a tram for expected service life is presented, too. Following costs for the LCC calculation were used: acquisition, preventive maintenance, corrective maintenance, accidents, cleaning, energy, track utilisation, power supply, overheads and salaries. Finally, the individual cost items are discussed.

Keywords – LCC, LCP, trams.

1. INTRODUCTION

It is a well-known fact that nowadays railway vehicles are designed and manufactured on much higher standard than older vehicles, many of them of obsolete concepts. On the other hand, nowadays railway vehicles designs are more complex and require much higher investment costs. Efforts to minimise costs and demonstrate the economic advantages of these new technologies and designs, throughout the life cycle (LC), launched a process of economic analysis called life-cycle cost analysis and life-cycle profit analysis (LCC and LCP).

2. PROBLEM ANALYSIS – CURRENT STATE

The term LCC analysis, also referred to as the analysis of life-cycle costs, can be understood as a sequence of actions aimed at estimation of the total or part of the costs incurred for the purchase, use and disposal of fixed assets throughout their life cycle. The life cycle is illustrated in Fig. 1.

The term analysis of the LCP, also referred to as the life cycle profit analysis, can be understood as the total profit that physical asset, in our case railway vehicle, bring throughout their life cycle. As well as the costs and the profits it is important to their distribution in time. Along with the time distribution costs can be very easy to identify when the owner will have insufficient funds for the operation.

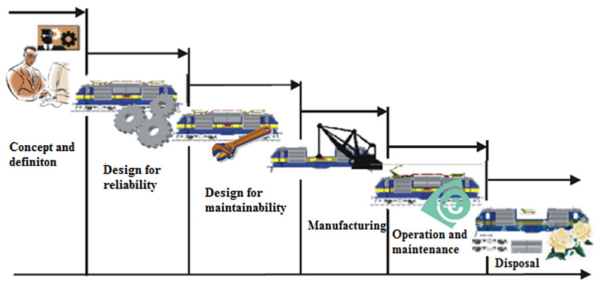


Fig.1. Life cycle of a railway vehicle [1]

Questions regarding the analysis of the total costs began to appear in the early nineties of 20th century.

[1] František RUMAN, Department of Transport and Handling Machines, Faculty of Mechanical Engineering, Univerzity of Žilina, Univerzitná 1, SK-010 26 ŽILINA, SLOVAKIA, frantisek.ruman@fstroj.uniza.sk
[2] Juraj GRENČÍK, Department of Transport and Handling Machines, Faculty of Mechanical Engineering, Univerzity of Žilina, Univerzitná 1, SK-010 26 ŽILINA, SLOVAKIA, juraj.grencik@fstroj.uniza.sk

At that time, the concept of life-cycle costs was understood by the International Electrotechnical Commission [6] as the total (cumulative) costs incurred for the product throughout its life cycle. They are defined as the total cost of system or equipment used for the purchase, installation, maintenance and disposal for a specified lifetime.

Complexity of the LCC issue for railway vehicles, especially concept and design, and further efforts to simplify some of the key processes has led European producers to the establishment of the Expert Group on this issue (The UNIFE LCC Group), under the title of the association UNIFE (The Union of the European Railway Industries) [3]. In terms of major foreign manufacturers among the members are: Alstom Transport, Bombardier Transportation, Siemens Transportation Systems, Stadler, Skoda Transportations. Furthermore, the LCC methodology in detail is covered in the standard EN 60300-3-3 Dependability management, Part 3-3: Application guide, Life cycle costing. Both methodologies are presented briefly hereafter in the following chapters.

3. BRAKEDOWN OF COSTS

One approach is a simplified breakdown of costs into the three cost categories.

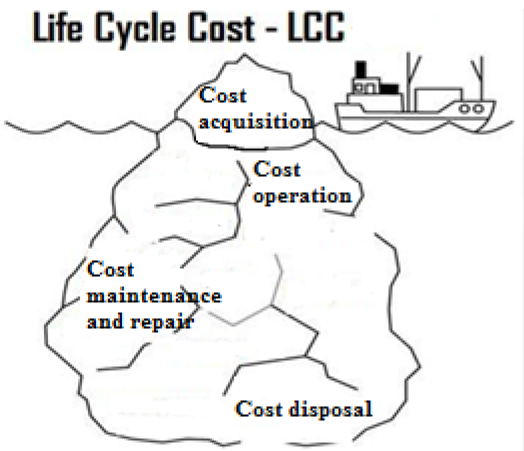


Fig.2. LCC [1]

A. The cost of purchase a vehicle.
  - Purchase price (which implies not only the unit costs, materials and wages, as well as one-off costs incurred by the supplier for research and development, investment in production facilities, new technologies, etc.).
  - Finance costs (costs associated with potential credit or leasing).
  - Other one-off costs incurred when buying a vehicle (staff training, testing, approval).

B. Costs of operating the vehicle.
  - The cost of preventive maintenance - the necessary materials, salaries, technology, etc.
  - The cost of corrective maintenance - required materials, salaries, technology and etc.
  - The cost of cleaning and cleaning services - the necessary materials, salaries, technology and etc.
  - The cost of operating materials (sand, oil, water and etc.).
  - The cost of staff salaries.
  - The cost for the use of infrastructure.
  - The cost of parking the vehicle.
  - Administrative costs and overheads.

C. Disposal costs of the vehicle.
  - The cost of dismantling the vehicle.
  - Disposal costs.

4. RAILWAY VEHICLE LIFE CYCLE PHASES AND LCC

Fundamental to the concept of life cycle costing is a basic understanding of a product life cycle and the activities that are performed during these phases [3].

There are six major life cycle phases of a product as follows:
- Concept and definition.
- Design and development.
- Manufacturing.
- Installation.
- Operation and maintenance.
- Disposal.

5. LCC MODEL UNIFE

In the UNIFE LCC [3] model the total costs of the life cycle are similar to the model according to STN EN 60300-3-3 [5], but have some differences. These costs are:
- Cost for acquisition.
- Cost for operation.
- Support costs throughout the life phase.
- By UNIFE LCC are life cycle phases:
- Concept and definition.
- Design and development.
- Manufacturing.
- Installation.
- Operation and maintenance.

6. LCC MODEL BY EN 60300-3-3

Life cycle costing [5] is the process of economic analysis to assess the total cost of acquisition, ownership and disposal of product.

There are six major life cycle phases of a product as follows:
- Concept and definition.
- Design and development.
- Manufacturing.
- Installation.
- Operation and maintenance.
- Disposal.

7. CALCULATION OF COST AND PROFIT LIFE – CYCLE OF A TRAM

The actual purchase cost of a vehicle still does not give a picture of the tram's profitability. It is necessary to calculate the other components of the life-cycle costs of the vehicle, including infrastructure. We present a case study for LCC and LCP analysis performed on a standard 30 meter long tram [4]. The total lifetime of the tram is 30 years' service life and the seating capacity is 60.

Methodology for monitoring costs is not consistent with public transport operators and this example must be taken as illustrative only.

On the other hand, it is important to realize that the renewal of the fleet of trams is an existential necessity. Its non-implementation leads to the creation of internal debt, the business will be passed to trade successor in a depleted state with the need of large investment. Artificially extending the life of the reconstruction of obsolete vehicles is not the solution; in fact it is only postponing the actual car fleet renewal in coming years.

The costs of the life-cycle of tram

Life cycle costs of a tram can be broken down by a large number of criteria. In this calculation the most important criteria for accurate calculation of life-cycle costs were included.

Acquisition costs

In the price of the vehicle may or may not be included: financial costs, transportation, testing, approval, documentation, training, corrective maintenance during the guarantee, spare parts, tools and the like. In case of loan it is necessary to calculate the additional cost factor.

For the selected tram daily mileage of 151.2 km is assumed. Then annual throughput with regards to preventive and corrective maintenance which represents about 95% availability of the vehicle is 54 428.6 km. Thus the total mileage over the 30 years' service life is 1 572 858 km.

Acquisition cost of the tram is about 2 450 000 €. When financed by a loan, the price of tram is 3 920 000 €. Acquisition costs calculated per km throughout the lifetime is the 2.49 € / km.

Operation costs

For operating costs the greatest impact has daily mileage of vehicles, the number of passenger seats and daily capacity.

Preventive maintenance

The basis for calculating the cost of preventive maintenance is the periodic inspection plan. Estimated cost of preventive maintenance throughout the lifetime tram is about 584 125 €, which gives 0.372 € / km or 0.006 € / km / seat.

Corrective maintenance

Is not planned – has random character (stochastic). Its occurrence and extent can be determined based on experience from the operation of similar vehicles and the detected data on failures. The approximate cost of corrective maintenance for the lifetime of the vehicle based on data on failures constitutes 87 620 €. Then the costs of corrective maintenance of life cycle tram are 0.056 € / km or 0.0009 € / km / seat.

Accidents

Traffic on city streets carries the risk of accident. Tram accidents are very common and occur about every 20 000 km. Usually, these are light damages, the costs are about 0.0012 € / km / seat.

Energy

It is a simple calculation of performance-transport work. For tram, the specific energy consumption is about 100 kWh / 1000t. The price of electricity for traction is about 0.064 € / kWh and costs of energy are 0.213 € / km or 0.003 € / km / seat.

Operating materials

It is a smallish item when calculated per kilometre run. These include sand, windscreen washer fluid, grease for flanges lubrication and the like.

Salary costs

The amount of the salary costs calculated on a passed kilometres decides in particular the number of board staff K_n, hourly wage M, employee productivity p, the ratio of labour costs to wages k_m, the ratio of the period of personnel service time to vehicles service k_s and turnaround in speed v_0. Then salary costs represent around 0.67 € / km.

$N_m = K_n * M * k_m * k_s / (p * v_0)$

$N_m = 1 * 4 * 1.4 * 1.2 / (0.9 * 14)$

$N_m = 0.53$ €/km

Costs of the transport route

Transport costs C in itself summarizes component for the operation of transport routes S1 component for ensuring the operability of the transport road S2, travelled distance L and mass m train. Regional Transport represents around 0.19 € / km for the operation of transport routes and 1.05 € / km for ensuring the operability of the track.

$C = S_1 * L + S_2 * L * m$ (€/km)

Costs of cleaning

Overhead costs

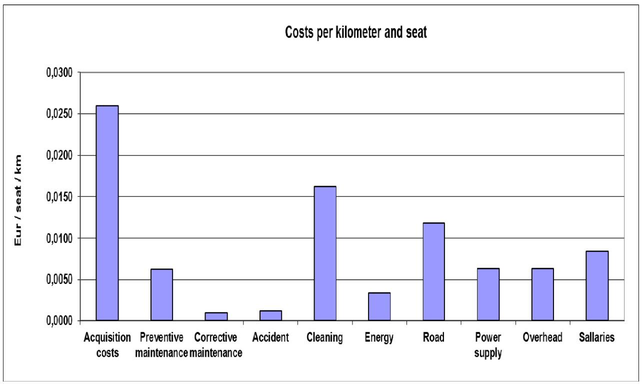


Fig. 3. Costs per kilometre and seat [7], [4]

In figure 3, results based on LCC calculations from [4], [7] are presented in graph, where similar tram have been analysed.

The calculations suggest that the total lifecycle costs for 30 meter tram with 60 seats and an annual mileage of 52428.6 km are 0.087 € / km / seat.

The cost structure as a percentageof total costs is shown on figure 4.

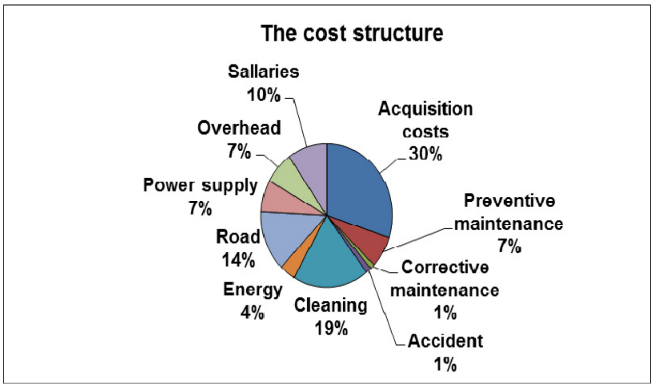


Fig.4. The cost structure [4]

Revenues for the life-cycle of tram

Profits in railway transport have several components. To achieve the profitability the minimum train occupancy rate is 20% for regional transport and 35% for long-distance transport.

Revenues from passengers

They range roughly between 1.37 € per kilometre. The total approximate amount of sales for the full occupation of seats and the entire lifetime is the 2 277 600 € [7].

Subsidies from the customer traffic

Subsidies for nationwide lines are about 3.9 € / km. Subsidies for regional lines are about 3.6 € / km / vehicle. Overall subsidies for tram throughout its lifetime are therefore 5 940 000 € [7].

Revenues from advertising

Advertising revenues are ranging about 0.2 € / km. Revenues from advertisements throughout the lifetime of tram are about 330000 € [7].

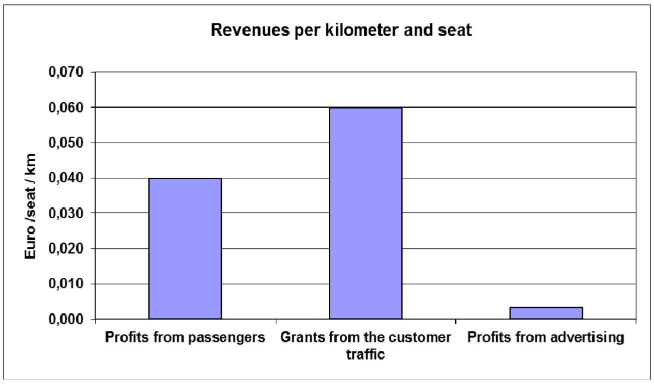


Fig.5 Revenues per kilometre and seat [7], [4]

The total approximate revenues of 30 meter tram over 30 years' service life and the mileage of 1 572 858 kilometres throughout its live are 8 547 600 €, or 0.09 € / km / seat.

8. CONCLUSION

In this paper an analysis of costs and profits during rail vehicle life cycle has been done. The description of both methodologies - UNIFE and EN 60300-3-3 was presented. The calculations suggest that the total lifecycle costs for 30 meter tram with 60 seats and an annual mileage of 52 428,6 km are 0.087 € / km / seat. The total approximate revenues of the tram over 30 years' service life and the mileage of 1 572 858 kilometres for throughout its life are 8 547 600 €, or 0.09 / km / seat.

The analysis of LCC and LCP can be used to determine whether the renewal of the vehicle fleet is necessary and whether the purchase of new vehicles is preferred. So that the renewal of the renewed rolling stock was profitable, the cost of operation should be lower than revenues from the operation.

REFERENCES

[1] Bronček, M.: Náklady životního cyklu kolejových vozidel, Dissertation thesis, VŠB-TU Ostrava, 2005.

[2] Ferreira A. L.: LCC – Life cycle cost, its relevace to Physical Asset Management, EuroMaintenance 2014, Edition 2, 32 – 37 s., ISBN 978-952-67981-2-7.

[3] Kjellsson, U.: Unife – unilife and Unife – Unidata – the first European life cycle cost interface software model: research report, 2000. 8 pp.

[4] Pohl, J.: Principy a trendy v tramvajové dopravě, Dopravní magazin, 2/2008, pp. 24 – 29.

[5] STN EN 60300-3-3: 2005, Manažérstvo spoľahlivosti. Časť 3-3: Návod na používanie. Náklady počas životnosti.

[6] STN IEC 60050-191: 1993, Medzinárodný elektrotechnický slovník. Kapitola 191: Spoľahlivosť a kvalita služieb.

[7] Výročná správa DPB za rok 2013.

DESIGN OF A DISTRIBUTED SYSTEM FOR MONITORING ENERGY CONSUMPTION OF ELECTRIC-TRACTION VEHICLES BASED ON GPRS-INTERNET

Nenad JEVTIĆ [1]
Dragutin KOSTIĆ [2]
Slobodan MITROVIĆ [3]
Petar MARKOVIĆ [4]

Abstract *– A system for acquisition and transfer of data on instantaneous electric energy consumption of traction vehicles is described. A laboratory prototype of this system is based on a laptop computer equipped by an additional NI DAQ USB-6009 module, for acquisition of data on voltages and currents at the input of the traction vehicle, and iCell MTCMR-E1-GP module, serving for reception of GPS signals and transmission of data through the selected local mobile telephony operator. Measurement of power is performed indirectly by measuring input currents and voltages of traction vehicles. For measurement of these physical quantities by the prototype model, Hall-effect sensors produced by LEM have been used. Signal from the sensors are fed to the acquisition module where AD conversion is performed. Digitized signal is then, via USB bus, transmitted to a PC where the instantaneous power is calculated. The obtained data on power are averaged over one second interval and together with data from the GPS receiver on instantaneous position and speed are formatted and sent to the central server. Data from the server are available for client application in a remote center where supervision and monitoring of traffic in electrified network are performed, thus the possibility is created for the quality traffic management and rational use of electrical energy.*

Keywords – measurement of energy, electric traction vehicles, GPS, GPRS, LabVIEW.

1. INTRODUCTION

Reduction of electrical energy consumption by traction vehicles has become very interesting topic and an important technical challenge in modern management systems of electric traction vehicles.

In order to optimize consumption of electric energy from the traffic management point of view, it is required to know dynamic data on real time electric power used by the vehicles. Consumption of electric energy used for traction is one of most significant direct costs of traffic. This cost is even more significant since the corresponding payment is calculated on the basis of the maximum engaged power over a defined short time interval.

Consumption of electric energy is directly related to the number, position, and operating mode (traction, braking) of vehicles in a supplied zone. By operative traffic management, it is possible to influence directly the cost of consumed electric energy without affecting a planned volume of traffic and time table if a dynamic data base on position, speed of vehicles in the network, and electric power used by individual traction vehicles is available to the operative traffic management center.

The paper presents the results obtained in the process of development of a system for measurement of consumed energy and a system for transfer of the measured data to the remote user terminals.

[1] Nenad JEVTIĆ, Faculty of Transport and Traffic Engineering, University of Belgrade, n.jevtic@sf.bg.ac.rs
[2] Dragutin KOSTIĆ, Faculty of Transport and Traffic Engineering, University of Belgrade, d.kostic@sf.bg.ac.rs
[3] Slobodan MITROVIĆ, Faculty of Transport and Traffic Engineering, University of Belgrade, cobaja@sf.bg.ac.rs
[4] Petar MARKOVIĆ, Faculty of Transport and Traffic Engineering, University of Belgrade, p.markovic@sf.bg.ac.rs

2. DECRIPTION OF THE SYSTEM FOR ACQUISITION AND TRANSFER OF MEASURED DATA

Since the system was expected to provide supervision and monitoring of energy consumption of a mobile traction vehicle, it was necessary to design a system for acquisition and processing of data on consumed energy and transfer of the measured data to the central computer.

Concept of the system for acquisition and transfer of measured data is shown in Fig. 1.

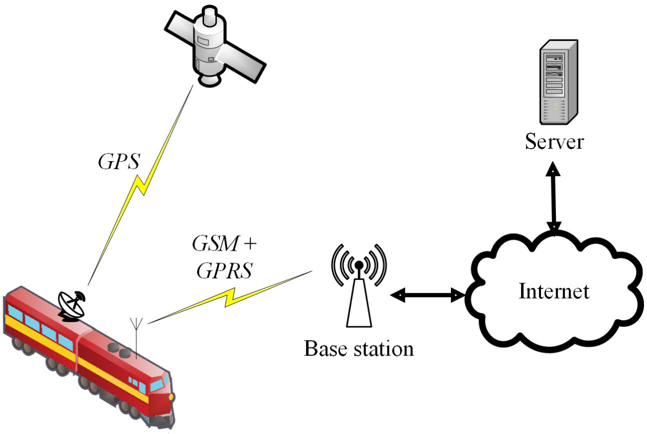


Fig.1. Concept of the system for locating a traction vehicle and transfer of measured data from the vehicle to the server

Owing to the mobile nature of traction vehicles, the system for data transfer relies on infrastructure of the local mobile telephony operators, which gives a satisfactory solution for an electric traction system in a city traffic. For railway traffic, a separate infrastructure of GSM-R system is used. Each traction vehicle is equipped by a GPRS (*General Packet Radio Service*) module and the corresponding SIM (*Subscriber Identification Module*) card of the selected mobile operator. Also, in order to carry out an efficient supervision, information on the position and speed of vehicles are required. For this purpose, the corresponding GPS (*Global Positioning System*) module is used.

At first, traction vehicle establishes a link with the remote central computer – server.

Role of the server is to provide interconnection of all active traction vehicles, to receive, process, and store data on all vehicles and that, if required, perform further distribution of selected data to remote clients. Upon connection to the server, traction vehicle transmits instantaneous values of the power and position by using packet data transmission and Internet technology.

The system conceived in this way can be used for transfer of control signals to the traction vehicles and also for transmitting different data concerning status of vehicles or current state of the traffic.

At this stage of development of the project, the part of the system described by Fig. 1 related to the electric traction vehicles of the public city transport has been tested at the level of a laboratory model and the corresponding prototype solution. Fig. 2 shows block diagram of the developed laboratory prototype model of the acquisition system and the way of connecting this system to the infrastructure of a traction vehicle.

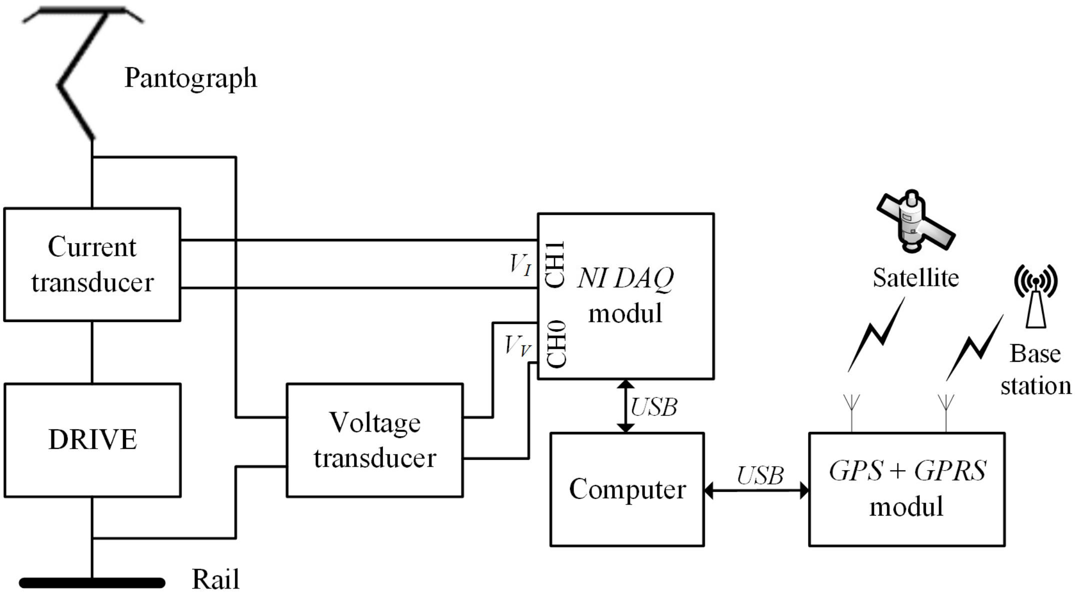


Fig.2. Concept of the system for location of traction vehicles and transfer of measured data form a vehicle to the central server

3. ELEMENTS OF THE VEHICLE MEASURING SYSTEM

Measurement of power is carried out indirectly by measuring currents and voltages at the input of the traction vehicle.

For the purpose of measurement of these physical quantities on the developed prototype, the following Hall-effect transducer produced by LEM have been selected:

- LT 505-S – current transducer.
- LV 100-800 – voltage transducer.

The current and voltage transducer have been adjusted to produce galvanically isolated voltage signals V_I (current transducer) and V_V (voltage transducer) within the range of -10V, +10V.

These signals are fed to the acquisition module *NI DAQ USB-6009*, produced by *National Instruments*. This module performs AD conversion of the input voltage and current signals taken form the traction vehicle. The applied sampling frequency is f_s =2kHz, which gives satisfactory results since harmonic spectrum of the trolleybus and tramway contact line voltage, in addition to the zero order harmonic, contains harmonics od the order 300 and 600Hz

The digitized signal is then, via USB bus, transferred to the PC for further processing. The PC performs recording of the obtained discrete values of the current and voltage at the input of the traction vehicle and then calculates the instantaneous value of power. The obtained results are averaged over the period of one second and formatted for transmission to the central server. At an instant corresponding to *k*-th second, the power is determined by:

$$P_k = \sum_{n=f_s(k-1)}^{f_s k-1} u_n i_n \ . \qquad (1)$$

By the process of cumulative adding of power samples, one obtains information concerning energy consumption of the traction vehicle.

In addition to power data, the simultaneously obtained data on instantaneous position of the vehicle are also sent to the central server. Obtaining data on the position and speed of the traction vehicle, as well as data transmission over the mobile operator network is performed by *MultiModem iCell MTCMR-E1-GP*, produced by *Multi-Tech Systems*, connected to the local computer by *USB* bus. This piece of equipment performs a two-fold function, GPS receiver and GPRS modem. The GPS receiver generates standard NMEA (*National Marine Electronics Association*) messages over the selected time interval of one second. Data on instantaneous position and speed of the vehicle are obtained from RMC (*Recommended Minimum Data for GPS*) NMEA message and, together with the previously obtained average power, transferred to the central server via GPRS modem.

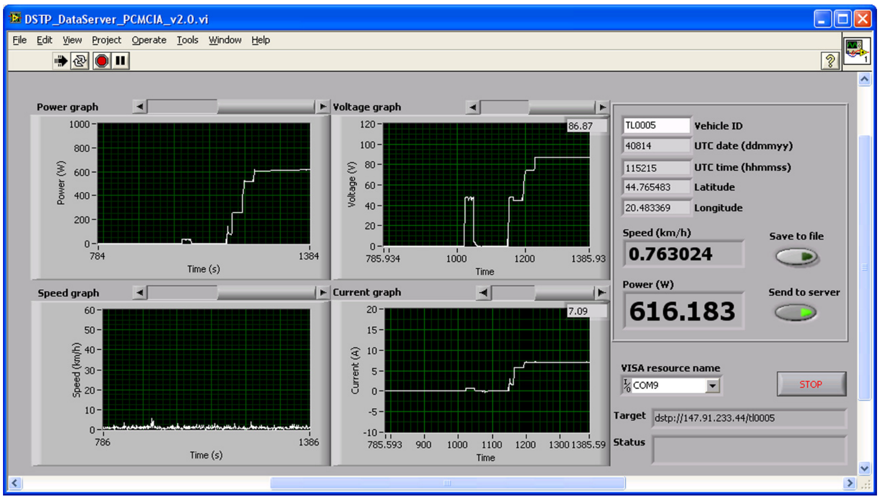


Fig.3. Graphical user interface of the client application program in a traction vehicle

4. PRESENTATION OF SOME OF THE RESULTS

Data sent from the local computer in the vehicle are collected by the central server. Communication between the vehicle, central server, and client is carried out by using TCP/IP Internet protocol. Fig. 3 shows graphical user interface of the application program in the vehicle, written by using LabVIEW program package.

In the present case, this is static location of the realized laboratory model in the Traction Laboratory of the Faculty of Traffic and Transport Engineering in Belgrade. The obtained results are also graphically presented in order to facilitate monitoring the operating regime of the vehicle, taking into account that positive value of the average power corresponds to the traction regime, whereas negative value of the average power is characteristic for the regime of electrical braking accompanied by recuperation.

Fig 4 shows graphical user interface of the client application program, written by using LabVIEW program package. Data concerning instantaneous power consumption, location, and speed of the traction vehicle, taken at one second intervals, are available to the remote center where supervision and monitoring of traffic in an electrified network are being performed. Data on instantaneous position and trajectory of vehicle moving are also graphically presented by using Google Maps technology.

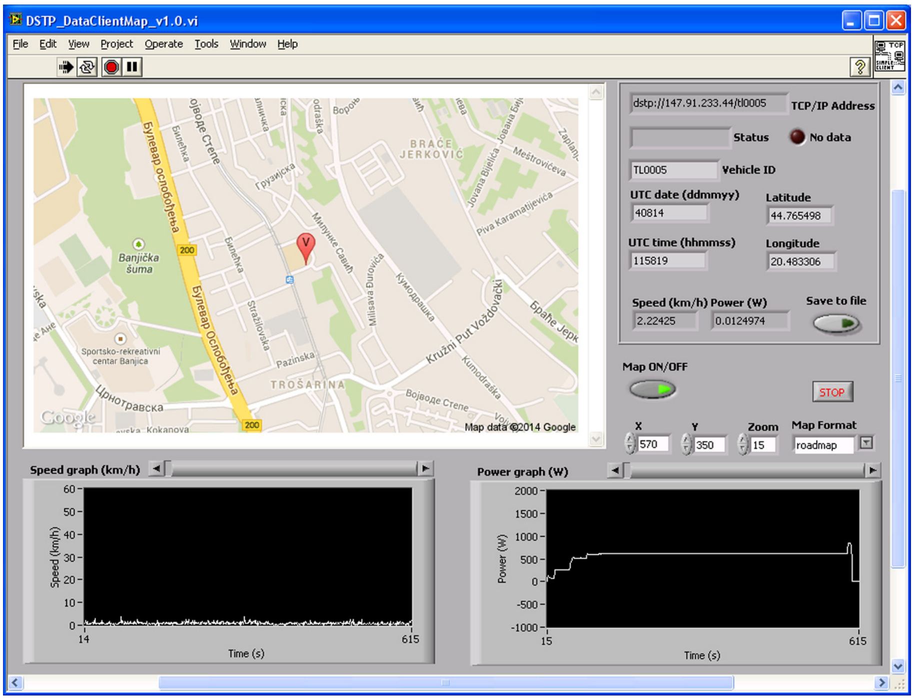


Fig.4. Graphical user interface of the client application program

5. CONCLUSION

Compared to the methods used so far for optimization of traction, the main innovation introduced by this work is the approach to reduction of electrical energy consumption based on experiment by measuring significant electrical quantities and calculation of the power of consumption. The relevant data are available not only to the driver controlling the vehicle, but also to the remote center where supervision and monitoring of traffic in an electrified network are carried out, therefore the possibility is created for performing a quality control of the traffic and achieving rational use of electrical energy.

Practical solutions obtained in the process of development of the laboratory prototype could form a useful basis for arriving at a systemic solution, which, including certain modifications, could be, applied to all electric traction systems.

ACKNOWLEDGEMENT

The Serbian Ministry of Science and Technological Development supported this work in project TR36047.

REFERENCES

[1] Jianjun, M., Chenghui, Y., Wenzhe, Q., *Servicing work safety supervision system for electric locomotive based on configuration software*, Proceedings of the International Symposium on Electronic Commerce and Security, Guangzhou City, 2008.

[2] Yunyan, W., Tiezhou, W., Linzhang, W., Jiaping, L., *Design and Realization of Ammeter Management System of Electric Locomotive in Railroad*, Proceedings of the International Workshop on Intelligent Systems and Applications, Wuhan, 2009.

[3] Popa, G., Mihailescu, M., Arsene, S., *Unified system for optimizing the transmission of technical data flow from railway vehicles*, Proceedings of the Electrical Systems for Aircraft Railway and Ship Propulsion (ESARS), Bologna, 2012.

[4] Lee T., Cho H., Kim S., Kim K., *Measurement and analysis of consumption energy for Korean high-speed trains*, Proceedings of the Innovative Smart Grid Technologies (ISGT), Washington DC, 2012.

[5] Zhijun C., Ming L., Xiaowei X., Fangping, Y., Huabiao, Y., *Design of distributed monitoring and diagnostic system for locomotive diesel based on GPRS-Internet*, Proceedings of the International Conference on Electrical and Control Engineering, Wuhan, 2010.

[6] Zhai X., Liu Z., *High-speed Railway Fundamental Information Database System and its GIS subsystem*, Proceedings of the Second International Symposium on Information Science and Engineering, Shanghai, 2009.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

APPLICATION OF THE MOBILE MACHINES IN RAILWAY TRANSPORT

Dragoslav JANOŠEVIĆ [1]
Jovan PAVLOVIĆ [2]
Vesna JOVANOVIĆ [3]

Abstract *– The paper first gives functional and parametric analysis of mobile machines that have found application in the railway traffic and transportation, and the construction and maintenance of railway infrastructure. Then, given conceptual and structural analysis of a modules, which installation on the classic moving mechanisms, provides motion on the railroads. At the end of paper a mathematical model is given, by which software was developed to determine the allowed load capacity of mobile machine at the loading and unloading function of railway transport.*

Keywords – Mobile machine, rail transport.

1. INTRODUCTION

A comperhensive set of mobile machines includes: construction, mining, transportation, agricultural and material handling machines, which are broadly used in all industries including railway traffic and transportation, also and construction and maintenance of railway infrastructure.

At the railway transport, the mobile machines are used for manipulative function of loading and unloading of different cargo such as: container, unit loads objects (packages, lumber) and bulk material (sand, coal, grain).

At construction and maintenance of the railway infrastructure, the mobile equipment commonly used in preparation of the field when railroads are building, installing and removing of a rails and sleepers, maintenance of a electrical installations and cleaning a railroads.

For all of these functions it can used different types of the mobile machines, but the most common are: hydraulic excavators, crawler tractors, dump trucks, graders and cranes (Fig. 1), small and medium-sized, weighing from 2,000 to 20,000 kg.

All types of the mobile machines which are used in the railway transport have a conventional (default) configuration of kinematic chain which principally consists of: supporting-moving mechanisms and manipulators. The supporting-moving mechanisms by conception can be derived from the caterpillar or tires. The manipulators are multimember kinematic chains with planar or spatial configuration with the last one changeable member in the form of various tools (buckets, grapples, hooks, magnets, ..) which directly manipulates with various items.

The application of conventional (standard) mobile machines in railway transport is achieved by installing special modules on the existing supporting -moving mechanisms, which allow suspension and movement of machines on railroads [1][2][3].

Fig. 1. Mobile machines and tools which are used in railway transport

[1] Dragoslav JANOŠEVIĆ, University of Niš, Faculty of Mechanical Engineering, A. Medvedeva 14 18000 Niš, Serbia, janos@masfak.ni.ac.rs
[2] Jovan PAVLOVIĆ, University of Niš, Faculty of Mechanical Engineering, A. Medvedeva 14 18000 Niš, Serbia, pavlovic.j@masfak.ni.ac.rs
[3] Vesna JOVANOVIĆ, University of Niš, Faculty of Mechanical Engineering, A. Medvedeva 14 18000 Niš, Serbia, vesna.nikolic@masfak.ni.ac.rs

2. ANALYSIS

Specifically modules, that allows to mobile machines a locomotion on railroads, are installed on the front and rear of a transverse undercarriage 1.6 (Fig.2) of the moving mechanism through its connection plate for which is connected a lever in the shape of the frame, on one side of the lever with the horizontal rotary joint.

On other side of lever there are rail wheels 1.2 that are connected with the rotary horizontal joints, and wheelbase corresponds to the width of the stripes. The lever, and with it the wheels, based to the undercarriage of moving mechanism can be raised and lowered by pair of hydro-cylinders 1.3. When the rail wheels are lifted, the machine movement is achieved through the tire 1.1 (Fig.2a) on the base without the railroad son, and when are lowered allows to the machine to travel by rail (sl.2b).

The motion modules according to drivetrains can be divided into:

- the motion modules with direct drivetrain,
- the motion modules with indirect drivetrain.

At the motion modules with indirect drivetrain the drive wheel 1.1 (Fig.3a,b) in a friction pair with wheel 1.4 (Fig.3a) direct or indirect (Fig.3b) transmitted drive on rail wheels 1.2.

At the motion modules with direct drivetrain there are two conceptions. The first conception achived motion of a machine by the friction pair of the drive wheel 1.1 and rail stripes. At the second conception motion modules have their own hydrostatic transmission which drives the rail wheels, independently of the transmission of the movement of the machine.

The motion modules have the brake system that is derived in the form of hydraulic disc brakes (Fig. 3).

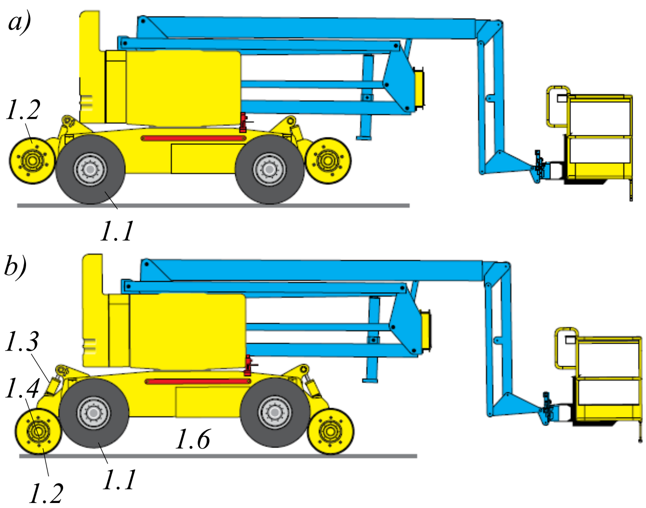


Fig.2. The position of motion modules when the machine is moving: a) on base without railroads, b) on the railraods

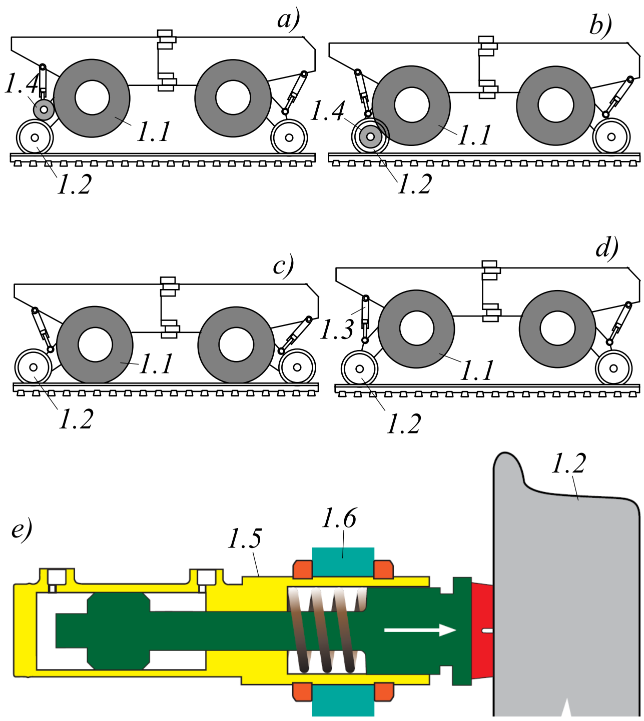


Fig.3. The conceptions of motion modules: a,b) with indirect drivetrain, c,d) direct drivetrain, e) the brake system

3. LOAD CAPACITY

Previous analysis shows that the mobile machies on the railway have usually manipulative tasks that are related to cyclic transport at loading and unloading of various materials and goods. Where manipulative tasks are cyclic change of same operations with very different requirements in terms of the reach of tools and dimensions and weight of the load. In such circumstances, for the safe operation is necessary knowledge of allowable capacity of tools (hooks, grapples, grips, ...) of the mobile machines throughout the whole work (manipulative) space.

In the desired position of the kinematic chain of mobile machines, tools permitted capacity is determined from the condition of the static stability of the machine and hydraulic stability of machines drivetrains

To determine the stability of the machine it is necessary first to define a mathematical model and range of overturn potential lines of machines, depending on the conceptions and methods of relying on the ground of the machine moving mechanism.

For the analysis of load capacity of machine, mathematical model is developed, which consists of a mathematical model of the kinematic chain and a mathematical model of drive mechanisms of manipulator of machines [4].

By the mathematical model of the kinematic chain here is include a general planar configuration of the machine that is consisted of: supporting-moving mechanisms L_1 (Fig.4) and members of the manipulator: L_2, ..., L_n.

The assumptions of the mathematical model of machines kinematic chain are: (1) ground surface and members of the machine kinematic chain are modeled with rigid bodies; (2) The first joint between supporting-moving member and the ground surface have variable position and shape, so that along fit line of supporting-moving member it has the form of translational - sliding joint, and on the ends of the fit line it has form of rotary joints, which axes are represent possible (transverse *x-x* or longitudinal *z-z*) (Fig. 4) lines of the machines overturns.

A space of the machine model is determined by an absolute coordinate system *OXYZ* (Fig. 4). The surface ground of the machines lies in a horizontal plane *OXZ* of an absolute coordinate system.

The member of kinematic chain L_i, is defined in its local coordinat system $O_i x_i y_i z_i$, by set of parameters:

$$L_i = \{\boldsymbol{e}_i, \boldsymbol{s}_i, \boldsymbol{t}_i, m_i\} \tag{1}$$

where is: - $\boldsymbol{e}_i$ - the unit vector of axis of the joint O_i where is a member L_i connected to a previous member L_{i-1}, $\boldsymbol{s}_i$ - the position vector of the joint center where is a member L_i connected to a forward member L_{i+1}, $\boldsymbol{t}_i$ - the position vector of the center of mass m_1 of member chain L_i in the absolute coordinate system, m_1 - a mass of the member.

The parameters of the drive mechanism are the parameters of actuators (hydro-cylinders) and in the mathematical model of machines they are determined by set of sizes:

$$C_i = \{ d_{i1}, d_{i2}, c_{ip}, c_{ik}, m_{ci}, n_{ci}, \boldsymbol{a}, \boldsymbol{b} \} \quad \forall \ i = 2,..,n \tag{2}$$

where is: - d_{i1},d_{i2} - the diameters of a piston and rod of hydro-cylinders, c_{ip} - the minimal length of hydro-cylinders when rod is fully pulled in, c_{ik} - the maximal length of hydro-cylinders when rod is fully pulled out, m_{ci} - the mass of a hydro-cylinder, n_{ci} - the number of hydro-cylinders of a drive mechanism, ***a***, ***b*** - the position vectors of center of joints in which are hydro-cylinders connected to kinematic pair members of the drive mechanism.

A static stability of the machine is determined by the ratio:

$$k_s = \frac{M_s}{M_p} \geq k_{sd} \tag{3}$$

where is: k_s - the coefficient static stability, M_s - the moment of stability, M_p - the overturning moment, k_{sd} - the allowed coefficient of static stability of the machine that is defined with standards, depending on the type of a machine and on concept of the moving mechanism.

The moment of stability, compared to the corresponding line of overturn, is defined by equation (Fig.4):

$$M_s = \sum_{i=1}^{n_s} g m_i (x_{ti} + x_l) \tag{4}$$

where is: x_{ti} - the postion coordinate of the center of mass of a member, x_l - the position coordinate of potentially overturn line of the machine, n_s - the number of members in the machine kinematic chain that create the stability moment.

The overturn moment, in relation to the proper turnover line, is defined by equation (Fig. 4):

$$M_p = k_d \sum_{j=1}^{n_p} g m_j (x_{tj} - x_l) + k_t g m_{ts} (x_t - x_l) \tag{5}$$

where is: x_{tj} - the position coordinate of the center of mass, m_{ts} - the mass of load that allows the static stability of the machine, x_t - the position coordinate of the center of mass of the load, n_p - the number of members in the machine kinematic chain that create the overturn moment, k_d - the dynamic factor of influence on the members of the machine kinematic chain (without loads) that affect to the overturning moment of the machine, k_t - the coefficient of mass increasing that is defined by standards depending on the type of machine.

The boundary capacity of the machine that is determined from the condition of the static stability of the machine, according to Equation 3, 4 and 5 has a value of:

$$m_{ts} \leq \frac{M_s - k_{sd} \cdot k_d \sum_{j=1}^{n_p} g m_j (x_{tj} - x_l)}{k_{sd} \cdot k_t (x_t - x_l)} \tag{6}$$

The hydraulic stability of the drive mechanisms of the machine is determined by the ratio:

$$k_h = \frac{M_{ci}}{M_{oi}} \geq k_{hd} \tag{7}$$

where is: k_h - the coefficient of hydraulic stability of the drive mechanism, M_{ci} - the torque of drive mechanism, M_{oi} - the torque of load that act on the drive mechanism, k_{hd} - allowed coefficient of

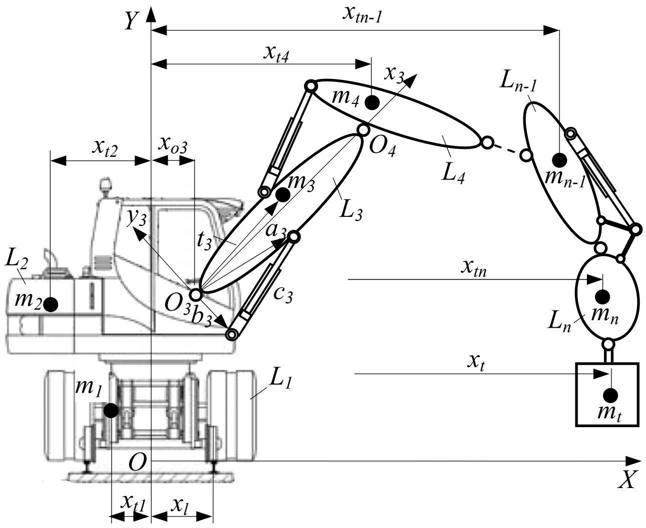


Fig. 4 Mathematical model of the machine

hydraulic stability of the drive mechanism that is defined with the standards depending on the type of the machine.

The torque of drive mechanism, which have for the actuators bidirectional hydraulic-cylinders, can be determined by the equation:

$$M_{ci} = \begin{cases} r_{ci}\, n_{ci}\left[\dfrac{d_{i1}^2 \cdot \pi}{4} p_{max} - \dfrac{\left(d_{i1}^2 - d_{i2}^2\right)\cdot \pi}{4} p_o\right]\eta_{ci} \\ r_{ci}\, n_{ci}\left[\dfrac{\left(d_{i1}^2 - d_{i2}^2\right)\cdot \pi}{4} p_{max} - \dfrac{d_{i1}^2 \cdot \pi}{4} p_o\right]\eta_{ci} \end{cases} \tag{8}$$

where is: r_{ci} - the transfer function of the drive mechanism, p_{max} - the pressure in the working port of the hydro-cylinder, p_o - the pressure in the return port of the hydro-cylinder, η_{ci} - the mechanical efficiency of the hydro-cylinder.

The torque of drive mechanism is determined by equation

$$M_{oi} = \sum_{j=i}^{n} g m_j \left(x_{tj} - x_{oj}\right) + g m_{thi}\left(x_t - x_{oi}\right) \tag{9}$$

where is: x_{oj} - the coordinate of the center of the joint of kinematic pair of the drive mechanism, m_{thi} - the mass of load which allowed by hydraulic stability of the drive mechanism of the machine.

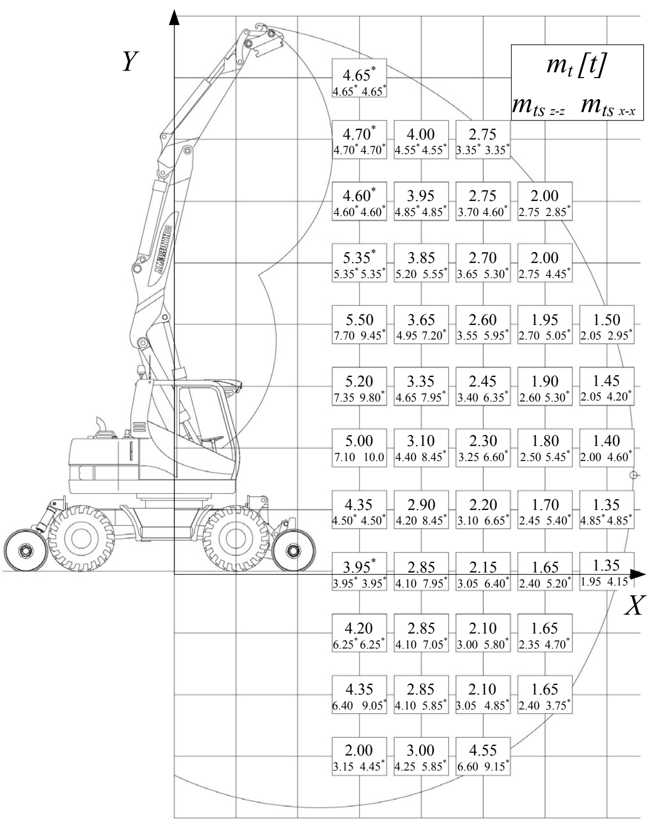


*Fig. 5. The permitted capacity in the working space of the machine, m_t - on tracks (90° transverse), $m_{ts\,z\text{-}z}$ - on wheels (90° transverse), $m_{ts\,x\text{-}x}$ - on tracks, front and rear, * - limited by the hydraulics*

The boundary capacity of the machine that is determined from the condition of the hydraulic stability of drive mechansim, according to Equation 7, 8 and 9 has a value of:

$$m_{thi} \le \frac{M_{ci} - k_{hd} \sum_{j=i}^{n} g m_j \left(x_{tj} - x_{oi}\right)}{k_{hd} \cdot \left(x_t - x_{oi}\right)} \tag{10}$$

The boundary capacity of the machine that is determined from the condition of the hydraulic stability of drive mechansim is determining for all members of the drive mechanism of kinematic chain of the machine ($i = 1,2, ..., n$).

Finally, the possible permitted capacity of the machine for the selected potential line of overturn and for the certain position of the kinematic chain, has a value of:

$$m_t = min\left(m_{ts}, m_{th1}, m_{ht2}, ..., m_{thn}\right) \tag{11}$$

Based on the above defined mathematical model it has been developed softwer for determination of the allowed capacity of the machine in desired numbers of coordinates in the whole working space of the machine tool (Fig. 5).

4. CONCLUSION

The mobile machines have been found its application in all industries including the railway traffic and transportation, and construction and maintenance of railway infrastructure. The most frequent manipulative tasks are related to cyclic transport at loading and unloading of various materials and goods. For these reasons in this paper have been developed the mathematical model and software to determine the allowable capacity in desire number of coordinates of the working space of the machine.

ACKNOWLEDGEMENT

This paper is result of technological project No. TR35049, supported by Ministry of Education, Science and Technological Development of the Republic of Serbia

REFERENCES

[1] *Runaway of a road rail vehicle and the resulting collision in Queen Street High Level Tunnel*, Rail Accident Investigation Branch, Department for Transport, Glasgow, 2013.

[2] *http://www.hydrema.co.uk/,* the official website of the manufacturer Hyderma.

[3] *http://www.unac-france.com/* the official website of the manufacturer Unac.

[4] Janošević, D., *Projektovanje mobilnih mašina,* Faculty of Mechanical Engineering University of Niš, Niš, 2006.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

INVESTIGATING THE GROUND BASE ALONG A DEFORMED SECTION OF THE SILISTRA-ALFATAR RAILWAY (BULGARIA)

Vanushka PETROVA [1]
Zornitsa EVLOGIEVA [2]

Abstract *– The objective of this paper is to present the research carried out on a 200-m long deformed section along the Silistra-Alfatar railway in Bulgaria. The railway is built in the base of a slope in a shallow excavation-embankment. The geological section of the slope consists of dense Pliocene clay, covered by deluvial clays. The groundwater formed in the deluvium is moistening the embankment. As a result, it settles together with the ballast bed, provoking deformation of the railway. The ballast bed subsides periodically on the weak over-moistened embankment. The continuous settlements of ballast under the sleepers lead to ballast trough formation that causes swelling of the embankment slopes. Horizontal and vertical displacements appear along the railway line.*
The ground base of the railway consists of an inhomogeneous embankment, represented by three layers – E1, E2 and E3. Their deformation moduli are respectively E_0*<5, 12.6 and 10.8 MPa. The embankment bed is of dense Pliocene clay with* E_0*=23.4 MPa. The conclusion from the slope stability analyses of the embankment is that its slopes are in a limit equilibrium state. Sliding occurs along the slopes with increasing of their water content. The recommendations for stabilizing the deformed section are in two aspects – water-protective (drainage) and geotechnical.*

Keywords – railway, ground base, embankment deformation, ballast bed.

1. INTRODUCTION

The paper considers the results from engineering geological investigations carried out in 2008 along a deformed section of the Silistra-Alfatar railway line. The section is 200 m long. It is at a distance of 5 km to the southwest of the town of Silistra. The railway line passes in a shallow excavation-embankment, with maximum embankment thickness of 7.8 m.

Photo 1. General view of the railway section

The geotechnical explorations carried out have elucidated the engineering geological conditions and causes, leading to deformations along the railway line. They include boreholes, standard penetration tests (SPT) and dynamic penetration tests. The elaborated engineering geological map contains seven transverse profiles. The paper shows the stability analyses and one of the profiles as an illustration.

2. GEOLOGICAL AND GEOMORPHOLOGICAL CONDITIONS

The studied section is situated at the boundary of a broad valley and a gentle slope (Photo 1). The elevations of the terrain are between 66 m and 72 m. A gully formed in the slope crosses the railway. The water from this gully flows under the railway through a small culvert, which is insufficient to transfer the available water quantities. The terrain above the railway line has become boggy due to water retention.

The region of the railway is built of Lower Cretaceous rocks of the Ruse Formation and Neogene

[1] Vanushka PETROVA, Assistant Professor, PhD, Geological Institute – Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bl. 24, 1113 Sofia, Bulgaria, vanushka@gmail.com
[2] Zornitsa EVLOGIEVA, M.Sc., PhD Student, University of Transport, 158 Geo Milev Street, Sofia 1574, Bulgaria, zrukova@abv.bg

sediments of the Sarpovo, Aydemir and Brusartsi Formations [3]. The sediments of the Brusartsi Formation outcrop in the railway vicinity – dense Pliocene clays, locally with intervals of sand lenses. Deluvial Pleistocene clays with a thickness of up to 5 m lie on top of them. Since the Pliocene clay represents an aquitard, conditions for shallow landslide ruptures exist in the deluvial clay.

The excavation of the railway line reaches the Pliocene clays and the embankment is made of deluvial clays.

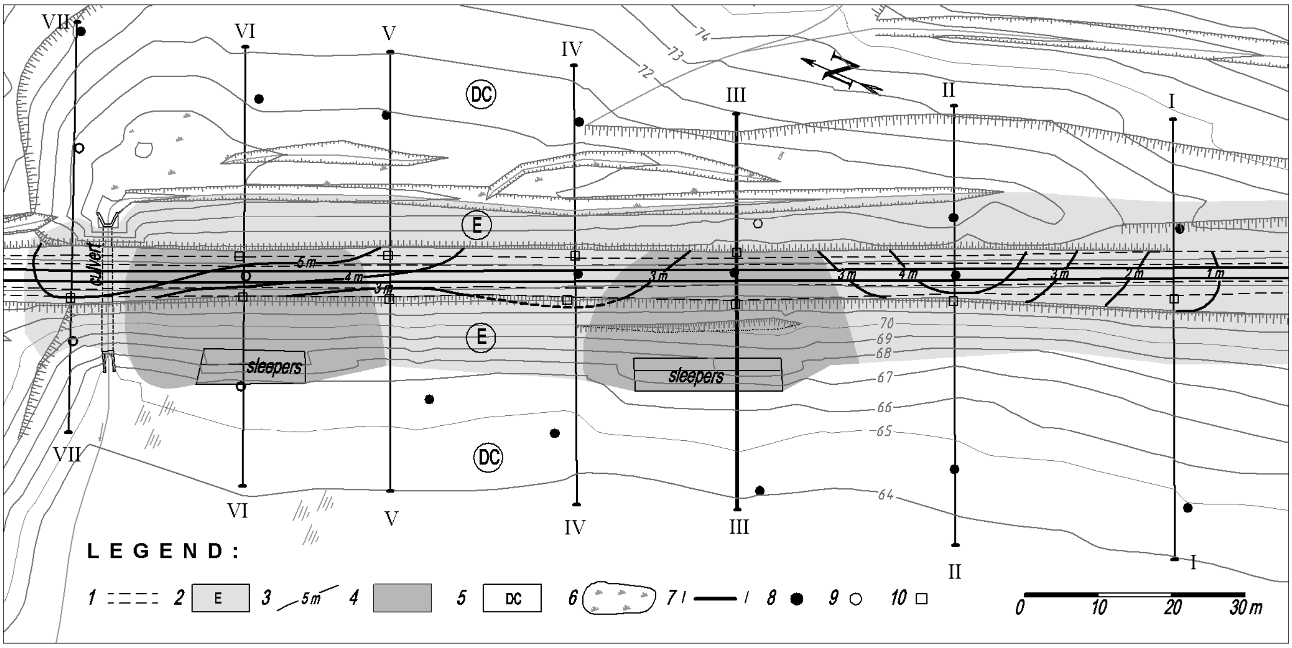


Fig. 1. Engineering geological map of the section.

1 – Contour of the ballast bed; 2 – Embankment; 3 – Thickness of the weak zone (Layer E1) with E_0<5 MPa; 4 – Subsection with swelling and sliding of the embankment slopes; 5 – Deluvial clay; 6 – Marshy-boggy terrain; 7 – Profile line; 8 – Motor borehole, 9 – Manually drilled borehole; 10 – Dynamic penetration

3. PROCESSES OF THE GEOLOGICAL HAZARD

The hazardous geological processes in the area are erosion, shallow groundwater, landslides and seismicity. The erosion is manifested in the unlined ditches in the slope base. The shallow groundwater from the slope is drained in small springs, forming marshy-boggy terrain. The water table is established in the embankment base and locally under the ballast bed. Landslides are formed along the slope, in the deluvium, but they do not affect the railway line.

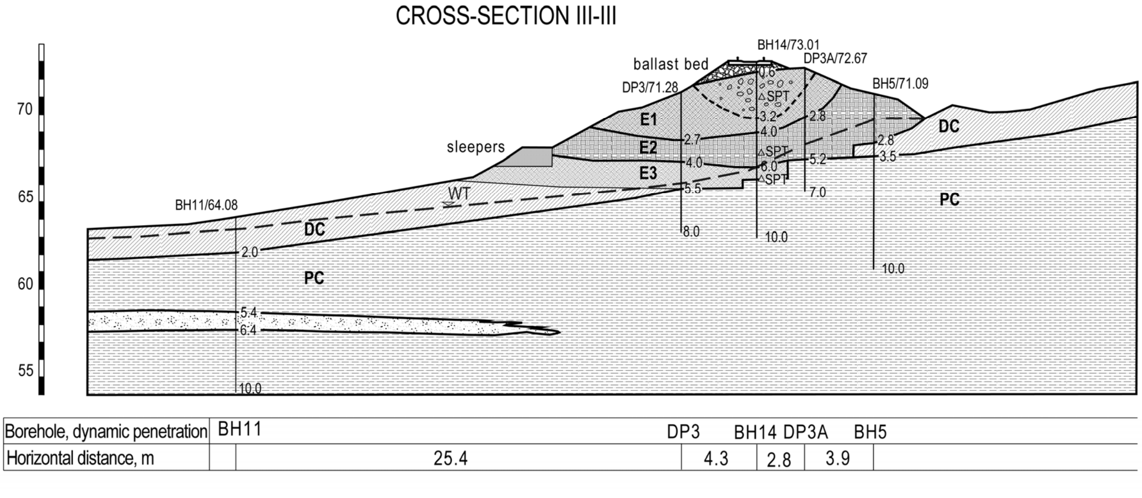


Fig. 2. Transverse profile III – III

E1 – Layer E1; E2 – Layer E2; E3 – Layer E3; DC – Deluvial clay; PC – Pliocene clay; BH11/64.08 – Borehole, elevation; DP3/71.28 – Dynamic penetration, elevation; WT – Water table; SPT – Standard penetration tests

The section is in the Vratsa seismic zone with seismic intensity of the VIII degree according to the MSK scale and seismic coefficent K_s=0.15 [2].

4. STATE OF THE EXPLORED SECTION

The ballast bed, built on the not well compacted embankment, subsides periodically into it. The embankment slopes are deformed due to over-moistening and swell and even slide down in the middle of the section in profile III-III (Fig. 1). This leads to horizontal and vertical displacements of the railway. The weak section is repeatedly stabilized by a retaining wall of sleepers and the line is tamped with residue quarry material with a gravelly sand size (Fig. 2). As a result of this frequent tamping the ballast bed thickness is increased to 2-3 m. Under the dynamic impacts the ballast bed sinks and slides and the embankment benches sag [4].

According to dynamic penetration test data for the embankment, a weak zone is established under the ballast bed (with deformation modulus E_0 lower than 5 MPa) (Fig. 1).

5. CHARACTERISTICS OF THE GROUND BASE

The investigation performed shows the existence of three engineering geological layers – embankment, deluvial clay and Pliocene clay. The embankment itself consists of three layers.

Layer E1 is situated immediately under the ballast bed. It is built of clay with small rock fragments with soft to firm consistency. Its thickness is from 1 to 5 m. According to penetration test data the plate modulus of total deformation is lower than 5 MPa (Table 1), typical for weak water saturated soils, representing a poor base for the ballast bed.

The ballast bed sinks into layer E1 to a maximum depth of 3.2 m in profile III-III.

Table 1. Average values of the physico-mechanical characteristics of the layers

Layer	Density	Dry density	Water content	Plasticity index	Shear strenght				Modulus of deformation	Bearing capacity
					peak		residual			
					Cohesion	Angle of internal friction	Cohesion	Angle of internal friction		
	ρ	ρ_d	w	Ic	c	φ	c_r	φ_r	E_0	R_d
	g/cm³	g/cm³	%	-	kPa	deg	kPa	deg	MPa	MPa
E1	1.97	1.57	25.1	0.75	19.8	8.3	9.2	5.8	< 5.0	0.10
E2	1.98	1.62	23.1	0.77	33.2	12.1	8.7	7.0	12.6	0.15
E3	1.99	1.60	24.7	0.67	36.6	13.2	17.1	10.7	10.8	0.18
DC	2.00	1.60	25.1	0.78	-	-	-	-	18.2	0.25
PC	2.05	1.66	23.3	0.91	30.0	19.5	-	-	23.4	0.28

Layer E2 is embedded under layer E1 with a thickness of up to 4 m. It is built of more homogeneous silty clay, locally with single rock fragments, with firm consistency (Ic=0.77).

Layer E3 is situated in the embankment base and is 1-2 m thick. It consists of dense silty clay with firm consistency.

The deluvial clay (DC) consists of reddish silty clay. It is outcropped only under the peripheral contours of the embankment. Under the railway line it has been removed within the range of the excavation. The embankment is built of this clay.

The embankment bed consists of *Pliocene clay (PC)*. It is represented by dense silty clay, variegated, with grey and rusty spots. According to the penetration tests it is with stiff to hard consistency and according to the laboratory data its consistency is stiff.

6. STABILITY ANALYSIS

6.1 Stability of the ground base

The ground base of the railway line under the ballast bed represents a weak inhomogeneous embankment with a thickness of up to 7.8 m. It contains clay, mixed with materials from the sunken ballast bed. It is with low bearing capacity, soft to firm consistency and modulus of total deformation less than 5 MPa. These data are extremely low for ground base of a railway. The existence of a ground base with low bearing capacity, subjected to dynamic impacts from the passing trains, leads to ballast sinking and formation of ballast troughs. In this case the compromised layer E1 should be rebuilt using suitable soil for embankment.

6.2 Stability of the embankment slopes

The calculations are made in two variants – one taking under consideration the peak shear strength values for all layers and another, using the residual strength for layer E1.

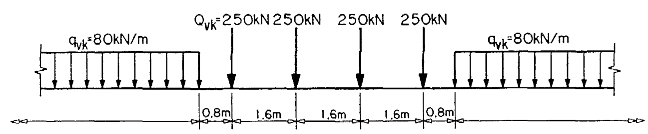


Fig. 3. The LM71 load model

The stability coefficient is calculated according to the method of Morgenstern-Price using the Geoslope software. The method takes into account the interlammellar shear and normal forces with smaller safety margin with respect to the stability coefficient compared to other methods [4]. The stability coefficient K_{st} is calculated for loads from own weight as well as for special loads (from rolling stock). The LM71 load model is applied (Fig. 3).

The stability calculations show that when using the peak shear strength values under operation conditions K_{st} is close but a bit lower than its admissible values (Table 2) assuming that the requirements of the Norms for Road Design in Bulgaria are valid.

Table 2. Results from the stability calculations for profile III-III

With peak values for **c** and **φ**		With residual values c_r and φ_r for layer E1 and with peak values **c** and **φ** for the other layers	
for basic loads	for operation condition	for basic loads	for operation condition
1.989	1.214	1.258	0.671

The calculations with residual values for the shear resistance of layer E1 yield values of K_{st}=1.258 without the impact of the passing trains and K_{st}=0.671, taking into account the loads from the moving rolling stock.

The conclusion from the stability analyses of the embankment slopes is that they are in a limit state and sliding may occur if the water content in layer E1 is increased, as actually was the case in 2005.

7. CONCLUSION

The explored 200-m section along the Silistra-Alfatar railway, Bulgaria, is affected by the following deformations: sinking of the ballast bed and the weak embankment, formation of ballast troughs, swelling and sliding of the embankment slopes.

The formation of troughs with concave lower surface creates the conditions for water retention under the ballast bed in the so-called "pockets" in the upper part of the embankment. This leads to the manifestation of plastic deformations in the uppermost layer E1. According to penetration test data this layer represents a weak zone with deformation modulus E_0 lower than 5 MPa and soft to firm consistency.

Sliding along the slopes is observed in profile III and the ballast bed sinking reaches up to 3.2 m.

The following measures are recommended for the safe functioning of the railway line in the considered section:

1. Water-protective:

- Construction of a trench-type drainage above the railway line preventing the access of groundwater from the slope into the ground base. The drainage should penetrate in the PC layer;

- Construction of new lined ditches and if necessary – of another culvert, with well organized vertical planning.

2. Geotechnical:

- Replacement of the weak part of the embankment (layer E1) with compacted soil, reinforced with geosynthetic materials;

- Construction of a light-type retaining wall (gabions with crushed stone) in the embankment foot in the zones with sagged benches (profile III) to replace the stabilization with sleepers;

- Establishment of a permanent geodetic monitoring network to follow the state of the section after the completion of the drainage, stabiliztion works and vertical planning.

REFERENCES

[1] Filipov, L., Cheshitev, G., Map sheet Tutrakan and Silistra. – In: Explanatory Note of the Geological Map of Bulgaria in scale 1:100 000. Committee on Geology, Sofia, 1992.

[2] Iliev, I. (Ed.) The Geological Hazard in Bulgaria. Explanatory Note of Map in scale 1:500 000. Publ. House of BAS, Sofia, 1994.

[3] Evlogiev, Y. The Pleistocene and Holocene in the Danube Plain. D.Sc. thesis, Sofia, 2006.

[4] Geotechnical Research Station of GI-BAS. Report on the Engineering geological exploration of a deformed section from km 105+200 to km 105+400 along the Silistra-Alfatar railway line. Archive of GRS, Ruse, 2008.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

A PROPOSAL OF LED MODULE DESIGN IN RAILWAY SIGNALS

Ranko BABIĆ [1]

***Abstract** – LED technology continues rapidly to spread out in the area of railway traffic signals as a consequence of unquestionable superiority of LEDs as light sources. There are several configurations of LED based railway signals. The Introduction of this paper accounts conventional configurations of railway signals with light bulbs and discusses its main properties (to reveal weaknesses). Next, we cosider properties of LEDs relevant for railway signals which is followed by a survey of current configurations of LED signals, including its reviews, particularly panel LED signals. Consenquently, a new design of the LED module is proposed where the necessary light output is attained by Cassegrian optical system but with two instead of one subreflector and by only two opposite high power LEDs which also provide exploitation reliability .*

Keywords – Railway traffic signal, LED, Cassegrian optical system, Reflector system, Energy effectiveness, Radiation diagram, Reliability.

1. LIGHT SOURCES AND OPTICS IN RAILWAY SIGNALS

1.1 Incandescent bulbs

Railway signals are of vital importance for transport security. Stringent regulations prescribe specifications of signals in all national railways [1,2]. Signals need uninterruptible power supply, as a combination of power from electrical grid and battery bank. Therefore, bulbs for classical signal lights are designed to run at low voltage to achieve long battery time span [2] (effective AC voltage 8, 10 or 12V, wattage 12–25W, [3,4]) as opposed to traffic lights (70–150W bulb running on 120V AC powered by the electrical grid) [5].

Low wattage of incandescent bulb and the need to provide conspicuous signal at sufficient range (dependant on train speed) lead to the use of more effective optical systems which concentrate available small optical power into a narrow beam of light.

There are several optical systems of the sort which can produce very bright, searchlight-like beam: (a) parabolic mirror with the bulb filament at the focal point, (b) collimator lens, (c) double Fresnell lens system, (d) combined reflector-lens system [6,7,8].

Since the incandescent bulb produces white light, each of these systems contains a glass filtar for getting a proper signal color. Much of research and inventive work has been done regarding designs of railway signal lights (e.g. [9]).

Such a narrow beam (e.g. 2^o–10^o [6]) is aimed in a direction which has to cover the mean approaching trajectory of train driver head. In other words, there are many exact trajectories forming a random ensemble which samples are situated closely arround the mean one, since the ensemble disperssion is small because of small variations in height of locomotives and driver positions, contrary to corresponding variations in road traffic.

Narrow beam imposes complex exploitation and maintenance, affected by temperature, vibration, wind, collisions with the posts, cleaning procedures, etc. The structure of the railway light also has to be very rigid, since a tilt of a few degrees will throw off the alignment of the signal beam [2]. Most bulbs have a pre-focused filament, which means no need for signal re-alignment each time after bulb replacement.

Filament (small) length and (horizontal) orientation take its part in signal light pattern, mainly determined by the optical system.

Main drawback of all these four optical systems is the glass lens and the glass colour filter where light absorption and Fresnell reflection takes place, and further reduce already low emitted optical power from the bulb. Signal unit cost can be reduced by replacing e.g. borosilicate glass elements with cheaper but high quality optical plastics, such as polyacrylates or polycarbonates [10].

Optical power losses are particularly prominent in the system (c) where only about 15% of radiated light is focused into a signal beam and the rest is absorbed by black painted interior of signal housing [8] or simply trapped behind the aperture [11]. Instead of one, two lenses are applied in order to increase flux capture from the bulb [7].

[1] Ranko BABIĆ, VŽŠSS Beograd, Zdravka Čelara 14, FTN K.Mitrovica, babic57@open.telekom.rs

Incandescent bulbs convert less than 5% of the electric energy into visible light, the rest is converted into heat.

Among possible factors influencing signal appearance [2] we will consider only the phantom or false signals. Combination of reflector and colored glass filtar in signal optical system may give the appearance that the signal is switched on - produce a false signal under the sunlight or train headlight shining into a signal. This may produce confusion for the train driver unless the luminous intensity of the real light signal is considerably greater than the intensity of any false signal. Recommendations on the acceptable minimum ratio of the intensities of the real and false signals vary from 12:1 [12] to 15:1. Simple external cowls (visors) and adequate beam intensity appear to be the solution for sunlight. As for train headlight it is evident that the signal brightness varies with the distance as we estimated from light pattern of modern locomotive headlight, which main intensity of the beam is within 4^{o}R and 6^{o}L [13].

1.2 LED properties

Light emitting diodes (LEDs) represent a reliable, rugged, cost-effective etc. lighting technology for many applications [14]. Rapid growth of the global LED lighting market is evident [15].

Incandescent bulbs produce about 15–20lm/W (of electrical power consumed). Once a red filter is added, about two-thirds of the light is filtered out. Just for that reason, red LED is at least three times more efficient than incandescent bulb. Furthermore, the red light produced is 'purer' and more penetrating (effective width of emission spectrum at 50% of peak intensity: LED's ~25nm versus 250nm of a red filter) [2].

Typical values of CFLs (compact fluorescent lamp) efficacy is roughly 65lm/W and up to 85lm/W for LEDs. LED packages could reach even more – a couple of hundreds lm/W but that value includes driver, thermal, and optical losses. It is also necessary to understand the different procedures and conditions used for measuring conventional and LED products, as well as the difference between commercially available products and laboratory samples [16].

Here one should mention application efficacy, defined as the power draw necessary to achieve specified illuminance criteria, for a specific application. If a luminaire directs a greater percentage of light to the target area – along the railway, for example – it may have a higher application efficacy despite having a lower luminaire efficacy [16].

The mean time between failure (MTBF) for LEDs depends on ambient temperature and for an AlInGaP LED (laboratory accelerated measurement) ranges from 6,599,000 (35^{o}C) to 1,220,000 (75^{o}C) hours [2]. LEDs are powered by electronic drive circuitry (>80% efficiency) [14] which is the weakest link in the whole LED lighting system regarding durability (Fig. 9 in [2] showing durability of electronic driver, LED itself and solder connection).

As opposed to incandescent lights, today's LED technology is less efficient at high temperatures - the decrease in light output with increasing temperature is significant – nearly 1% for each degree of temperature above 20°C. Specifications for LED signal lights need to ensure the light output is maintained over the temperatures likely to be encountered in real operation.

Incandescent bulbs did not have particularly long life spans, and did not vary much with temperature. LED lights have very long life, and do have significant temperature issues. For this reason, it is important to specify end-of-life requirements and temperature range performance for LED signal modules. Real life spans of LED systems are about 30,000 to 50,000 hours. In other words, one LED headlight can out-live 300 incandescent or 50 halogen headlights [14].

Being solid-state, LEDs are much more durable than fragile incandescent bulbs and are perfect to withstand vibrations and shocks.

With no filaments and no moving parts LED systems have the lowest maintenance costs of any lighting technology and this feature prevails in their cost effectiveness.

The LED far-field emission pattern can be shaped in various ways by primary and secondary optics. Common patterns include Lambertian, isotropic and collimated attained by geometry of the LED epoxy housing shaped as planar, hemispherical and parabolic lens, respectively, representing primary LED optics (e.g. [17]).

More electric current through LED means more light but also more dissipated heat in LED chip which must be cooled to preserve attained light efficacy. Therefore, packages of high power LEDs are configured mainly to provide good dissipated heat drainage.

Indicator-type GaAsP LEDs are limited to a dissipation of 100mW or less by their design. Their epoxy encapsulant cannot withstand temperatures above 120° C, and the wire leads cannot dissipate the excess heat generated by the chip. High power LEDs are of different heat sink concept (Lumileds) and must have quite different heat sinks (Luxeon) which enable driving currents up to 140 A/cm^2 (for red-orange-amber AlInGaP chip) [18].

One could say that the brightness is a matter of heat sink and efficient cooling. In an extreme example, a 30W white LED, given in [19], 3x10 LED chips are disposed on a circle area of 30mm diameter.

LED's output spectrum also changes with temperature: the central wavelength and its peak [20,21,22]. Cooling properties can be further improved by pulsed drive current (with e.g. 10% duty cycle), quite impossible to apply on incandescent bulbs

Star PCB (printed circuit board) package of RGB or white high-powered PC (phosphorus converted) LEDs provides particular contacts for different drive currents needed for R, G and B LED. The same three R LED chips in a package will give super red LEDs [23].

2. LED TECHNOLOGY IN RAILWAY SIGNALS

Technology (principles) underlying railway signals and headlights are quite similar. Cheap and easy mountable TH (through the hole) LEDs do not possess adequate luminance to attain necessary brightness. Therefore, arrangements of such LEDs are simply formed over the panel of signal light where the number of LEDs varies from 50 to 300 (and even up to 600 [2]), depending on the manufacturer and signal purpose (e.g. main red signal with 84 LEDs on a 125 mm panel, beam angle 5^o H/V at 50 % peak intensity [24], or with 300 LEDs for road traffic lights [25]). Another configuration also relyes on 19 (pole type signal) or 7 (ground type signal) high power LEDs but optically empowered by secondary optics [26]. Similar solution contains 88-132 LEDs on a panel each with small reflector arranged in the form of honey-comb. It is interesting to compare red LED signal power (18 and 15 W) with visibility distance (600 and 1500 m), number of LEDs (132 and 88) and beam angle at 50% of peak ($\pm 9^o$ and $\pm 6{,}5^o$) [27].

Light generated in LED chip can be shaped in various, application dependant radiation patterns by primary and secondary optics [28]. Primary optics is incorporated in LED epoxy housing – acting as the lens [29]. There are several typical housing shapes, providing typical light patterns (Lambertian, hemispherical, batwing etc.).

Step shaping of ordinary through hole LED lens could provide much narrow beam [30].

High-power LED is structurally similar but constructively different, mainly in respect to heat sink and are surface mount devices (SMD), also referred to as emitters.

Secondary optics, attached on SMD LED, can be (mini)lens or reflector or a combination of both, shaped to produce necessary radiation pattern [31–35].

There are also other optical systems for attaining desired emission light pattern [36]. Similar considerations can also be applied to locomotive headlights [13].

3. LED SIGNAL MODULE WITH DOUBLE SUBMIRROR CASSEGRAIN REFLECTOR

Existing railway signals usually use about a hundred of TH LEDs or several (typically 1+6) HP LEDs to provide prescribed brightnes. In the first case the monolithic LED package optics determines radiation diagram while in the second case a combination of mini reflectors and mini lenses concentrace emiter light into a beam [25, 26].

Very instructive comparative analysis of incandescent and LED railway signal can be found in [37].

The intention of this paper is to acomplish bright beam by using a minimum number of LEDs, but to preserve reliability, to attain temperature stability of LED emiter, to avoid passing light through additional optical plastic parts of a system in order to minimize losses, to provide easy adjustemet of beam pattern according to signal purpose and operation distance.

To reach such goals we based optical system of the signal on parabolic reflector type [38]. Instead of one HP LED of about 5W emission power placed in the focus of such reflector we have chosen Cassegrain structure of signal module but with two opposite subreflectors instead of one, as it is usual in this configuration. Such a solution enables use of two HP LEDs which restrains problem of high driving current in only one LED and brings better temeperature (dissipation) conditions of LED chips. Two LEDs also give a reserve of light resources and not strain one LED to its extremal output. The second LED also could take a role of beckup light source which improves the system reliability, which is parallel to incandescent bulbs with two filaments.

The proposed solution is presented on Fig.1 where an assemblage of all these elements can be seen. Subreflector of this Cassegrain configuration is composed of two opposite mirrors: hyperbolic (SM_1), which focus F_2 coincides with the focus of the main reflector M, and conical (SM_2). The (HP LED) D_1 is placed on its cooler C_1 and over the submirror SM_1.illuminates the central part of the surface of the main reflector M_1. The radiation pattern of D_1 matches the apperture of SM_1. Another HP LED, labelled by D_2, is placed in front of M, and also resides on its cooler C_2. Over submirror SM_2 it illuminates the rest of the surface of M_1.

Coolers C_1 and C_2 are outside the signal unit and are fully exposed to fresh air.

To harmonise illumination from the two opposite sources on the same reflector, its edge is slightly broaden into a mirror M_1. The presented solution is only a conceptual one, and is subject to refinement and optimisation, first of all the curve and diameter of SM_1.

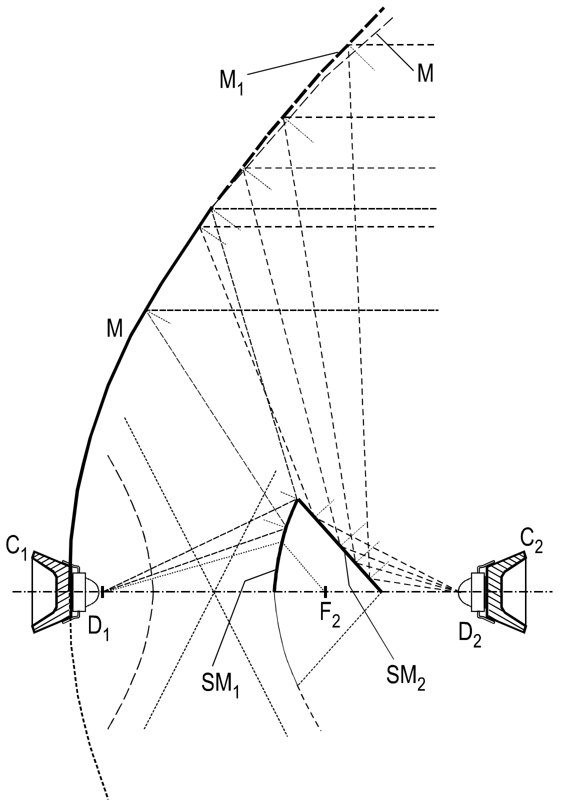


Fig.1 Optical system geometry of railway signal module with Cassegrain configuration which comprises two opposite submirrors.

Mechanical supports and housings of submirrors and LEDs are not shown in Fig.1. Submodule D_2-C_2 is adjustable to provide different radiation patterns for specific signal purpose.

This solution does not suffer from phantom signals since it does not comprise any color filter which would change the color of outer passing through light. All what a train driver would see is a weak (tiny) white reflection.

4. CONCLUSION

The goal of this paper is to attain maximum luminosity with minimum power by an optical system which collects whole avaliable emited light into a narrow beam. It is different from existing solutions for railway signals, with many LEDs on a panels and with several LEDs, each opticaly empowered by mini refelecor and lens. Cassegrain oprical system is a very promising cofiguration for such intention. The imrovement is a double subreflector which involves two opposite mirrors and enables the use of two LEDs instead of only one. In that way sufficient optical power is available to attain desired signal beam luminosity. Various signal radiation patterns, necessary for signal purpose, are attained by adjustable positioning of the submodule D_2-C_2. The proposed module is cost effective since its fabrication is based on mass production, polymer plastics moulding, chemical vapor deposition methods for reflective mirror surfaces.

As opposed to incandescent reflector railway signals which suffer from phantom signals because of collor filters, the proposed solution overrides this problem. The proposed soltion is a starting point for further research but can be very quickly brought to industrial application level.

REFERENCES

[1] http://www.damarww.com/subcategory.asp?sub=114
[2] D. Green, M. Milanovic, *LED Technology for Improved Conspicuity of Signal Lights at Highway-Railway Grade Crossings*, Carmanah Technologies Inc., Victoria, BC, February 2003
[3] http://amglo.com/10_volt_10%20watt_18_watt_or_25_watt_lamps_for_wayside_signals_crossing_signals
[4] http://www.osram.com/osram_com/products/lamps/specialty-lamps/lamps-for-traffic-signalling-equipment/low-voltage-over-pressure-dual-coil-lamps%2c-railway/index.jsp?productId=ZMP_60687
[5] http://www.damarww.com/subcategory.asp?sub=114
[6] R. Krstić, Železnička SS i TK postrojenja, Grafika, Beograd 1994.
[7] М.И.Вахнин и др., Автоматика и телемеханика на перегонах, ГТЖИ, Москва 1957.
[8] http://www.railroadsignals.us/signals/color/
[9] US 4152756 A (Railroad crossing signal lamp)
[10] F. Languy et al., Flat Fresnel doublets made of PMMA and PC: combining low cost production and very high concentration ratio for CPV, Optics Express, Vol. 19, Issue S3, pp. A280-A294 (2011), at http://www.opticsinfobase.org/oe/fulltext.cfm?uri=oe-19-S3-A280&id=211677
[11] http://www.navpooh.com/sigpics.html
[12] A. Fisher, A Photometric Specification for Vehicular Traffic Signal Lanterns, Part 3:The Necessary Limitation of Sun Phantom. Department of Motor Transport, New South Wales, 1971
[13] http://www.jwspeaker.com/products/headlights/model-8770-7-round-par-56-led-locomotive-headlight
[14] http://issuu.com/jwspeaker/docs/10reasons?e=0/4111013#search
[15] http://www.ledsmagazine.com/articles/2011/08/mckinsey-releases-lighting-market-report.html
[16] http://energy.gov/sites/prod/files/2014/04/f14/led_energy_efficiency.pdf
[17] http://www.digikey.com/en-US/articles/techzone/2011/may/optical-considerations-for-bridgelux-led-arrays
[18] http://www.bluehaze.com.au/modlight/Luxeon.htm; http://www.philipslumileds.com/ uploads/273/DS12-pdf; http://www.luxeonstar.com/assets/downloads/DS25.pdf ; http://www.luxeonstar.com/lxhl-pd09-red-luxeon-iii-emitter-led-140lm; http://www.farnell.com/ datasheets/38512.pdf
[19] http://www.superbrightleds.com/moreinfo/high-powered/30w-white-high-power-planar-cob-led/1255/
(For the rest of reference list contact the author)

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

APLICATIONS OF FBG SENSOR SYSTEM FOR TRAIN AXLE COUNTING IN RAILWAY

Ivan STANKOVIĆ [1]
Nenad T. PAVLOVIĆ [2]

Abstract *– Fiber Bragg grating (FBG) sensors are finding increasing applications in smart structures. They can be embedded in civil structures such as bridges, buildings, etc. It can be used for the detection and monitoring of parameters such as strain, pressure and temperature. It allows assessments on the integrity of structures at various manufacturing and construction stages, and facilitates health management of many important structures in their subsequent operations. However, their application in railway engineering is rare. This paper presents a review of the novel optical fiber sensor signaling system which contains the sensor operation, field setup and axle detection solution set. Railway signaling facilitates two main functions, namely, train detection and train control, in order to maintain safe separations among the trains. Subsequent adoption of axle counters further allows the detection of trains under adverse track conditions. However, with electrification and power electronics traction drive systems, aggravated by the electromagnetic interference in the vicinity of the signaling system, railway engineers often find unstable or even faulty operations of track circuits and axle counting systems, which inevitably jeopardizes the safe operation of trains. A new means of train detection, which is completely free from electromagnetic interference, is therefore required for the modern railway signaling system.*

Keywords – Axle counting, Fiber Bragg Grating (FBG), railway, train detection.

1. INTRODUCTION

Railway engineers are understandably very conservative in the use of any new technology for train operations. Only proven technology with good track record will be used. Any change to the conventional equipment and methodology must be brought-in under a technically and commercially prudent manner. Fiber Bragg grating (FBG) technology has been widely adopted in smart structure engineering with good records. Its application on railway engineering is limited at this stage, although there are applications in, for example, the monitoring of the strain/stress on the train bogie frame composite structure [1]. An in-depth review on the FBG characteristic revealed that it can bring massive benefits to railway operation by giving additional train operational information to rolling stock engineers and signaling engineers in the monitoring and planning of the train traffic. One of its possible applications is on the railway axle counter in tracks. Due to its unique construction nature, the cost of FBG axle counter is relatively low when compared with those of conventional technologies that are used to provide the same technical and operational information. There is a good future in using FBG axle counter to operate a smart railway service.

2. AXLE COUNTER

Each axle counter consists of literally a pair of electromagnetic coils mounted on either side of the rail head as shown in Fig. 1, one being the transmitter and the other the receiver.

Fig.1. Axle counter consists of two pairs of transmitter and receiver [2]

[1] Ivan STANKOVIĆ, University of Niš, Faculty of Mechanical Engineering, stankovic.s.ivan@gmail.com
[2] Nenad T. PAVLOVIĆ, University of Niš, Faculty of Mechanical Engineering, nenadtp@gmail.com

A magnetic field is established between the two coils. When a train wheel is running on the rail and between the coils, the magnetic field is so distorted that the induced voltage on the receiving coil changes direction, which registers the passage of one wheel. Two sets of axle counters are installed at the two ends of a signaling block; and a comparison of wheel passage count of the two axle counters verifies whether there is train occupancy in the block or whether the train has moved away from the block [3], [4]. However, as the operation hinges on the delicate changes of magnetic field, EMI remains to be a genuine concern for the reliable operation of axle counters.

This study presents a review of an innovative and EMI-free approach of axle counting, a fiber Bragg grating (FBG) sensor system, for the detection of train wheel passage. The purpose of the described system is to enhance the accuracy and reliability of train detection and hence provide the signaling system with better safety assurance.

3. FBG SENSORS

FBG sensor is an in-fiber narrowband reflective optical filter resulted from periodical variation of refractive index inside the core of optical fiber. A conventional way to fabricate a FBG sensor is to illuminate a short section of optical fiber by ultraviolet laser source under a phase mask, the periodical pattern of the mask is photo-imprinted onto the optical fiber by modulating the refractive index of the fiber core. The Bragg wavelength λ_B of FBG sensor written in single-mode optical fiber is given below [5]

$$\lambda_B = 2n\Lambda \tag{1}$$

where n is the effective refractive index of the fiber core and Λ is the period of the refractive index modulation. Fig.2. and Fig.3. illustrate an FBG sensor and its spectral characteristics. When a broadband light source is passed onto a sensor, a narrowband optical spectrum centered at λ_B is reflected while others pass through. Mechanical and thermal perturbations alter the modulation pitch as well as refractive index of the FBG and hence λ_B. By measuring the wavelength change of the FBG sensor, these perturbations can be determined. Typical wavelength changes of FBG written in standard single-mode fiber at 1550 nm region due to mechanical strain and temperature variation are ~1 pm/$\mu\varepsilon$ and ~11 pm/°C, respectively. Because of its compact size, low optical loss, self-referencing, and wavelength multiplexing capability, FBG sensors have been widely applied in a wide range of condition monitoring applications [6] – [10].

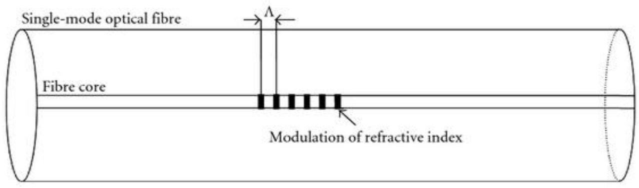


Fig.2. Illustration of an FBG sensor [11]

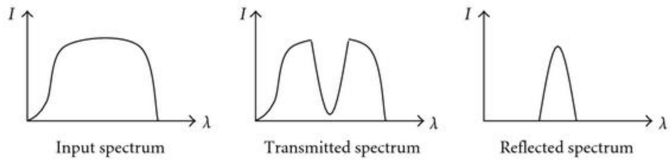


Fig.3. The spectral response of FBG sensor [11]

An interrogator is employed to measure the wavelength of FBG sensor array. Fig.4. shows a simplified schematic of a typical FBG interrogator.

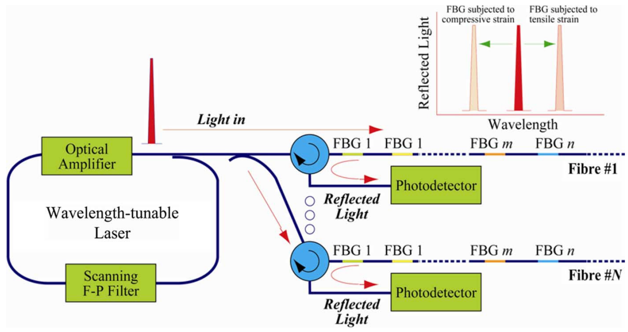


Fig.4. Block diagram of an FBG interrogator [2]

To produce a wavelength tunable optical source with high output power for accurate wavelength measurement, scanning ring laser consists of an optical amplifier and a tunable narrowband Fabry-Perot filter in a ring cavity configuration is employed, the laser scans the FBG sensor array periodically and the signal reflected from the FBG sensors is directed to the photodetector through an optical circulator. The photodetector performs optical to electrical domain conversion, any peak in the converted electric signal reflects the existence of an FBG and the wavelength of the FBG can be retrieved by the timing of scanning signal. Commercially available interrogators usually have four measurement channels with a wavelength measuring range of ~80 nm, depending on the spectral occupancy of the FBG sensors in the array. Up to 40 serially connected FBG sensors (assuming 1 nm measuring range with 0.5 nm guard-band at both longer and shorter wavelength sides) can be measured simultaneously at a maximum sampling rate of 2 kHz by a single measurement channel. In this study review, a four-channel interrogator with a sampling rate of 1 kHz is used.

3.1 Applications

FBG sensors have been widely used to measure temperature and strain in various engineering applications, such as oil refineries and civil infrastructures, because of their electromagnetic immunity, low loss, and multiplexing capability [6], [10], [12]. Moreover, coupled with suitable transducers, the FBG sensors can also be employed to measure other parameters, such as pressure, and displacement.

FBG sensors have also been increasingly employed in the rail way industry in recent years. Successful applications of FBG sensors for train speed measurement, train load estimation, de-railment detection, wheel-defect detection, rail crack detection, strain monitoring of train structures and bogie health monitoring have been reported [13]–[16]. FBG sensing systems indeed have good potentials to become the future technology for railway applications.

4. AXLE COUNTING BY FIBER BRAGG GRATING SENSORS

Axle counting by FBG sensors is based on measuring the strain changes in the rail upon the passage of trains at the measurement points. When a train is running on a measurement point, the rail in the vicinity is momentarily deformed, i.e., the rail head is in compression while the rail foot is in tension, due to the shear weight of the train. FBG sensors installed on rail therefore measure the strain change of the deformed rails. It is expected that a conspicuous and distinctive peak can be identified in the strain change signals measured by the FBG sensors when a train wheel is pressing on the rail in the vicinity of the measurement point.

4.1 Site Test Arrangement

Eight FBG sensors were fabricated and glued onto the rail beam as shown in Fig. 5.

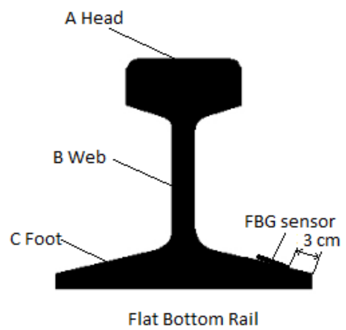


Fig.5. FBG sensor on rail [14]

The weight of the Electro-multiple Units (EMUs), i.e. the trains, would create both tensile strain and stress on the rail beam. The corresponding changes in Λ thus resulted can be detected by attaching FBG sensors on the neutral plane, the FBG could be used to measure the ambient temperature of the rail beam. Practically, changes in the FBG grating Λ sensed would be presented as changes in λ and hence, according to the principle, the weight of the EMU will trigger a shape change in wavelength ($\Delta\lambda$). Once it is captured, it will represent the presence of an axle that is entering into a given section of the rail track. Eight FBG sensors were fabricated and glued onto the rail beam at rail station. The layout of the sensors are as shown below in Fig.6.

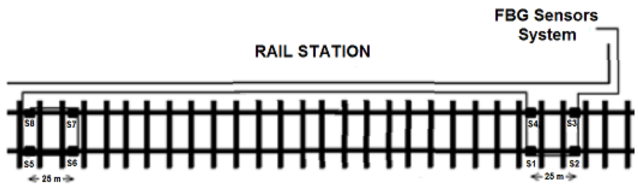


Fig.6. FBG sensors layout at railway station [14]

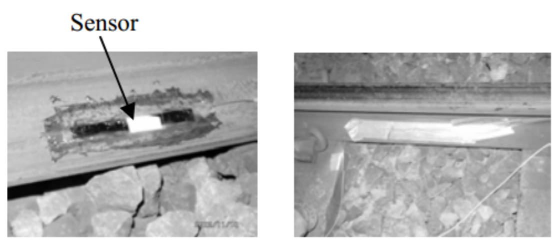
The eight FBG sensors were located at the entrance and exit of the station. Their spacings were in line with the bogies and axles distances of the passenger coach. The wavelength of these sensors was shown in the table below [14].

Tab. 1. Wavelength of FBG sensors

FBG SENSOR	Wavelength (nm)
1	1536.7
2	1544.4
3	1562.3
4	1539.91
5	1546.81
6	1549.72
7	1555.2
8	1558.19

The range of lightwave's wavelength of the FBG sensor is set within 1530nm – 1570nm in accordance to the specifications of the optical interrogation system being used.

The photos in Fig.7. indicate how the sensors were glued onto the rail.



Glue on the rail Finished

Fig.7. FBG sensors at Rail Station [14]

Optical sensor interrogator and portable computer were used to record the data. The optical fiber sensors were connected in series and fed into the input port of the interrogator. The block diagram of the complete set up for measurement is shown in Fig.8. Data obtained were then transferred to the computer for recording purpose. Results are presented in terms of continuous waveform, showing the weight of the train passing all the sensors.

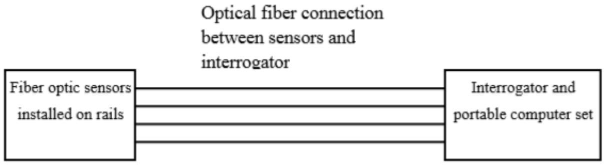


Fig.8. Block diagram showing the complete set up for the Measurement [14]

5. TRAIN SPEED DETECTION USING FBG AXLE COUNTER

By placing FBG gratings suitable along a short length of track, one can detect the timing when the axle passes through them and one can calculate the train speeds as shown in Fig.9., which is another important data in checking the running profile of the train along the entire section of track.

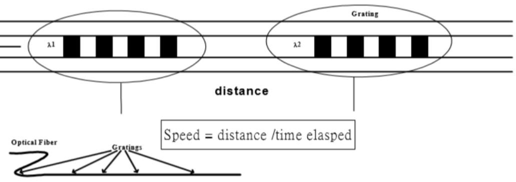


Fig.9. Speed Detection [14]

6. CONCLUSIONS

In this paper basic operating principles of Fiber Bragg Grating (FBG) sensors, and its axle counting in railway are shown. The FBG system could be tailor-made for the following railway applications including: counting the numbers of axles in and out of a given section, train identification by tracking the differences of axle bases, weights and car numbers of various train stocks, speed detection. In essence, a small piece of FBG sensor can generate lots of train running information with good data integrity. It can be applied to monitor the train running pattern of the railway by building a virtual signal system on top of the conventional one as a standby system. A smart railway can be constructed based on fiber Bragg grating (FBG) axle counter. The FBG axle counter will become a strong competitor to conventional systems. Once the physical integrity of FBG systems is proven to be satisfactorily, one can extend its application to build a smart railway, particularly as part of a new generation of signalling systems.

REFERENCES

[1] L. Maurin, J. Boussoir, S. Rougeault, M. Bugaud, P. Ferdinand, A.G. Landrot, Y.-H. Grunevald, T. Chauvin, *FBG-based smart composite bogies for railway applications*, Optical Fiber Sensors Conference Technical Digest, 91 - 94 vol.1, 2002.

[2] C. Lai, S. Liu, W.H. Chung, T.K. Ho, H. Tam, S.L. Ho, A. McCusker, J. Kam, K.Y. Lee, *A Fiber Bragg Grating Sensor System for Train Axle Counting*, IEEE SENSORS JOURNAL, vol.10, no.12, 2010.

[3] I. Lucic, *Holistic safety performance forecasting for train detection system*, IEEE Int. Conf. System, Man and Cybern., vol. 3, pp. 2973–2978, 2005.

[4] P. R. Goundan and A. Jhunjhunwala, *Axle counter based block signaling for safe and effcient train operations*, IEEE Veh. Tech. Conf, vol. 2, 1999.

[5] A. D. Kersey, M. A. Davis, H. J. Patrick, *Fiber grating sensors*, Journal of Lightwave Technology, vol. 15, no. 8, pp. 1442–1462, 1997.

[6] T. H. T. Chan, L. Yu, H. Y. Tam, *Fiber Bragg grating sensors for structural health monitoring of Tsing Ma bridge: background and experimental observation*, Engineering Structures, vol.28, no.5,pp. 648–659, 2006.

[7] E. J. Friebele, C. G. Askins, A. B. Bosse, *Optical fiber sensors for spacecraft applications*, Smart Materials and Structures, vol. 8, no. 6, pp. 813–838, 1999.

[8] N. E. Fisher, J. Surowiec, D. J. Webb, *In-fibre Bragg gratings for ultrasonic medical applications*, Measurement Science and Technology, vol. 8, no. 10, pp. 1050–1054, 1997.

[9] B. O. Guan, H. Y. Tam, and S. Y. Liu, *Temperature-independent fiber Bragg grating tilt sensor*, IEEE Photonics Technology Letters, vol.16, no.1, 2004.

[10] Y. J. Rao, *Recent progress in applications of in-fibre Bragg grating sensors*, Optics and Lasers in Engineering, vol. 31, no. 4, pp. 297–324, 1999.

[11] C. Wei, Q. Xin, W. H. Chung, S. Liu, H. Tam, and S. L. Ho, *Real-Time Train Wheel Condition Monitoring by Fiber Bragg Grating Sensors*, Int. Journal of Dist. Sensor Networks vol. 2012, 2012.

[12] P. Ferdinand, S. Magne, V. Dewynter-Marty, C. Martinez, S. Rougeault, and M. Bugaud, *Applications of Bragg grating sensors*, in Eur. Opt. Soc. Amer. Tech. Dig., vol. 16, pp. 14–19, 1997.

[13] H. Y. Tam, S. Y. Liu, B. O. Guan, W. H. Chung, T. H. Chan, and L. K. Cheng, *Fiber Bragg grating sensors for structural and railway applications*, Adv. Sens. Syst. Appl. II, pp. 85–97, 2004.

[14] K. Y. Lee, K. K. Lee, and S. L. Ho, *Exploration of using FBG sensor for axle counter in railway engineering*, WSEAS Trans. Syst., vol. 3, no. 6, pp. 2440–2447, 2004.

[15] K. Y. Lee, K. K. Lee, and S. L. Ho, *Exploration of using FBG sensor for derailment detector*, WSEAS Trans. Syst., vol. 3, no. 6, pp. 2433–2439, 2004.

[16] H. Y. Tam, S. Y. Liu, W. H. Chung, T. K. Ho, S. L. Ho, and K. K. Lee, *Smart railway sensor network using FBG sensors as sensing elements*, in Adv. Smart Materials and Smart Structures Tech., vol.1, 2005.

Poster presentations

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

TESTING OF THE DYNAMICAL BEHAVIOUR IN RUNNING CONDITION OF THE NEW DMU FOR THE SERBIAN RAILWAYS

Milutin KRIVOKAPIĆ [1]
Marija VUKŠIĆ-POPOVIĆ [2]
Saša RADULOVIĆ [3]
Borisav BOGDANOVIĆ [4]

Abstract *– In this paper a short review of testing of the running safety and dynamical behaviour of new DMU series 711, manufactured by ''METROWAGONMASCH''Russia, for Serbian Railways (ŽS) is shown. This test is performed by "Institute Kirilo Savić"from Belgrade for approval of this DMU for Serbian rolling stock. Testing was done according to chapter 5 of the European standard: EN 14363 at the Serbian lines in frame of type testing of this train. A short analysis of tests conditions from the point of view of: test zones, tracks geometry quality are given. The testing procedure was explained and representative parameters of accelerations were commented.*

Keywords – Running safety, dynamical behaviour, DMU, testing.

1. INTRODUCTION

Serbian Railways (ZS) has, for its own need, bought a new Diesel Motor Units (DMU), manufactured by OAO "METROWAGONMASH" from Russia. Since this is about a new type of rail vehicles for ZS, which are to be registries in Serbian rolling stock after serial number 711, the need for type tests is appeared. In this paper test procedure in short will be shown as well as processing of the test results of safety and dynamical behaviour by driving this DMU at the Serbian rail lines. This test was performed for approval of the type of DMU for public traffic on the Serbian rail network. Institute ''Kirilo Savić'' (IKS) from Belgrade was carried out this test according to chapter 5 of the European standard: [1] in accordance with the conditions which meets on the best way the requirements of this standards, that are possible to achieved on the Serbian rail network.

2. TESTING OBJECT

The testing object is DMU consisting of two motor cars for passengers, which are coupled with coupler and gangway between coaches [2]. Motor cars have two two-axle bogie and driver's cab at the head of the train. Bogies near to driver's cab are motor bogie and the bogies near to coupler are free. Figure 1 shows this DMU, which is object of testing.

Fig.1.New DMU of series 711 for Serbian Railways

One car was equipped with measuring devices – acceleration sensors for measuring of acceleration in lateral and vertical directions and pulse converter for determination of speed of the vehicle. Car with

[1] Milutin KRIVOKAPIĆ, M.Sc.Meh.Eng. "Kirilo Savić" Institute, Vojvode Stepe 51, Belgrade, milutin.krivokapic@iks.rs
[2] Marija VUKŠIĆ-POPOVIĆ, M.Sc.Meh.Eng. "Kirilo Savić" Institute, Vojvode Stepe 51, Belgrade, marija.vuksicpopovic@iks.rs
[3] Saša RADULOVIĆ, M.Sc.Meh.Eng. "Kirilo Savić" Institute, Vojvode Stepe 51, Belgrade, sasa.radulovic@iks.rs
[4] Borisav BOGDANOVIĆ, M.Sc.Meh.Eng. "Kirilo Savić" Institute, Vojvode Stepe 51, Belgrade, borisav.bogdanovic@iks.rs

measuring equipment was designated with number 1 and car without measuring equipment was designated with number 2. This was done because of making difference in measuring driving, and then testing in both directions was performed.

The train was tested in: working condition. The mass of empty DMU was 87.663 kg and was determined by weighing.

3. TEST CONDITIONS

3.1 Test track layout

The test tack was divided in 4 parts: A, B, C and D. At those track parts, which are situated on different places around Serbian rail network, all of four test zones as per European standard [1] in point 5.4.2, are represented. In table 1 is given comparative view of these line sections, test zones -TZ, total length – L, as well as maximum achieved speeds during test driving - V_{max}.

Tab. 1. Review of testing sections with achieved maximum running speeds

Line part	Section	Test zone	L [km]	V_{max} [km/h]
A	Ruma – Putinci	1	10,62	112,8
B	Polumir – Pusto Polje	4	5,34	62,9
C	Vrtište – Vitkovac	1 and 2	33,3	101,55
D	Stalać - Djunis	3 and 4	17,3	84,6 64,8

Test zones are defined as follows:
- 1 straight track and curves of the very large radius
- 2 curves with large radius
- 3 curves with small radius 400 m ≤ R≤ 600 m
- 4 curves with very small radius 250 m ≤ R < 400 m

3.2 Track geometry quality

Assessing of geometrical parameters of tracks at Serbian railways is processed in a different way, as the standard [1] provides. Namely, according to regulations [3] maximum values of the parameters such as: direction, stability, gauge, cant and twist, are use for assessing of track geometry quality. While, according to European standard [1] for assessing of track geometry quality, standard deviations of two parameters, alignment which correspond to direction and longitudinal level which correspond to stability as per regulations [3], are use. Maximum values of parameters are presented only for information. So according to report of track measurement with Serbian measuring vehicle it is not possible to establish a direct correlation with assessment method that provides European standard [4].

Serbian Railways uses for measurement of the geometric parameter of tracks, inspection vehicle type: EM-80L by Plasser & Theurer. Factor – k for correction of track geometry parameter in relation to the NS measuring system, which is use as a standard, is not known.

Because of that, geometry quality of track was assessed according to procedure and criteria of Serbian Railways, defined in the regulations [3]. Namely, on ZS, geometry quality of tracks is assessing according to criteria of total length of all errors in two quality levels: B and C in length of 1 km. There are in total 4 assessments of track geometry quality in dependence of total length of errors in meters: very good, good, satisfactory and unsatisfactory.

At the most number of selected track sections prevails middle geometry quality: satisfactory and good. The best geometry quality has part C at the section Vitkovac-Vrtište nearby city of Niš, where sections with very good quality can be found. But at length of 1 km one part of track was registered with unsatisfactory quality. At that part, recorded parameters during the measurement driving were not taken in consideration [5]. However, layout of testing track in respect to geometry quality does not correspond to reference from point C.3 of standard [1]. Anyway, selected sections had the best geometry quality according to ZS criteria at recommended test zones. This means that, testing conditions were more unfavourable as European standard [1] recommends.

4. TEST PROGRESSION

4.1 Type and method of testing

The type of on-track test of safety and running behaviour of new DMU was partial. The measuring method, which is applied, was simplified according [1] and [5].

According point 5.2.1 of standard [1] extent of applied tests was reduced, because the train was tested in partially load condition. The measuring method is according point 5.2.2.1, [1] simplified, because testing vehicle meets the requirements from point 5.2.2.2 for use of simplified method, by measurement of accelerations only. This method means measuring of lateral and vertical accelerations at the car body and lateral accelerations at the bogie frames.

4.2 Measuring values and positions

During on-track tests, lateral accelerations were measured in the position of axles of two external wheelsets at the frames of two bogies, motor bogie and free bogie (one sensor per bogie). At the figure 2, measuring positions for acceleration transducers at the car unit number 1 is shown.

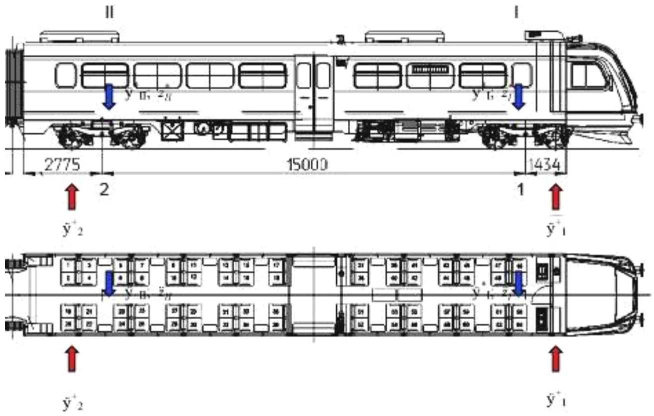


Fig.2 –Transducer's layout

In total, 6 transducers were placed for measuring signals of acceleration for assessing of running safety and dynamical behaviour of this train. These are signals of acceleration at the bogie frames above external wheelsets 1 and 2 - $\ddot{y}_1^+$ and $\ddot{y}_2^+$ respective, acceleration's signals on the car body above bogie pivots I and II in lateral - $\ddot{y}_I^*$, $\ddot{y}_{II}^*$ and vertical direction, respective. Beside acceleration, a vehicle speed was measured as well and by means of pulls counter, which was fitted at the axle-box bearing.

For recording of acceleration signals, transducer of type: B12/200 produced by HBM was used and for speed registration pulls counter: FAIVELY/ESPAS was used. As a data acquisition system, device: Quantum X MX 840 by HBM with software – Catman was used. During recording, measuring signals were sampled with a frequency of 300 Hz.

Testing DMU was riding in both directions during recording of measuring signals where it was possible to conduct. The weather conditions during the test were appropriate and rails were dry.

5. PROCESSING AND PRESENTATION OF THE RESULTS

5.1 Statistical processing of measuring signals

Statistical processing of measuring signals was done in two levels. Firs level was statistical processing per sections and a second level was statistical processing per test zones.

By statistical processing per test sections, at first filtering of measuring signals was carried out according to point 5.5.2 of standard [1] and in that way were obtained assessment parameters for evaluation of running safety and dynamical behaviour of the train. Processing of those parameters was hereafter follow per sections of appropriate length depending on test zone. At sections divided in this way for assessment parameters, statistical processing on the N or 2N members of sample was done in depending of type of parameters and test zones. Number N corresponds to number of sections at the certain test zone. A value of certain assessment parameter, per section (exponent/s of section) in histograms of distribution by test zone, was obtained from cumulative curve of a parameter for certain frequency. These frequencies are: $h_1 = 0,\ 15\%$ for a lower extreme value; $h_0 = 50\%$ for a median and $h_2 = 99,\ 85\%$ for upper extreme value.

From so obtained values of parameters for assessment by sections, histograms of distribution of parameters per test zones are obtained. The maximum expected values were calculated according to one-dimensional statistical analysis from [1] and were compared with the limit values. In that way parameters by sections on the straight track and full curves are processed.

Parameters for assessment in transition curves are processed separately. The number of processed transitions curves corresponds to number of curves at the observed test zone, which was taken in consideration. Maximal values of assessment parameters, which are obtained from a curve of cumulative distribution - $y\ (h_j)$ are compared with a limit values from [1].

5.2 Test results

Considering to numerous of data, the best way of theirs presentation is by the histograms of distribution of parameters for assessment by test zones. Here will be presented histograms of two test zones: test zone TZ 1, straight track and curves with very large radius (Figure 3, at the line part A) and test zone 4, curves with very small radius (figure 4 and 5, at the line parts B and D). In those histograms parameter: lateral acceleration at the forwarding bogie I, above leading axle 1 - $\ddot{y}_1^+$ in full curves (figure 3 and 4) and in transition curves (figure 5) was chosen. This parameter was selected as the most representative parameter in terms of running safety [5].

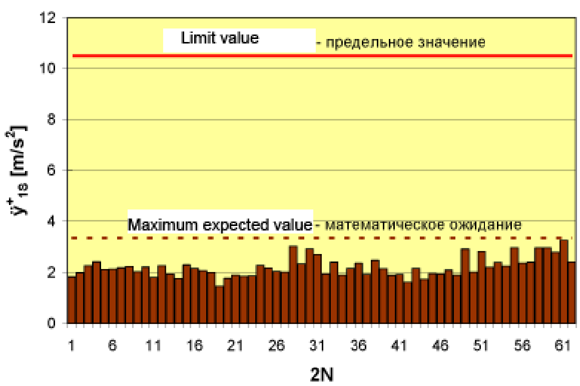


Fig. 3 – Histogram of distribution of lateral acceleration $\ddot{y}_1^+$ in full curves, at the TZ 1, by $V_{max,\ A} = 112{,}8$ km/h

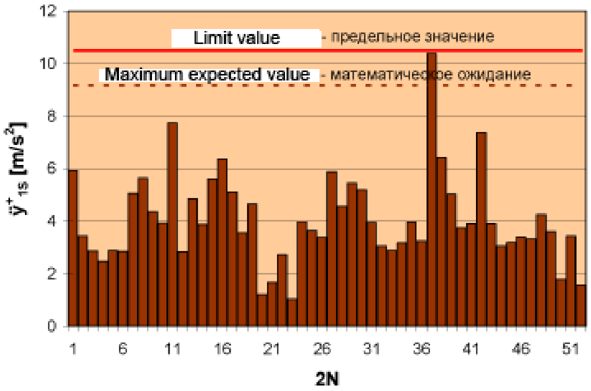


Fig. 4 – Histogram of distribution of lateral acceleration $\ddot{y}_1^+$ *in full curves, at the TZ 4 by* $V_{max,B}$ *= 62,9 km/h and* $V_{max,D}$*=84,6 km/h*

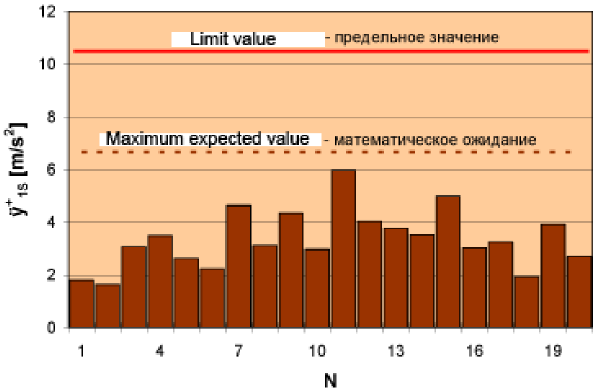


Fig. 5 –Histogram of distribution of lateral acceleration $\ddot{y}1^+$ *in transition curves, at the TZ 4 by* $V_{max,B}$ *= 62,9 km/h and* $V_{max,D}$*=84,6 km/h*

Although at one section upper extreme value of lateral acceleration - $\ddot{y}_1^+$ on the test zone 4 was approached to limit value (Fig. 4), further processing of test results was shown that all maximum expected values of assessment parameters of running safety are below limit values. That can be seen in chosen histograms of distribution of the selected parameter from the testing elaborate [5], which is presented in this paper. It is notable that the difference between limit value and maximum expected value at the very small radius curves section, significantly lower is (for 4,6 times) than at straight track sections. The testing showed that, all parameters of safety and dynamical behaviour of the train are satisfactory.

Criteria of cant deficiency by running through curves of different radii could not be met, except at the test zone 1, at curves of very large radius. Achieved average value of cant deficiency at that test zone was 28, 56 mm and the recommended value is per [1] $cd \leq 40$ mm. This was by reason of superstructure state and for adherence of limit speed from working timetable of ZS during measuring rides [5].

6. CONCLUSION

The testing of safety and dynamic behaviour of the new DMU series 711 for Serbian Railways have shown good ride quality of this train in running over different track categories respecting straight tracks and curves. Also from conducted testing [5] and this short analysis, it can be concluded that on Serbian lines can be conducted dynamic behaviour tests for purpose of vehicle type approval, which are foreseen for domestic traffic use only.

In order to be able to perform test for vehicles intended for traffic on the international railway network, it is necessary to raise the level of construction and maintenance of railways in order to meet criteria for testing tracks according recommendations from [1].

REFERENCES

[1] EN 14363 Railway applications – Testing for the acceptance of running characteristics of railway vehicles – Testing of running behavior and stationary tests CEN, Brussels, June 2005

[2] Diesel Motor Unit Series 711, Technical Description – Description of the Structure and Functioning, 750.250000.000 РЭ-001, OAO ''Metrowagonmash'', Mitischi 2011 (in Russian and Serbian)

[3] REGULATIONS 339 on Uniform Criteria for Control of the State on JZ Railway Network, Community of Yugoslav Railways, Belgrade (in Serbian)

[4] REVIEW OF THE TRACK CHARACTERISTICS ON THE CORRIDOR 10 TRACKLINE SEGMENT, Third Scientific-Expert conference ''Corridor 10'', 25. October 2012, Belgrade, M. Krivokapić, M. Vukšić-Popović, S. Radulović, B. Bogdanović (in Serbian)

[5] TESTING ELABORATE of DMU, Series 711. Part 3 – Testing of running safety and ride quality as per EN 14363, M. Krivokapić, M. Vukšić-Popović, B. Bogdanović, Z. Starčević, S. Radulović, D. Mijuca, "Kirilo Savić" Institute, Belgrade, 2011 (in Russian and Serbian).

THE POSSIBILITY OF USING A SUPPLEMENTARY COMPONENT FOR THE COMBUSTION EFFICIENCY OF LOCOMOTIVE DIESEL ENGINES

Miloš MILOŠEVIĆ [1]
Jovica PEŠIĆ [2]
Ljubiša TJUPA [3]
Boban NIKOLIĆ [4]
Vojislav TOMIĆ [5]

Abstract *– Taking into consideration more and more rigorous regulations on vehicle exhaust emissions as a part of global environmental protection policy, as well as critical energy, economic and political problems throughout the world reflected through the depletion of fossil fuels, many engineers and scientists agree that the solution to all of these global problems could be substituting the conventional combustion of fossil fuels. Notable fuel cost savings have been demonstrated using hydrogen in the operation of small internal combustion engines. This paper extrapolates improving fuel conversion efficiency from smaller diesel engines to much larger low-speed diesel engines (as used in locomotives and other heavy vehicles) on the basis of the experimental researches of the effects of adding a supplementary component generated by a catalitic reactor on the combustion of the primary fuel at diesel engines of a car and electric generator. The experimental results have shown that the use of the supplementary component improves the energy value of the combustion process which may reflect in diesel consumption decreasing, the reduction of harmful and toxic substances emission in the exhaust gases as well as the increase of engine performances. The proposed system is easy for installation, it requires neither modification of the engine nor additional loading of the vehicle electrical system and it is completely self-regulating because the amount of the produced supplementary component is directly proportional to the engine load.*

Keywords – Catalytic Reactor, Diesel Engines, Energy saving, Ecology.

1. INTRODUCTION

Fossil fuels (i.e., petroleum, natural gas and coal) possess very useful properties, not shared by non-conventional energy sources, that have made them popular during the last century in internal combustion engines most commonly used in transport of all vehicle types (cars, motorcycles, trucks, construction and agricultural machinery, ships, airplanes, locomotives and so on). Unfortunately, fossil fuels, which meet most of the world's energy demand today, are being depleted rapidly and they are not renewable. Moreover, global utilization of fossil fuels for energy needs is rapidly resulting in critical energy, economic and political problems throughout the world. Also, their combustion products (e.g. CO, CO_2,C_nH_m, SO_x, NO_x, radioactivity, heavy metals, ashes, etc.) are causing global problems, such as the greenhouse effect, ozone layer weakening, acid rains and pollution, which represent great danger for living environment, and eventually, for the total life on our planet [1]. Many engineers and scientists agree that the solution to all of these global problems could be replacing the conventional combustion of fossil fuels with some cleaner process. Since the oil crisis of 1973, considerable progress has been made in searching of renewable and alternate energy sources [2,3]. Simultaneously, systems of fuel supplements based on hydrogen being installed at internal combustion engines for increasing the conversion efficiency of primary fuels. Thus, there are systems producing the HHO gas, also called oxyhydrogen or

[1] Miloš MILOŠEVIĆ, Faculty of Mechanical Engeneering, University of Niš, Serbia, mmilos@masfak.ni.ac.rs
[2] Jovica PEŠIĆ, LINEX Pirot, Serbia, jpesic2001@yahoo.com
[3] Ljubiša TJUPA, ETŠ Mija Stanimirović, Niš, Serbia, tjupa@medianis.net
[4] Boban NIKOLIĆ, Faculty of Mechanical Engeneering, University of Niš, Serbia, nboban@masfak.ni.ac.rs
[5] Vojislav TOMIĆ, Faculty of Mechanical Engeneering, University of Niš, Serbia, vojislav@masfak.ni.ac.rs

Brown's gas. It is produced by electrolysis process, where an electrical power source is connected to two electrodes which are placed in a mixture of water and electrolyte. The HHO gas is a mixture of hydrogen and oxygen gases, typically in a 2:1 atomic ratio, the same proportion as water [4,5]. This gas enriches fuel mixture in petrol [6-10] or diesel [11,12] engines improving the combustion of fuel-air mixture. Moreover, the technology of "fuel reformer" works well and gives a significant increase in fuel economy [13]. The fuel reforming releases hydrogen by catalitic reactions from both the fuel and the water [14]. Many inventors have made fuel reformers and they work well, for example, the Multi-Fuel Processor (PMC - Processeur Multi-Carburants) is patented technology by the inventor Paul Pantone [15,16]. There is a vast dissemination of replications using PMC variants. One of the successful replications of this technology claims that it seems already sufficient to process only the water through the PMC reactor [17]. In that way G Pantone system (G – Giller, the name of the inventor) has been developed as an efficient catalytic generator.

The focus of this paper is on the possibility of using a supplementary component, generated by a catalytic reactor developed using the G pantone technology, for the fuel conversion efficiency improvement of the primary diesel fuel at locomotives. This paper outlines a path forward validation of the expectation that proven fuel conversion efficiency for car and electric generator engines should be approximately the same for much larger locomotive diesel engines.

2. THE CATALYTIC DEVICE

The used catalytic device Reactor S-1 represents a basic unit applying to motor vehicles with engines up to 2000 cm^2 of capacity. Multiplying the basic unit of the catalytic device Reactor S-1 a optimal catalytic device can be obtained for vehicles with engines of higher capacities. Appropriate combination of basic units influences the multiplication of the quantity of the generated supplementary component.

Fig. 1. The basic unit of the catalytic device Reactor S-1

The basic unit of the catalytic devices Reactor S-1 has a circular cross section and ending with threaded parts for easy installation. The outer layer of the reactor is made of steel, while the interior of the reactor is made according to the technology of the PMC reactor. External dimensions are: diameter Ø17 mm and length 110 mm, while the weight is 0.210 kg. The basic unit of the tested catalytic device Reactor S-1 is shown in Fig. 1

3. THE CATALYTIC SYSTEM

The catalitic system for generating a supplementary component for improving the combustion efficiency of the primary diesel fuel at internal combustion engines of locomotives should be done as a system consisted of:

- the multiplied catalytic devices Reactor S-1,
- a bubbler representing a distilled water tank,
- a diffuser of the supplementary component placed on the engine air intake part,
- two tubes for transporting humid air and the supplementary component.

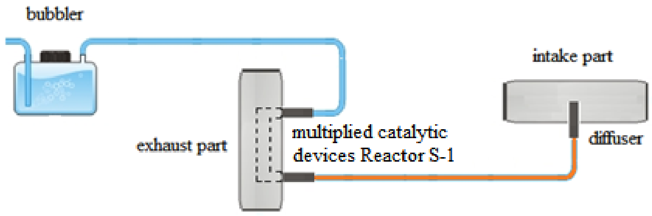


Fig. 2. The schematic diagram of the catalytic system with multiplied catalytic device Reactor S-1

The schematic diagram of the catalytic system with multiplied catalytic devices Reactor S-1 is shown in Fig. 2. The multiplied catalytic devices Reactor S-1 should be installed in the exhaust system of the locomotive diesel engine, while the diffuser of the generated supplementary component should be inserted into a hole on the engine air intake part. The operating principle of the catalytic system can be described according to Fig. 2. Due to the vacuum in the intake part of the engine there is the suction of a certain amount of the ambient air into the tank with the distilled water through the one-way valve. The sucked air forms the humidified air by passing through the water. On that occasion, there is a "bubbling" of the water in the tank, called a "bubbler". Further, by passing through the multiplied catalytic devices Reactor S-1 which is heated by the exhaust gases, the humidified air is transformed to the supplementary component which is then supplied via a diffuser into the engine air intake part and further leaded into the engine combustion chamber where it is mixed with air and atomized fuel improving the fuel conversion efficiency of the diesel fuel at locomotive engines. The catalytic function of the multiplied catalytic devices Reactor S-1 is activated when the exhaust gases reach the operating temperature of about 300^{o}C.

4. THE PREVIOUS VALIDIFICATION

The effectivenes of using a supplementary component generated by the catalytic device Reactor

S-1 has been proven by the experimental research of effects of adding a supplementary component on the combustion of the primary fuel at test diesel engines DMB 3 DM 515 coupled to an electric generator (Fig. 3) and Opel 1.6D SOHC (Fig. 4). A diesel engine (also known as a compression-ignition engine) is an internal combustion engine that uses the heat of compression to initiate ignition to burn the fuel that has been injected into the combustion chamber. The diesel engines can have a thermal efficiency that exceeds 50%.

Fig. 3. The schematic diagram of the catalytic system with catalytic device Reactor S-1

Fig. 4. The schematic diagram of the catalytic system with catalytic device Reactor S-1

The block diagram of the experimental setup with the measuring equipment that was used for the measuring purposes for analyzing effects of using the supplementary component generated by the catalytic device Reactor S-1embedded in the exhaust systems of the examined test diesel engines is shown in Fig. 5. The measuring equipment consisted of: exhaust-gas measuring device BOSCH BEA 250 (for measuring: RPM's of the engine crankshaft, oil temperature of the engine, concentrations of CO, CO2, HC, O2 and values of the Air-Fuel equivalence ratio λ), smoke-opacity measuring device BOSCH BEA 150 (for measuring the degree of opacity) and infrared thermometer FLUKE 66 (for the temperature measuring on the exhaust part where the catalytic reactor was built).

According to the experimental results [19] of the test engines it was concluded that temperatures of the exhaust parts and oil in the engines were slightly increased for combusting the mixture of intake air, diesel and the supplementary component. Further, for the exhaust gases of the test engines it was observed that concentrations of CO and HC decreased for combusting the mixture of intake air, diesel and the supplementary component, with the significantly smaller amounts of the HC component. In accordance with these, the concentrations values of CO_2 were higher for combusting with the supplementary component than for the case without it. The combustion of the mixture of intake air, diesel and the supplementary component leaded to decrease values of the concentration of O_2 and the coefficient of excess air λ in relation to the engine operation with the primary diesel fuel. The most important result was obtained for the observation of diesel particulate matter as the main parameter of ecological regulations for diesel engines. It was noticed that the values of the degree of opacity for the combustion process of the mixture of intake air, diesel and the supplementary component obtained at the test engines were significantly smaller compared to the mixture without the supplementary component. Finally, the analysis of the results of the diesel fuel consumption of the test engines it was perceived that adding the generated supplementary component to the mixture of intake air and diesel resulted in the saving of the primary diesel fuel of around 12% in comparison to the combustion of the mixture of only intake air and diesel.

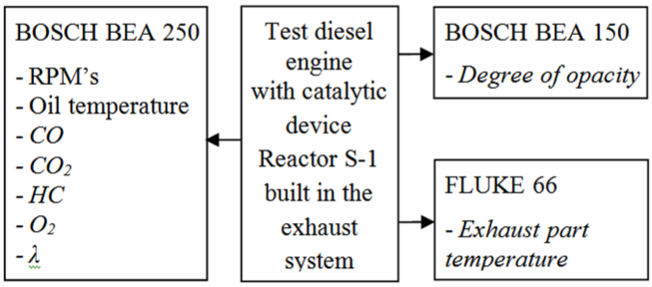


Fig. 5. The block diagram of the experimental setup for testing the catalytic device

All these facts pointed out to the conclusion that the combustion with the help of the supplementary component resulted in better quality of the exhaust gases and in fuel savings. These benefits were reported for different ranges of the number of crankshaft rotations of the test engines, as well as for various operating load conditions of the test engines.

5. CONCLUSION

Notable fuel cost savings have been demonstrated many times using hydrogen in the operation of small internal combustion engines. That is not in doubt. But, this paper extrapolates improving fuel conversion efficiency from smaller diesel engines to much larger ones. That extrapolation is the weak point, because it has not been proven that fuel cost savings could be obtained for low-speed diesel engines (as used in trucks, ships, locomotives, heavy equipment, electric generators and other applications where overall engine weight is relatively unimportant), for example for the world's largest diesel engine Wärtsilä-SulzerRTA96-C Common Railmarine diesel of about 84,420 kW [20]. Moreover, this paper outlines a path forward validation of the expectation because it is based on the experimental research of the composition of the exhaust gases as well as the consumption of primary fuel of diesel engines of a car and electric generator operating without and with adding the supplementary component generated by the catalitic device Reactor S-1 for improving the combustion of the primary fuel generated by a catalytic reactor. From the researched results, it can be concluded that the addition of the supplementary component for the combustion of the primary fuel improves the energy value of the combustion process leading to the reduction of harmful and toxic substances emission in the exhaust gases and less consumption of the primary fuel for any type of internal combustion engines (diesel/petrol), both for new and old generations. By an appropriate combination of the basic units of the catalytic reactor it is possible to obtain adequate response in the quantity of the generated supplementary component for combustion of the primary fuel corresponding to different capacities of engines vehicles. The installation is easy, as well as the removal. It does not require modification of engine feed/fuel injection systems. There is no additional load on electronic systems of adapted vehicles. The system is completely self-regulating, the engine sucks a certain amount of humid air required for that operating mode which, by passing through the reactor, becomes the supplementary component for the combustion of the primary fuel, so the system uses all the generated supplementary component and it is not necessary to store it. Hence, the amount of the produced supplementary component is directly proportional to the engine load. The proposed system after installation requires no additional maintenance other than periodic refueling of clean distilled water in the bubbler.

REFERENCES

[1] Rossman, R.E., The Effect of Vehicular Emissions on Human Health, Yale-New Haven Teachers Institute, Yale University, New Haven, Connecticut, USA, 2009

[2] McKinney, J., et al., Benefits Report for the Alternative and Renewable Fuel and Vehicle Technology Program, California Energy Commission, Fuels and Transportation Division, Sacramento, California, USA, 2011

[3] ***, Federal Energy Management Program: Energy Policy Act of 2005, U.S. Government Printing Office, www1.eere.energy.gov/femp/pdfs/epact_2005.pdf

[4] Brown, Y., Arc-Assisted Oxy/Hydrogen Welding, US patent number 4081656, 1978

[5] Milenković, M., Milošević, M., Stamenković, D., Pavlović, M., Research of Effectiveness of HHO Production for Use in Internal Combustion Engines, Proceedings of 16th SIMTERM, Sokobanja, Serbia, 2013

[6] Al-Rousan, A.A., Reduction of fuel consumption in gasoline engines by introducing HHO gas into intake manifold, International Journal of Hydrogen Energy, 35, 2010

[7] Anh, T.L., et al., Improving Performance and Reducing Pollution Emissions of a Carburetor Gasoline Engine by Adding HHO Gas into the Intake Manifold, SAE Technical Paper, 2013-01-0104, 2013

[8] Musmar, S.A., Al-Rousan, A.A., Effect of HHO gas on combustion emissions in gasoline engines, Fuel, 90, 2011

[9] Leelakrishnan, E., Lokesh, N., Suriyan, H., Performance and Emission Characteristics of Brown's Gas Enriched Air in Spark Ignition Engine, International Journal of Innovative Research in Science, Engineering and Technology, 2, 2013

[10] Milošević, M., Pešić, J., Nikolić, B., Milenković, M., An Experimental Research of Effects of Adding a Supplementary Component Generated by a Catalytic Reactor on the Combustion of the Primary Fuel at Internal Combustion Engines, Proceedings of 16th SIMTERM, Sokobanja, Serbia, 2013

[11] Yilmaz, C.A., Uludamar, E., Aydin, K., Effect of hydroxy (HHO) gas addition on performance and exhaust emissions in compression ignition engines, International Journal of Hydrogen Energy, 35, 2010

[12] Premkartikkumar, S.R., Annamalai, K., Pradeepkumar, A.R., Effectiveness of oxygen enriched hydrogen-HHO gas addition on DI diesel engine performance, emission and combustion characteristics, Thermal Science, OnLine-First 00, 2013

[13] Gable, C., Gable, S., Hydrogen Reformers for Fuel Cell Vehicles, http://alternativefuels.about.com/od/researchdevelopment/a/hydrogreformers.htm

[14] Fuel Saving and Pollution Cutting Retrofitting Modifications, Panacea-BOCAF On-Line University, http://www.panaceatech.org/FuelSaving&PollutionCuttingModifications.pdf

[15] Pantone Motor, Panacea-BOCAF On-Line University, http://www.aktion-kehrwoche.com/de/wp-content/uploads/2010/06/pantone_motor.pdf

[16] Pantone, P., Fuel pretreater apparatus and method, US patent number 5794601, 1998

[17] Bowers, B., et al., Multi-Fuel Fuel Processor and PEM Fuel Cell System for Vehicles, SAE Technical Paper, 2007-01-0692, 2007

[18] Milošević, M., Milenković, M., Pešić, J., Nikolić, B., Stamenković, D., Effects of Using a Supplementary Component Generated by a Catalytic Reactor on the Combustion of the Primary Fuel of a Loaded Diesel Generator, The Fifth International Conference Transport And Logistics, TIL 2014, Niš, Serbia, 2014

[19] ***, Fuel cost reduction when hydrogen is used to supplement diesel for a single ship, www.phillipscompany.4t.com/SFS.pdf

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

COMPARISON OF THE OPERATING PROPERTIES OF COMPOSITE ORGANIC RAILWAY BRAKE BLOCKS WITH CAST IRON BRAKE BLOCKS P10

Daniel KALINČÁK [1]
Rudolf ŘEZNÍČEK [2]
Martin MIKOLAJČÍK [3]

Abstract *– This paper is devoted to description of operation behaviour of various friction materials of brake blocks (cast iron and composites) of railway brakes with regard to braked wheels. Rim of the wheel is exposed to wear and thermal loading during the braking process. The thermal loading and stressing depends also on material of used brake blocks.*
The mechanical and thermal loading of the wheels results in various stress in its rim and disc. The consequence of this is deformation of a wheel shape. By application of various brake materials is exerted influence on mentioned phenomena, moreover on the wear and others damages of the wheel rim as well. It is caused by various properties of different brake block materials, with for example the different heat conductivities and frictional properties.
The paper is devoted to comparison of influence on mechanical and thermal loading, shape deformations and deterioration of railway wheels, after utilisation of various brake block materials. In the paper are quoted the results of experiments as well.

Keywords – composite brake blocks, cast iron brake blocks, thermomechanical assesment, tangential stress in the rim.

1. INTRODUCTION

In the past the demanded frictional and thermal properties of brake materials were reached by utilization of asbestos fibres and several others organic and mineral fillers. After forbiddance of asbestos usage, friction materials without asbestos are used in present.

The composite organic brake materials, contrary to sinter materials, are materials compounded mainly on the basis of polymerized phenol-formaldehyde resin filled by fibre and powder substances of inorganic origin.

The composite railway brake blocks have to fulfil requirements of UIC CODE 541-4 [1].

The railway wheel is exposed to severe stresses in railway operation. The thermal stresses during and after intensive braking cause the strain mainly in wheel rim and in wheel web as well. The induced tensile residual stresses after intensive braking especially on heavy slopes can raise and originate the cracks on the friction surface of wheel rim.

The second negative effect of high rim residual stresses is residual lateral displacement of rims. It can be dangerous mainly in running through rail switch and also it can cause derailment during railway operation. The railway wheels have to be approved in accordance with EN 13979-1:2003+A1:2008 [2] and UIC CODE 510 – 5 [3].

The classical cast iron brake blocks are gradually replaced by organic composite or sintered composite brake blocks. Thermal conductivity of these new brake blocks is much smaller then thermal conductivity of cast iron brake blocks. That negatively increases the thermal strain especially of wheel rim and induced larger tensile residual stresses. On the other hand the cast iron blocks have disadvantage in much higher level of emitted noise.

In the text of this contribution are presented results of braking the monobloc wheels with using the

[1] Daniel KALINČÁK, Department of Transport and Handling Machines, Faculty of Mechanical Engineering, Univerzity of Žilina, Univerzitná 1, SK-010 26 ŽILINA, SLOVAKIA, daniel.kalincak@fstroj.uniza.sk
[2] Rudolf ŘEZNÍČEK, Department of Transport and Handling Machines, Faculty of Mechanical Engineering, Univerzity of Žilina, Univerzitná 1, SK-010 26 ŽILINA, SLOVAKIA, rudolf.reznicek@fstroj.uniza.sk
[3] Martin MIKOLAJČÍK, Department of Transport and Handling Machines, Faculty of Mechanical Engineering, Univerzity of Žilina, Univerzitná 1, SK-010 26 ŽILINA, SLOVAKIA, martin.mikolajcik@fstroj.uniza.sk

composite organic brake blocks of K-type and cast iron P10 brake blocks.

In our Department there is devoted attention to solving problems connected with using modern brake materials and its impact on thermal and mechanical loading of railway wheels. There were published several papers concerning to theoretical and experimental solving of these problems, e.g. [4, 5, 6, 7].

2. TEMPERATURE DISTRIBUTION IN THE BRAKED RAILWAY WHEELS

Thermal conductivity of organic composite brake blocks is much lower then thermal conductivity of cast iron brake blocks. This leads to higher temperatures of wheel rim at braking with composite brake blocks.

The analytic evaluation of temperature distribution in wheel is problematic with respect to complicated shape of railway wheels. Usually there is used FEM for such evaluations, e.g. [7]. In technical approval procedures of railway wheels is necessary using of experimental methods [2, 3].

2.1 The UIC test bench of University of Zilina

The UIC test bench of University of Zilina is on *Fig.1*. Braking stand point of disc brake or brake block brake station consists of measuring frame with tensiometric sensor for measuring of friction force. Normal force is measured by tensiometric sensor placed in connection of brake levels in disc brake or in draw-rods of brake units of brake block station.

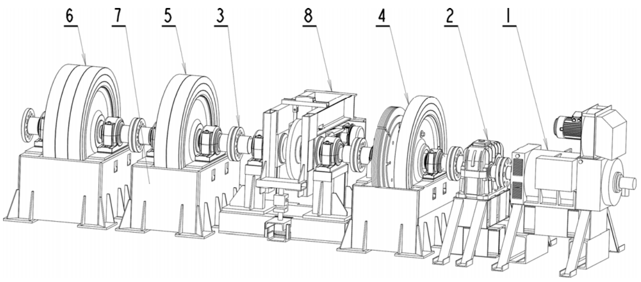


Fig. 1. The scheme of UIC flywheel test bench of University of Žilina
1 - electromotor (P = 265 kW, P_{max} = 400 kW, n = 3200 min^{-1}), 2 - gearbox (i = 1.5, respectively i = 1.72, i = 2,5 and i = 4), 3 - clutch BKN, 4 – flywheel 400 kgm^2 = 280 kgm^2+ 120 kgm^2 (2x5 + 3x10 + 4x15), 5 –flywheel 600 kgm^2, 6 – flywheel 900 kgm^2, 7 – frame, 8 – disc brake or tread brake.

The temperature measuring is performed by thermocouples of type K of firm OMEGA, that was embeded according leaflet UIC 541-3 [8] or UIC 541-4 [1]. The analog signals from thermocouples are leaded by slip head Hottinger to amplifier and multiplex card PCLD-889 and then to acqusition and measuring card PCL 816 placed in PC. There are also measured signals from revolution sensor and from tenzometric sensors of forces and pressure in cylinder. This card PCL-816 also control revolutions of motor via thyristor generator.

2.2 Conditions of thermomechanical assessment of wheels

The procedures, techniques and measurements are appointed in European standard EN 13979-1 [2] and UIC CODE 510-5 [3].

Ten brakings on slope (drag brakings) of wheel is carried out during braking test at the test bench. Each braking is characterized by constant braking power (usually 50 kW), constant speed 60 km/h and period of braking 45 minutes. Immediately after termination of each such braking is measured residual stress in wheel rim and lateral displacement of rim. The lateral displacement of rim is measured after cool down again with measurement of residual stress in wheel rim. The brake blocks used at those tests are in configuration 2Bg, dimension 320 x 80 mm. Brake blocks are exchanged after each fifth braking.

2.3 Temperatures in wheel rim

Temperatures of wheels rim were measured with three thermocouples type K, embeded 9 mm under central circle of wheels rim. There were used two identical monoblock wheels (steel grade ER7) with diameter 920 mm (new) and 850 mm (worn) for each type of brake blocks.

The results of temperarture measurements of "new" wheel braked by both types of brake blocks are shown at the *Fig.2*.

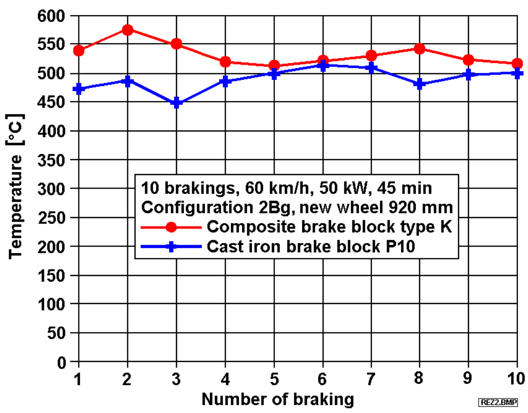


Fig. 2. The courses of wheel rim temperature at the new wheel (920 mm)

The mean temperature of wheel rim is approximately 490 °C during braking by cast iron brake blocks P10. The mean temperature is approximately by 43 °C higher when composite brake blocks asre used.

The results of temperarture measurements of “worn” wheel with 850 mm diameter braked by both types of brake blocks are shown at the *Fig.3*.

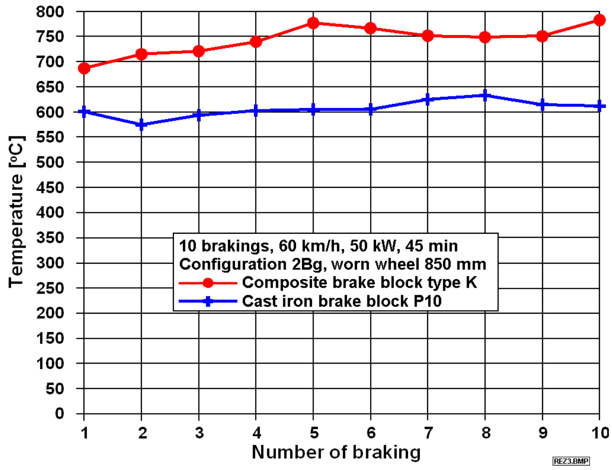


Fig.3. The courses of wheel rim temperature at the worn wheel (850 mm)

The situation in this case is worse than in previous one. The average temperature during braking by brake blocks P10 is approx. 607 °C and during braking by composite brake blocks type K is about 137 °C higher.

3. MEASUREMENT AND COMPARISON OF RESIDUAL STRESS IN THE WHEEL RIM

The ultrasonic stress measurement is based on relationship of stress and velocity of ultrasonic waves. The stress is determined from measurement of cross polarised ultrasonic waves passage time in radial and tangential directions through the whole width of wheel rim. Using of that method can be calculated tangential tensile stress, that is dangerous for creation and propagation of wheel rim cracks, from this equation:

$$\sigma_{tan} - \sigma_{rad} = \frac{K(t_{rad} - t_{tan})}{t_{tan}} \quad (1)$$

where:

σ_{tan} and σ_{rad} are main stresses in radial and tangential directions,

t_{tan} and t_{trd} are times of ultrasonic waves passage in given directions,

K is acoustoelastic constant, which is determined by using calibration specimens:

$$K = \frac{t}{\sigma(t_0 - t)} \quad (2)$$

where

t_0 is the ultrasonic travel time in non stressed material,

t is the ultrasonic travel time in stressed material,

σ is the applied external stress or thermal induced residual stress in specimen.

The residual stresses are measured in three radial cross sections equally spaced (120°) around of wheel and in four levels below running surface (*Fig.4*).

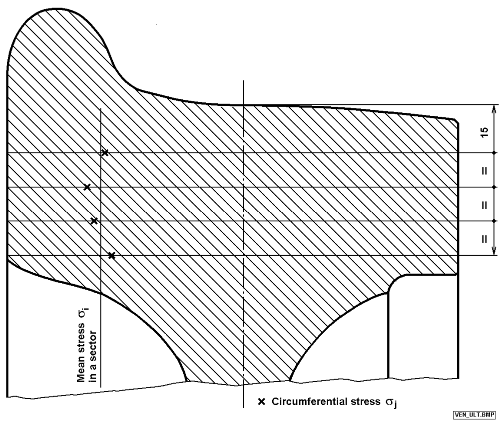


Fig.4. The positions of ultrasonic measurements of tangential stress

Two values of residual stress are considered:

- stress in a sector:

$$\sigma_i = \frac{\sum_{j=1}^{n} \sigma_j}{n} \quad (3)$$

- stress in the rim (average):

$$\sigma_r = \frac{\sum_{i=1}^{3} \sigma_i}{3}. \quad (4)$$

The results of measurements with DEBRO 30 in the level 15 mm below running surface are at *Fig.5*.

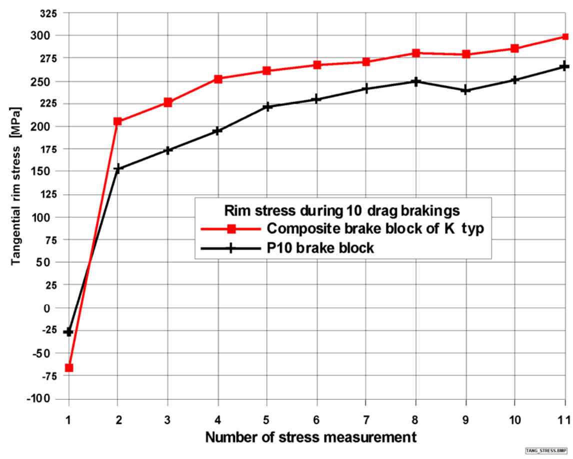


Fig.5. Tangential stresses 15 mm below central surface of rim

There was defined maximal allowable value of dangerous tangential tensile stress for new and maximal worn wheels in service, for purpose to ensure the safety of railway operation.

The level of circumferential residual stress at the end of the test after cooling should not exceed for wheel steel grade ER6 and ER7 +200 N/mm^2 as the average of measurements across three circumferential positions and + 250 N/mm^2 for each measurement. For wheels with a rim at maximum wear limit this maximum allowable stresses are +275 N/mm^2 as the average and + 300 N/mm^2 for each measurement.

4. MEASUREMENT AND COMPARISON OF RIM DISPLACEMENTS

The changes of lateral displacement of wheel rim are very important from view of running safety. For new wheels the maximum lateral displacement is restricted to +3.0/-1.0 mm during braking and in cold state after braking too.

The results of rim displacements measurements are in the *Fig.6* and *Fig.7*.

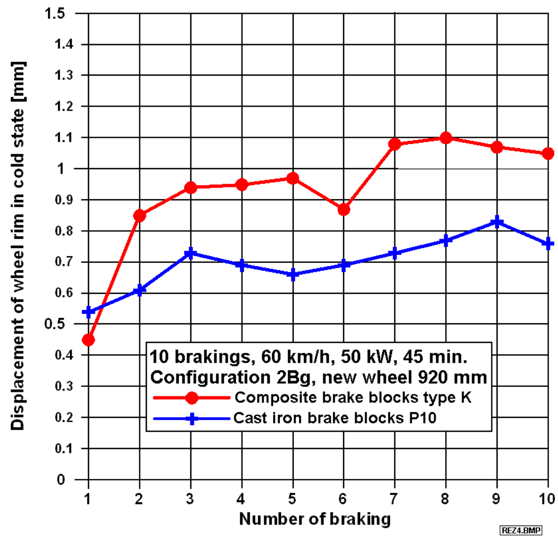


Fig.6. The rim lateral displacements in cold state

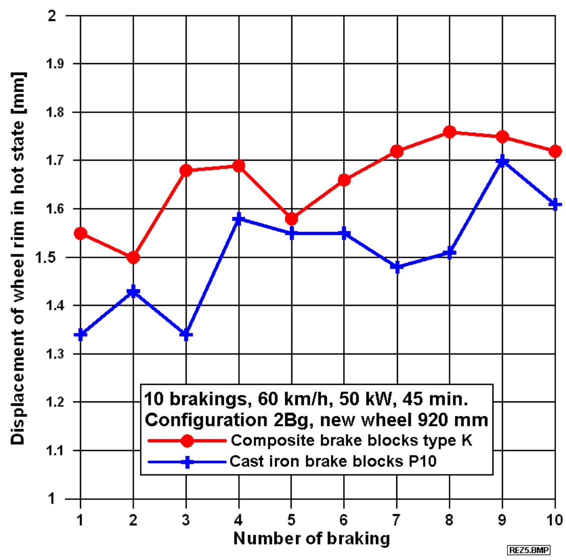


Fig.7. The rim lateral displacements in hot state

5. CONCLUSION

From performed experiments on two monoblock wheels in new and worn states, results that intensive braking with composite brake blocks increases the temperatures in wheel rim, the values of rim temporary displacement in hot and rim permanent displacement in cold state. Also tangential circumferential stresses in wheel rim are higher after intensive braking by composite brake blocks, which act nearly as thermal insulant.

Nevertheless thanks to another advantages, particularly advantageous acoustical behaviour, utilization of composite brake blocks is spreading more and more.

ACKNOWLEDGEMENT

This paper was created during the processing of the project No. 1/1098/11: "Stress Distribution in a Braked Railway Wheel" and No. 1/0347/12: "Railway wheel tread profile wear research under the rail vehicle in operation conditions simulation on the test bench", supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences.

REFERENCES

[1] UIC CODE 541 – 4, 4th edition, December 2010. Brakes – Brakes with composite brake blocks – General conditions for certification of composite brake blocks.

[2] EN 13979-1:2003+A1:2008 Railway applications – Wheelsets and bogies – Monobloc Wheels – Technical approval procedure – Part 1: Forged and rolled wheels.

[3] UIC CODE 510 – 5, 2nd edition, May 2007, Technical approval of monobloc wheels. Application dokument for standard EN 13979-1.

[4] Kalinčák, D., Řezníček, R., New brake materials in railway operation. Proceedings of BullTrans 2013, 16-18 October, 2013. TU Sofia, ISSN 1313-955X, pp. 91 – 94.

[5] Suchánek, A., Harušinec, J., Gerlici, J., Lack, T., Analysis of models for simulation computations and experimental detection of stress in braked railway Wheel. TRANSCOM 2013. University of Žilina, 2013. ISBN 978-80-554-0695-4. Pp. 283 - 287.

[6] Suchánek, A., Harušinec, J., Gerlici, J., Lack, T., Experimentálne a analytické zisťovanie napätí a teplôt v brzdenom železničnom kolese pri brzdení klátikovou brzdou. Strojírenská technologie. ISSN 1211-4162. Year 18, №. 2 (2013), pp. 111 - 116.

[7] Suchánek, A., Gerlici, J., Lack, T., Harušinec, J., Analysis of temperature distribution in a braked railway wheel during braking by the brake block. TRANSCOM 2013, University of Žilina, 2013. - ISBN 978-80-554-0695-4. pp. 289-292.

[8] UIC CODE 541 – 3, 7th edition, October 2010. Brakes – Disc brakes and their application - General conditions for the approval of brake pads.

.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

RISK ANALYSIS OF DELAY OF PASSENGER TRAINS IN THE RAIL NETWORK

Svetla STOILOVA[1]

***Abstract** – In the study has been made research of the reliability of the passenger train schedule in the railway network of Bulgaria and delays for passenger trains on the categories and the reasons that cause them. The frequency, duration and type of delay are studied. The research presents a methodology for assessing the risk of train delays. In the study are determined the probability distributions of duration of delays, a matrix of risk probability of delay. In the paper has done the Event Tree Analysis determining cause for delay. The study results suggest lognormal distribution of minutes of delay of passenger trains and lognormal distribution of the number of delayed trains. A value of one minute per passenger, which he lost due to delay of the trains, is determined.*

Keywords – passenger train, delay, event three, distribution.

1. INTRODUCTION

The delays of passenger trains are an important problem in assessing the reliability of rail transport. They affect travelers in their choice of transport mode. Delays of passenger trains could lead to disruption of trains at stations, which means a disadvantage compared to other modes of transport. The study delays and improving reliability of train services is of great importance from the viewpoint of saving travel time, increase the safety of transport, and increase the users of rail transport services. With the regulation of the European Parliament and the Council of 23 October 2007 on rail passenger's rights and obligations, the measure of travel time reliability has become an obligation for railway operators, [1]. This regulation establishes rights and obligations for rail service users in order to improve the efficiency and appeal of rail transport for passengers. It obligates railway operators to inform passengers about their service quality and to compensate the users in case of delays. The operators need of a measure of travel time reliability. They have to pay the monetary compensation in case of delay.

In public transport, the term delay has normally used to refer to the difference between scheduled arrival time and actual arrival time at stations, which may result in early or late arrival

Identifying the distribution of delays is an important first step in describing, measuring and valuing reliability. The distribution might give us what mechanism determines delays.

In [2] three main types of delays are modeled, namely: terminal/station delays; track related delays; and rolling stock related delays. Some researchers have done studies to determine the distribution of delays, [3, 4]. In [3] are determined the negative exponential distribution, [4] examines the British railway and establishes so-called q-exponential functions for delays. In [5] is a used simulations method to categorize and quantify the delay due to different types of conflicts and operational causes.

For a network of Bulgaria have not been studied delays for passenger trains.

The aim of the study was to determine the performance of railway timetable, to investigate the delays to passenger trains on the categories and the reasons that cause them. This would allow gaining a clear idea of the problems of the railway network and the status of the reliability of trains. For the implementation of this aim is necessary to perform the following tasks: study of the frequency, duration and reasons for delays of passenger trains on the categories; determination the distribution of the delays; determining the risk of delays; determination of the probability of delay of passenger train; determination of the value of duration of a delay for passengers.

2. MODELING TRAINS DELAYS

2.1 An overview

On the railway network in Bulgaria are daily moved national express, fast, passenger and suburban trains. National Railway Infrastructure Company shall keep a register of delays for passenger trains only at the final station. In this research are examined 46574

[1] Svetla STOILOVA, Assoc.Prof. PhD, Thechnical University of Sofia, Bulgaria, e-mail: stoilova@tu-sofia.bg

cases of delay of passenger trains in the final station for three years (2011, 2012, 2013).

In this reserch the modeling passenger trains delays includies the folloing steps: determination the risk matrix of delays; compilation of event three of delays; determine the distributions of minutes of delays and distributions of number of trains delays; study of the relationship between the number of delays and the duration in minutes. This methodology is apropriated for all railway lines in Bulgara's railway network separetly for all categories of passenger trains.

2.2 Risk matrix to estimated the delays

The risk matrix could be use to determine the level of risk in different consequences and causes. The risk levels are determined in three zones: green (the risk cannot be ignored); a yellow (the risk must be analyzed) and red (the risk must be managed). The advantage is that it can define both aspects of risk (probability and consequences), which is important for the selection of measures to reduce risk.

In this study, the reasons for delays of passenger trains were structure into three groups: the fault of the railway infrastructure manager, the fault of the rail carrier operator and the fault of other causes.

The others causes include delays caused by weather conditions, theft, accidents and malicious activities injured and killed as their fault. Table 1 presents the raisons for delay for railway infrastructure manager, for railway operator and others reasons. Table 2 shows the matrix of the risk of delay of express passenger trains. In study was defined the following zones of risk taken into account of probability of delay per day: green (from 0,00 to 0,19); a yellow (from 0,20 to 0,49) and red (from 0,50 to 1,00).

Tab.1. Matrix of reasons of delay

Source	Raisons for delay	
Railway infrastructure Manager (RIM)	I_1	Controlling the movement of trains and capacity
	I_2	Railway track and equipment
	I_3	Communication technique
	I_4	Power supply
	I_5	Conections
Rail passenger transport operator (RO)	P_1	Locomotives
	P_2	Wagons
	P_3	Passenger
	P_4	Conections
Others reasons for delay		Weather conditions, accidents, thefts

Tab.2. Matrix of risk of delay

Express train										
Minutes of delay	**Railway infrastructure manager**					**Rail passenger transport operator**				**Others reasons for delay**
	Reasons for delay					Reasons for delay				
	I_1	I_2	I_3	I_4	I_5	P_1	P_2	P_3	P_4	
0-10	0,50	0,82	0,83	0,69	1,00	0,69	0,53	0,90	0,44	0,48
11-20	0,04	0,15	0,12	0,14	0,00	0,20	0,24	0,06	0,44	0,27
21-30	0,01	0,02	0,03	0,06	0,00	0,06	0,12	0,02	0,11	0,07
30-60	0,00	0,01	0,02	0,03	0,00	0,02	0,03	0,01	0,00	0,04
Over 61	0,00	0,00	0,00	0,05	0,00	0,00	0,00	0,00	0,00	0,00

Red zone

Yellow zone

Green zone

The observations of minutes of delay have been separate into five groups. To analyze delays by categories trains the risk matrix could be draw up for each of them separately. Table 3 show a matrix of risk for express trains. The delays to ten minutes are in red zone. In yellow zone are part of delay to ten minutes and part of delays from 11 to 20 minutes. The green zone is biggest then others. That show that should to take measures to reduce the risk.

2.3 The event tree method for delay

Event tree analysis is an inductive method that enables a structured description of the possible consequences of an event. The event tree is a graphical technique for qualitative and quantitative analysis, presenting a series of fundamentally independent events after the main event. An Event tree analysis can result in many different possible outcomes from a single initiating event. It provides the capability to obtain a probability for each outcome. The tree branches off at "no/yes" ports, typically depending on whether the different safety systems succeed or not.

Quantitative assessment of the consequences includes the determination of the values of the probability of the final events. These values are determined by multiplying the probabilities of the initial and all intermediate events that lead to the final:

$$P_j = P_{IE} \cdot \prod_{i=1}^{n} P_i \qquad (1)$$

P_{IE} is the probability of the initial events.

In this paper the initial event is the delay of passenger trains in final station.

P_i is the probability of the intermediate event i leading to the final event j; P_j is the events for final event, n is the number of intermediate event. In reserch the intermediate event are: delay by one reson, delay by two resons, delay by three resons.

For example for event three shown in fig.1, the final event P_A which determines the probability that a passenger train is delayed for three reasons are given by the formula:

The event tree can be draw for each category passenger's trains. Figure 1 shows the event tree for all passenger trains.

$$P_A = P_{IE}.P_{1Y}.P_{2Y}.P_{3Y} \qquad (2)$$

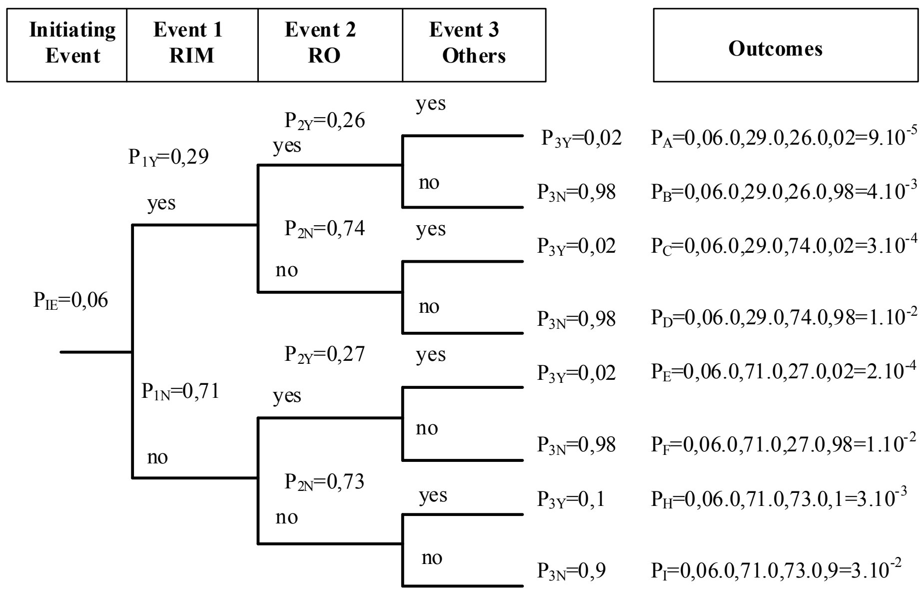


Fig.1. Event tree -The reasons for delay for all categories passenger trains

The event tree can be draw for each category passenger's trains. Figure 1 shows the event tree for all passenger trains.

The event three shows that the probability that a passenger train is delayed through the fault of the infrastructure manager or the fault of the carrier is the same (1.10^{-2}).

Fig. 2 show the evet tree for resons for delay due to Railway infrastructure Manager. The main raison for delay is railway track and equipment (41%).

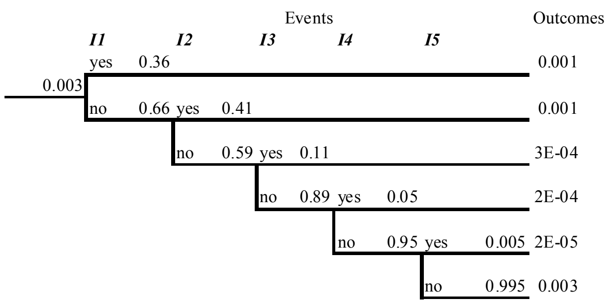


Fig.2. Event tree - Railway infrastructure Manager

The main raison for delay due to Railway passenger transport operator is by resons of the locomotives (43%).

2.4 Determination of the distribution for delay

In this resersh was determined the distribution of minutes of delay and distribution of number of delay. The experiment was performed with data for delays for three years for all railway lines in Bulagatia's railway network.

The Chi-squared test (χ^2) measures how well an expected frequency of a fitted distribution resembles the observed frequency in data. A comparison was made of the three distributions: lognormal, erlang and gamma. Table 3 show the results.

Tab. 3. Chi-Square test for distribution of delay

Number of delay			
Distribution	χ^2	χ_t^2	P value
Lognormal	5,60	12,07	0,59
Erlang	7,19	12,07	0,41
Gamma	10,87	12,07	0,14
Minutes of delay			
Lognormal	13,21	13,36	0,10

To accept the law of distribution should be performed the condition:

$\chi^2 \leq \chi_t^2$, (3)

where: χ_t^2 is taken from the table.

It can be assumed the idea those minutes of delay and number of delay comes from a lognormal distribution with 90% or higher confidence.

Fig.2 shows the lognormal distribution for minutes of delay.

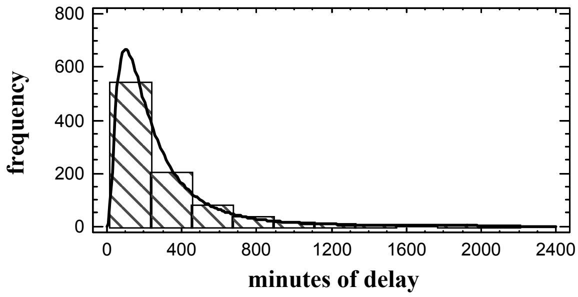


Fig.2. Histogram of lognormal distribution

2.5 Determination of the the relationship between the number of delays and the duration in minutes

In the reserch is determined power correlation between minutes of delay per day D_M and number of cases of delay per day (number of passenger trains that delayed) D_N.

$D_M = 124{,}2.D_N^{-0{,}54}$, minutes/day (4)

Correlation coefficients is R=- 0,87, coefficients of determination is R^2=0,77.

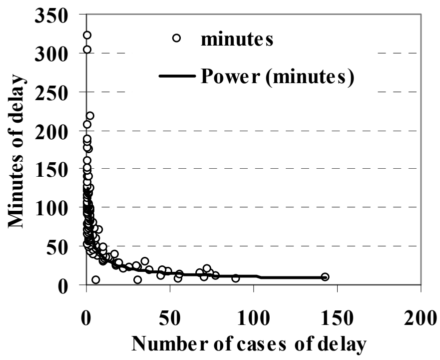


Fig.3. Relation ship between minutes of delay and number of trains that delayed

3. DETERMINATION OF VALUE OF THE MINUTE DELAY FOR PASSENGERS

The value of one minute delay of the train, which is a loss for the passenger, can be determined by formula:

$$R = \frac{VT_{FT,ET}}{60}.\gamma.\alpha_{ET,FT}.\beta_{ET,FT} + \frac{VT_{PT,ST}}{60}.\gamma.\alpha_{PT,ST}.\beta_{ET,FT}$$

€/min. per passenger (5)

where: $W_{ET,FT}$ is the number of delayed express and fast trains; $W_{PT,ST}$ is the number of delayed passengers and suburban trains; W is the total number of passenger trains, γ is the ratio of the total number of passenger trainkilometers PL and the total number of trainkilometers TL. All indicators are for a year.

$$\alpha_{ET,FT} = \frac{W_{ET,FT}}{W} \quad (6); \quad \alpha_{PT,ST} = \frac{W_{PT,ST}}{W} \quad (7)$$

$$\beta_{ET,FT} = \frac{M_{ET,FT}}{M} \quad (8); \quad \beta_{PT,ST} = \frac{M_{PT,ST}}{M} \quad (9)$$

According to general guidelines for the cost-benefit projects supported by [6], the value of business travel per passenger is 11,9 €/per passenger hours, the value of others travels is 4,19€/per passenger hours. Therefore, it can be assumed that:

- ♦ $VT_{ET,FT}$ = 11,9 €/per passenger;
- ♦ $V_{PT,ST}$ = 4,19 €/per passenger hours.

In this paper was determined the value for a minutes delay for passenger 0,36/€ minutes per passenger.

4. CONCLUSION

The research allows making the following important conclusions:

♦ For delays of passenger trains per day is construed a matrix of risk. The types of risks areas are determined.

♦ For delays of passenger trains per day is performed an event tree analysis.

♦ A lognormal distribution for arrival delays of passenger trains at the final stations is determined.

♦ A multiplicative correlation between minutes of delay and the number of passenger trains that delayed for day period is determined.

♦ In the paper is determined a formula for calculation the price for the passenger for a minute delay.

REFERENCES

[1] *Regulation (EC) number 1371/2007 of the European Parliament and the Council of 23 October 2007 on rail passenger's rights and obligations*, OJ L315, p.14-41, 3.12.2007.

[2] Higgins, A., Ferreira, L, Kozan, E. *Modeling delay risks associated with a train schedule,* Transportation Planning and Technology, 19(2), pp.89-108, 1995.

[3] Yuan, J., *Stochastic Modeling of Train Delays and Delay Propagation in Stations*, Delft: Delft University, 2006.

[4] Briggs, K., Beck, C., *Modeling train delays with q-exponential functions,* Physica A: Statistical Mechanics and its Applications, 378(2), pp. 498-504, 2007.

[5] Dingler, M., Koenig, A., Sogin, S., *Determining the Causes of Train Delay*. Proceedings of the AREMA Conference, p.14, 2010.

[6] *Guide to cost-benefit analysis of investment projects. European Commission*, 2008.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

INFRASTRUCTURE OF URBAN RAIL SYSTEMS

Ivana VIĆENTIĆ [1]
Zdenka POPOVIĆ [2]

Abstract *- This paper is the result of research in diploma thesis "Infrastructure of Urban Rail System" on Faculty of Civil Engineering, University of Belgrade. The research in this paper includes the tram system and modern light rail transportation systems. Characteristics and differences between these systems in terms of routing, the geometric design of the route, type of superstructure and types of vehicles are defined in this paper. There were pointed out attitudes of the European transport policy, the human aspect of the planning, the necessity of including the city's rail system into a unique transport chain in the city, as well as the systems for noise protection of the urban environment. The starting idea for considerations in this paper emerged from the review of the current state of urban traffic in streets of Belgrade. The development of tram transport in Belgrade is presented through a brief history, with an overview of the current situation. Research presented in the paper is intended to draw attention to the lack of legal and technical framework for planning, design, construction and maintenance of urban rail systems, as well as the lack of modern literature in this field on Serbian language, with the need to educate students and engineers in this field.*

Keywords – Urban rail system, tram, light rail system, infrastructure.

1. INTRODUCTION

Traffic in cities has an important role in terms of development and connection of urban areas and the development of socio-economic activities. It was often the major indicator of the development of urban structure. Bearing this in mind, the public transport system, as part of the city transport system, is very important to improve the quality of life and productivity, due the fact that the city cannot rely on individual transport. Vehicles and infrastructure for public passenger transport are, regarding the performance (energy efficiency, capacity, speed, quality and impact on the environment), the important factors that affects the sustainable urban development.

Research in this paper is related to the infrastructure of surface rail systems in urban area, including tram system as the oldest urban rail system, and modern light rail transit (LRT) system.

2. HUMAN PLANNING AND DESIGN OF INFRASTRUCTURE IN URBAN AREA

It is common to use the term "reference vehicle" in the field of planning and design of urban rail infrastructure. Modern planning and design of sustainable urban rail system introduces the concept of "reference passenger" (Fig.1). The "reference passenger" is the basis of flexible module, which can be used to design spatial entities and define dimensions of vehicles and infrastructure intended for passengers. Unlike Corbusier concept, principle of human measurement in the planning and design of urban rail systems should be based on the proportions of passengers of all age groups, including people with special needs and disabilities.

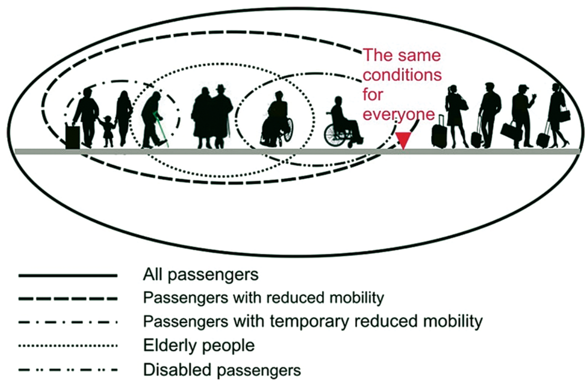


Fig.1. Characteristics of "reference passenger" [1]

In order to determine the characteristics of the reference passenger, diploma thesis [2] presented the principle of analysis of the structural characteristics of

[1] Ivana VIĆENTIĆ, EnCon doo, Cara Lazara 3, Belgrade, Serbia, vanci6@gmail.com
[2] Zdenka POPOVIĆ PhD. CE, University of Belgrade, Faculty of Civil Engineering, Bulevar Kralja Aleksandra73, Belgrade, Serbia, zdenka@grf.bg.ac.rs

passengers in the area covered by the light rail system. The example of the analysis of characteristics of passengers in Serbia was provided in [1].

Infrastructure and vehicles must provide a dignified and safe access for all passengers (Fig. 2). Diploma thesis [2] considers infrastructure for barrier-free access areas (pedestrian crossing at the same level as the pavement, paving, dropped curbs, floors, tactile flooring, stairs and ramps, escalators, elevators, and protection from obstacles) and station facilities (waiting and seating areas, platforms, guide paths on platforms, preference for footbridges, tunnels or subways, and crossing tracks). Infrastructure for interchange terminals was specially considered in [2].

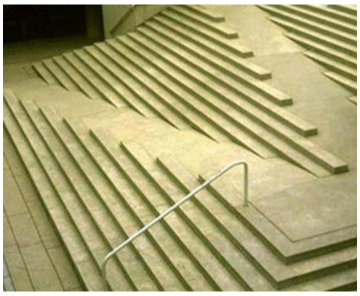


Fig.2. Barrier-free access to terminal for everyone

3. BASIC CHARACTERISTICS OF TRAM AND LRT TRACK ALIGNMENT DESIGN

Tram system is a type of surface rail system, which is designed for passenger transport in the urban area using tram vehicles that run on the surface route. Although there are sections that do not comply with this principle because there may be, underground and overground tram sections. The tram routes are designed to guarantee the safety of the tram traffic, as well as the safety of all other traffic participants (passengers, officials, workers on the construction and/or maintenance of the tram line), the functionality that involve an optimal level for transport services and minimal effects on spatial development and the environment, the acceptable costs of construction, maintenance and management [3].

Tram tracks can be designed:
- on the common route with road traffic (within the street profile, or regulation width of the street)
- or on the independent route (outside of the street).

In the case of the tram line within the street profile, tram line zone implies the tram line as a separate functional element, which can be:
- vertically separated from the street, when it can be used only for tram traffic,
- or at the same level of the street, when it can be used for both tram and road traffic.

In general, tram line at the same level of the street decrease the safety of all traffic participants and reduce the reliability and efficiency of tram traffic (Fig.3). Also, this leads to the limitation of the maximum speed as well as spatial and environmental constraints. Maximum speed on the surface rail systems is 50 km/h in the urban environment and 70 km/h in suburban area. In the area of surface intersections and on turntables tram speed is limited to Vmax = 20 km/h.

Fig.3. Tram line at the same level of the street

Tram is a railway vehicle designed primarily for the passenger transport which runs on rails, and which is connected to the power supply line. The main characteristic of tram catenary system is the power (600 W to 700 W), that is three to four times lower than the power in metro catenary system (4x70 kW), and amperage is 500 A and 600 A. Tram weight can range from 25 t to 40 t, and maximum speed range from 60 to 70 km/h.

The Law on Road Traffic Safety [4] allows the usage of the tram lane and lane dedicated for the movement of public transport vehicles for vehicles with right of way and escorted vehicles. Therefore, this definition of traffic restrictions maintains reliability of tram traffic.

The default gauge of the tram track is 1435 mm. In addition, there are tram systems with a track gauge 1000 mm, for example: Belgrade, Augsburg, Frankfurt, Mainz, Zurich, Basel, Helsinki, etc. However, as the standard gauge of the new tram track it is considered the width of 1435 mm (Paris, Oslo, Amsterdam, Rotterdam, Brussels, The Hague, Istanbul, Chicago, etc.). There is a solution with two or more gauges (Fig.4).

Fig.4. Tram tracks on the independent surface route with two gauges (1000 and 1435 mm) [5]

Light rail system is a type of surface rail system, which allows easy connection between urban core and suburbs. In our country, for the light rail system it is accepted term LRT. LRT is a light rail system for passenger transport in the urban and suburban area, which runs on a separate route, with surface, underground or above ground sections (Fig. 5).

Fig.5. Above ground LRT section

Surface intersection with road public transport is possible, but should be kept to a minimum because it loses its fundamental meaning as a rapid rail system for connection between urban core and suburbs. The route is designed without collisions with other transport modes, so it unconditionally guarantees the safety of traffic, passengers, officials, workers on the construction and maintenance. Infrastructure manager must define whether the route of the LRT will be used only for LRT vehicles, or it would allow the conventional railway vehicles.

Design speed on sections that are connecting center and suburb depend on the vehicle performances. The usual speed on suburban sections corresponds to the maximum vehicle speed Vr = Vmax = 70-100 km/h. Speed in the stations must be limited to 40 km/h where LRT vehicles do not stop. On the LRT sections through the urban area, design speed is dependent on the radius of horizontal curve and the designed cant. Anyway, dynamic characteristics of the route must match the performance of the vehicle. Typical track gauge of LRT track is 1435 mm.

LRT vehicles should provide rapid urban rail transport (a maximum speed on suburban sections of 70-100 km/h) and should enable quick change of passengers (low floors, wide doors, the announcement of the next station, a sufficient number of seats, greater comfort for standing, special places for the people with special needs, wheelchairs, prams, bicycles, etc.). LRT vehicles are two-way, with traction at both ends, which eliminates the need for turntables at the end of the LRT lines and faster change of travel direction.

Diploma thesis [2] considers alignment design parameters for tram system and modern light rail transportation systems: radius of horizontal curve, length of transition curve, length of cant transition, cant, length of alignment elements (circular curves and straights) between two transition curves, and radius of vertical curve.

4. DESIGN OF SUPERSTRUCTURE

Design of the superstructure generally must fulfill the usual requests for transmission of the static and dynamic load, safe guidance and directing of the rail vehicle, as well as comfort for the passengers, and if possible, improvement of ecological relations in the environment.

In urban environment, the influence of superstructure design on the noise and vibrations emission is of particular importance. In addition, these structures must meet the aesthetical requirements, accessibility requirements, as well as specific conditions for construction and maintenance in urban environment.

Superstructure of the urban rail systems can be laid in ballast bed (Fig. 6) or on the slab track (Fig. 7).

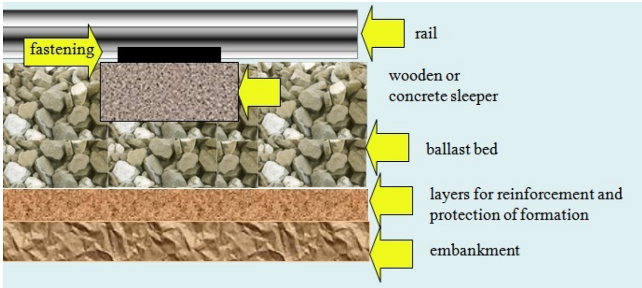


Fig.6. The elements of the track superstructure with ballast bed and substructure [6]

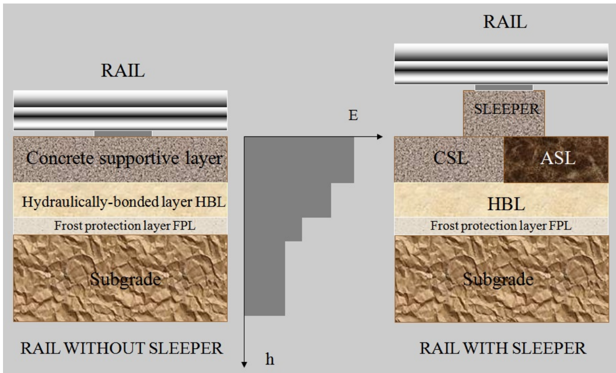


Fig.7. Slab track with continuous and discrete rail support [6]

The type of superstructure is determined for each specific case [7].

Application of superstructure solution with ballast is limited in the urban environment due to disadvantages of this solution: track geometry deterioration, reduction of drive comfort, increase of emission of noise and vibration, necessity of track geometry correction, inevitable pollution of ballast (hygienic and aesthetic problem, as well as noisy machine cleaning with addition of new ballast material), and favourable environment for rodents (especially in the tunnels) and reptiles.

Minimal maintenance expenses, as well as long service life, give the superstructure solution without ballast an advantage in the urban environment.

In cases of rails installed flush with the street surface, grooved tramway rails are as a rule used. The rails are installed onto a supporting layer of asphalt or concrete. According to the rail support, there are two solutions: with discrete and continuous rail support. The continual rail support is an effective measure for reduction of corrugation of the rail head running surface. This solution has lower maintenance costs and lower noise emission.

The diploma thesis [2] presented and analyzed different solutions of the superstructure. It also presented the different possibilities for track covering (Fig. 8), which depends on the track purpose (mixed traffic, pedestrians, green area).

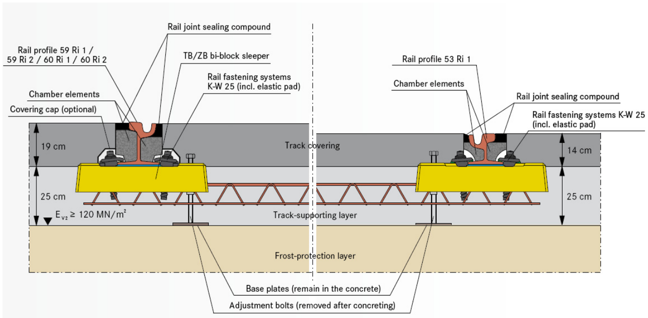


Fig.8. RHEDA CITY -D system, with elastic discrete support of the rail on the sleeper

5. CONCLUSION

Designed transport infrastructure shapes the mobility in the city.

The development of rail systems in cities is not an alternative, it is perfectly acceptable and reasonable solution, that meets the requirements for the sustainable transport development in any particular urban area [8, 9, 10]. Rail systems must meet the capacity needs, modern demands for transportation of all passenger categories and control of the impact on the environment throughout the entire life cycle (noise, vibration, engaged space, electro-magnetic radiation, stray currents, etc.). The development of rail systems should be performed with the creation of transportation chain, which must provide "door to door" transportation of passengers. This principle implies the interchange between urban and remote traffic, and implementation of integrated timetables and billing system. For the realization of these goals, rail routes that are independent in the relation to other transportation modes are necessary. Collisions with other transportation modes, if any, should be minimal and limited, with adequate superstructure and substructure, and associated services that meet the needs of all passenger categories [11].

The types of superstructure is determined for each specific case and have to be designed in a way that maximizes positive economic impact and minimizes negative impact on the environment.

In general, application of track superstructure with ballast bed is limited in the urban environment.

Ballastless tracks have economic and environmental benefits in an urban environment in the long term.

Ballastless tracks with continuous elastically supported rails have relatively less noise emission and maintenance costs comparing to tracks with discrete elastically supported rails.

ACKNOWLEDGEMENT

This work is the result of research in preparation of diploma thesis “Infrastructure of Urban Rail Systems" on the Faculty of Civil Engineering, University of Belgrade. I would like to express my great appreciation to mentor Zdenka Popovic and assistant Luka Lazarevic for help and support in the preparation of thesis.

REFERENCES

[1] Popović Z., Puzavac L., Lazarevic L., *Passenger railway in Serbia – state of the art and potential*, Technics Technologies Education Management, Volume 8 , Number 3 , 2013.

[2] Vićentić I., *Infrastruktura površinskih gradskih šinskih sistema*, diplomski rad, Građevinski fakultet, Beograd, 2014.

[3] GSP Beograd, *Pravilnik za projektovanje, građenje i održavanje tramvajskih pruga u Beogradu*, Beograd, 2004.

[4] Ministarstvo građevinarstva, saobraćaja i infrastrukture, *Zakon o bezbednosti saobraćaja na putevima*, Službeni glasnik RS, 41/2009, 53/2010, 101/2011 i 32/2013.

[5] Popović, Z., *Gornji stroj železnica*, Građevinski fakultet, Podgorica, 2007.

[6] Popović, Z., *Konstrukcije koloseka na čvrstoj podlozi*, monografija, Građevinski fakultet, Beograd, 2010.

[7] Popović, Z., *Konstrukcije koloseka na čvrstoj podlozi*, Građevinski kalendar, br.43, 2011.

[8] Popović, Z., Lazarević L., *Uloga železnice u evropskoj saobraćajnoj politici*, Izgradnja, vol. 67, br. 7-8, 2013.

[9] Popović, Z., Puzavac, L., Lazarević, L., *Kontrola buke u dodiru točka i šine*, Ecologica, vol. 18, br. 63, 2011.

[10] Popović, Z., Puzavac, L., Lazarević, L., *Šinski sistemi i zaštita urbanog okruženja od buke*, Ecologica, vol. 18, br. 63, 2011.

[11] Popović, Z., Stevanović, K., Puzavac, L., *Railway terminals: Accessibility for persons with reduced mobility*, Spatium, br. 20, 2009.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

THE ISSUE OF PERFORMANCE MANAGMENT SUCCESS IN SERBIAN RAILWAYS COMPANY

Aleksandar BLAGOJEVIĆ [1]
Radmila ČURĆIĆ [2]

Abstract – *Performance Management is a continual process which follows, evaluates and increases the contribution of employees to overall success in achieved goals of an organization in a defined time period. It is one of the main aspects of managing human resources, Performance appraisal being the most important part in that process. In order to have an effective success management in a workplace, it is necessary to have developed systems as well as update and evaluation indicators and methods for work success. The purpose of this paper is to analyse global principles of work success management as well as certain specific aspects related to railway activities.*

Keywords – Management of success, railway traffic.

1. INTRODUCTION

Several theoreticians have dealt with the issue of Performance management. Those are D. Vujić, B. Bogićević Milikić, S. Ćamilović, B. Čukić, V. Zimonji, V. Stefanović, Ž.Pržulj and others. Other theoreticians in former Yugoslavia also dealt with the same issue: J. Brekić, F. Bahtijarević Šiber, N. Pološki, D. Pupavac, S. Marušić and others. Numerous foreign experts have also written theoretical expositions on the issue, such as H.K.Bernadin, J.E.Russell, M.Armstrong, A.Baron, E. Lawler and V.H. Vroom. Numerous managers have also exposed their views on the topic.

Performance success on the part of employees means a continual follow-up, evaluation and direction of the work outcomes and behavior based on an annual formalized and structured procedure, whereas the basic goal of management would be to achieve strategic obejectives as set by an organization via enahced performances from employees. Performance success also entails regular systematic check and performance evaluation by employees in a short time period, usually a month, with the purpose to establish income levels that are based on performances which can be measurable achievements.

2. PERFORMANCE FOLLOW-UPS AND EVALUATION AS A FORMALIZED AND STRUCTURED PROCEDURE TO MEASURE SUCCESS

Follow-up and evaluation of performances by employees as a formalized and structured procedure to measure performance management is a system which encompasses management activities and instruments which allow for achievement of success goals and company's strategic objectives. That system is shown in the figure below.

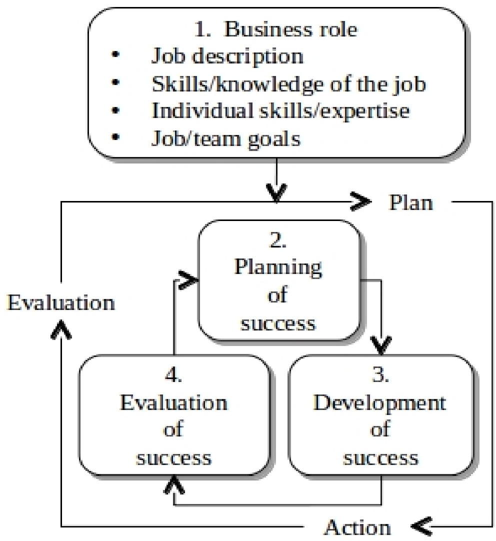


Fig.1. System of managing success [1]

[1] Aleksandar BLAGOJEVIĆ, JSC Serbian Railways,Novi Sad, aca.vucans@gmail.com.
[2] Radmila ĆURČIĆ, High School of Professional Studies for Traffic Management, Niš, radmilica.75@gmail.com

Performance management is a part of human resources managment which falls under strategic managment. It has two important functions, evaluational and developmental. Evaluational function is being achieved by selecting and securing „the right persons“ to accomplish strategic plans, as well as to enhance management methods. Developmental function is in place for the sake of establishing goals and development plans, analyzing educational and developmental needs of employees and improving future successful work.

Follow up means a contiual evidence of performance of all employees in a company be achieved measurable result in a defined time period, or be it personal characteristics needed to perform certain activities. Follow up is carried out for the sake of greater work efficiency and overall work success, as well as to achieve developmental goals as set by an organization. It is also carried out for the sake of employees, so that they might obtain feedback on their work being a basis for just reward, professional improvement and career development.

Evaluating employees' performances is a „process whereby their contribution to achievement of organizational goals in a defined time period“ is established [1]. Performance or work outcomes is a „measurable result which has been achieved, or acting and personal characteristics necessary for certain activities in a defined time period“ [2]. In all of this it is very important to have exactly and precisely defined work effects that are thought of when perfomance success is a subject to evaluation so that fair and realistic evaluation can be provided by evaluators. When it comes to human resources management, it is usual practice to use the following relevant work dimensions as the most frequent subjects of evaluation.

Industrial psychologists also take similar criteria as basis to establish work success: individual personality, capabilities and personal traits, work results, organizsational behavor characteristics, accomplishment of objectives, cooperant's potentials and so forth [4]. As far as evaluators are concerned, those could be immediate managers and most frequently they are, as well as colleagues, then employees themselves. When it comes to service orientied activities, evaluators could be both customers and clients. Recently, the worldwide companies have been applying a multiple evaluation concept called „360 degrees“. Evaluation method a company would opt for depends on numerous factors, such as organization's size, type of work, organization design, management style, organization culture, desired information and so on.

Different methods are employed in evaluation process. Basically, all such methods could be classified in three groups: comparison methods, evaluation ladder methods and „check list“ methods. These methods differ in how they are applied, in levels to which they are developed and in their advantages and disadvantages.

Table 1. Six work dimensions that might be subjected to evaluation [3]

No.	Dimensions
1.	Quality: degree to which a process or result of a certain activity approaches perfection, that is an ideal way to perform certain activities.
2.	Quantity: Manufactured or sold amount as expressed either in financial value, unit numbers, or number of completed cycles of an activity.
3.	Keeping within the deadline: weather an activity was finished in a given time, or within the earliest desirable deadline from a perspective of coordination with other activities and maximizing time which is necessary for other activities.
4.	Expenditure efficacy: degree to which usage of organization's resources has been minimized to achieve maximal results or diminish losses.
5.	Need for supervision and instructions: degree to which an employee is able to independently perform work not only without having advice from his immediate superior, but also without a necessary intervention to prevent employee's mistakes.
6.	Interpersonal influence: degree to which an employee promotes feeling of self-satisfaction, good will, cooperation with colleagues and leadership.

In practice, unclear standards are often basic problem when it comes to evaluating work performances. That leaves a room to evaluator's subjective estimations. Also, typical evaluation mistakes are hallo effect mistakes, central tendency mistakes, mild or stern stance toward an employee, methaforical generalization and so on. It is therefore necessary always to strive to avoid any mistakes and achieve maximal objective attitudes and fairness in suggested evaluation grades.

Evaluation cycle is contined by the last magangement stage - „feedback interveiw“. Such interview is a discussion between manager-evaluator and employee, which is a particulary important part in performance success management. The purpose of such dissusion is to provide a feedback to employees related to their work and recommendations on improving their performances in the next evaluation cycle so that employees would increase both personal and collective work success and achieve both their personal goals and goals of the organization in the next evaluation period.

Performance management is a complex process. In order for it to be effective, it is necessary that all stages of that process be done with a good quality. That is to say, all preparations should be carried out properly: establish the goals of performance management and standards, follow up, selection of evaluation methods, competence and objectivity on the part of evaluator, effective discussion with employees on success and so on.

All those preparations should have significant positive effects. The most important effects are increased motivation, greater fairness in determination of income levels, planning employees training programs, achievement of organization's goals and so on. That is why performance management requires both motivated managers and employees.

3. GRADES OF SUCCESSFUL EARNING BASED ON PERFOMANCE APPRAISAL

Achieved performances represent a basis for evaluating comparative individual contribution to organization's objectives and performances based incomes. Beside the system of basic income that is determined based on the value of job done by an individual, worldwide companies today use a system by which performance of all employes is being evaluated. Thus, the extent of the overall income is tied to achieved performances, in accordance with so-called „new approach to establish levels of income" [6].

The objectives which an organization wants to achieve by tying incomes for achieved performances are to motivate employees by establishing a direct link between achieved perfomances and income levels, as well as to achieve organization's strategic goals by rewarding performances that are in the function of adopted strategy, send a message to employees about desired performances and others. Such a concept is based on Vrum's theory of expectancy. It is one of the most popular motivation theories which says in essence that there is a direct and visible link between perfomances of employees and the levels of income [7].

Incomes based on achieved performances might be short term and long term stimulations. Stimulations are rewards and incentives for achieved effects, while management of incomes, that is stimulations and rewarding, belong to basic processes in human resources management. In developed market economies the short term stimulations that companies apply in their work are raises, bonuses, special rewards and various individual and collective rewards. At the same time, long term stimulations mean participation in ownerships, options, gifts, rights to profit from rising action prices and others. Only a limited number of companies in Serbia have such elaborate rewarding system that is applied for acheived performances.

4. PERFORMANCE MANAGEMENT IN RAILWAY TRAFFIC

The area of work relations, which involves criteria and standards for evaluating work effects on the part of employees is also regulated in Serbia by the law on employment and collective contracts. When it comes to railway traffic in the Republic of Serbia, the practice is that basic income is achieved based on criteria used in a measuring quality, volume of performed work and employee's attitude about work requirements. Income is determined by having a basic profit as a product one hour work price worth, coeficient of work according to work contract and time spent at work in a prescribed time.

Changeable part of income, that is increse of basic earning as the most important form of short term stimulation is formed based on evaluation criteria for work performances. Those are: volume of performed work compared to planned work volume, quality of performed work, carring work out within established deadline, effective usage of work time, attitude about work, means of work and savings in the area of material expenditures. Top management decisions define criterias and standards. There are altogether 14 standards that are defined by employees' acheived performances in a defined time period for a month. Work effects are evaluated by immediate supervisors. Other evaluators are not planned for. The immediate supervisors also suggest rewards.

By comparing that criteria with six work dimensions as displayed in Table 1, it can be established that a number of dimensions in the table, such as „quality", „quantity", „keeping within the deadlines" also come as subjects of evaluation in railway traffic in Serbia. As far as other dimensions are concerned, a comparative analyses might reveal that „interpersonal influeces" dimension corresponds to „attitude about work", while dimension caled „expenditure efficacy" corresponds to criteria „savings in material expenditures and attitude to the means of work". On the other hand, dimension called „need for supervision and instructions" is not even provided as a subject to be evaluated. This is justified since work technology as well as work operations in the sphere of railway traffic are strictly standardized and formalized being obligatory actions that are precisely defined by numerous instructions and standards so that employees are not allowed any personal improvisations and/or unverified innovations. For that reason there is a „school" – a program of continual training for engineers and other staff. At „school“ they are systematically introduced to new internal instructions and current orders to all work operations that are in place for the sake of functional traffic and transportation of stocks and passengers.

Railways system is an orthodox, hierarchical one, thus technological discipline in that area must be absolute due to a high risk caused by any deviation from standards and defined work regulations. Precise regulations belong to specific traits of railways and are significant for the process of employee performance evaluations.

Performance management system in railways also has other specific characteristics that stem from work technology which is also specific to railways. Railways technology certainly affect employees in their performances. Those specific technological forms are particularly related to „quality“ and „quantity“ dimensions, as well as the dimension of „keeping the deadlines“. There are also other specific aspects to railway performances. Namely, outcomes and work effects that refer to quality, quantity and keeping deadlines in the railways to a large extent are not under direct control of the performers since there are numerous external factors that affect their performances. For example, the railway infrastructure in Serbia has been run out. Besides, there are frequent failures in transportation and traction vehicles. Railway services timetables, as well as keeping within the deadlines, often depend on other factors from the general traffic. The aforementioned factors affect performance, results and work behavior of employees who are subjected to evaluations. On the other hand, railways have another unique feature: there is no need for direct supervision and instructions, as has been explained above.

Speaking in general terms, performance management is certainly one of the most important aspects in human resources management of railways activities. Therefore it is important that salary system based on performances be further developed so that employees would display maximal devotion to both the company and improvements in their work. These two aspects are the most important preconditions to achieve strategic objectives.

4. CONCLUSION

Based on the above survey, we may conclude that Performance Menegement system represents a basis for overall success of an organization, as well as for actual achievement of its strategic objectives. Domestic companies that have not yet adopted this system to a satisfactory level should udertake all the necessary activities to develop it because such a system is in the interest of both organizations and individuals. This is certainly true to the current railways system in the Republic of Serbia.

REFERENCES

[1] Барјактаревић, Ф.Б: (1999), Менаџмент људских потенцијала, Голден Маркетинг, Загреб.

[2] Вујић, Д: (2008), Менаџмент људских ресурса и квалитет, Центар за примењену психологију, Београд.

[3] Source: Bernardin, J.H., Russell, J.E., Human Resource Management: An Experiental Approach, Irwin McGraw-Hill, 1998.

[4] Богићевић Миликић, Б: (2010), Управљање људским ресурсима, ЦИД, Економски факултет, Београд.

[5] Armstrong, M., Baron, A: (1998), Performance Management: Thenew reallies, Institute of Personnel and Development, London.

[6] Bernadin, H.K., et. all. (1995), Performans appraisal desing, development and implementation, in Handbook of Human resource Management, ed.G.R.Ferris, S.D. Rosen and D.J. Barnum, Blackwell, Cambridge, Mass.

[7] Vroom, V.H: (1964), Work and Motivation, Wiley, New York.

[8] Furnham, A: (2004), Performance Management systems, Europen Business.

[9] Kolektivni ugovor za JP „Železnice Srbije“, Službeni glasnik Republike Srbije, razni brojevi, Beograd.

XVI SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '14

THE EFFECT OF AGING TEMPERATURE ON SILICA REINFORCED POLYISOPRENE/ CHLOROSULPHONATED POLYETHYLENE RUBBER BLEND IN RAILWAY INDUSTRY

Gordana MARKOVIĆ [1]
Milena MARINOVIC-CINCOVIĆ [2]
Vojislav JOVANOVIĆ [3]
Suzana SAMARŽIJA-JOVANOVIĆ [3]
Jaroslava BUDINSKI-SIMENDIĆ [4]

Abstract *– The effect of thermal aging test under different temperatures was carried out to investigate the effect of aging temperatures on the tension properties of rubber blend composites based on polyisoprene (NR) and chlorosulphonated polyethylene rubber (CSM) (NR/CSM=80:20) compounds filled with different silica (Si) loading. The obtained results of six different compositions for NR/CSM rubber blend with 0, 20, 40, 60, 80 and 100 phr of silica were analyzed. Tensile and tear strength of the compounds decreases with temperature of aging increases. Changes in these properties can be approximately correlated with changes in structure only at high temperature. In general, retention of properties of NR/CSM rubber blends is the best. The properties after aging do not exclusively depend on the network structure, nature of cross-link, rank of sulfur, or pendant or cyclic sulfide. The backbone structure is important in all these cases. Possible application in suspension of railway vehicles can be expected.*

Keywords - NR/CSM rubber blend composites; silica; thermal aging, railway industry.

1. INTRODUCTION

Rubber blends have gained much attention in the railway industry because, when properly formulated, the blend could combine the best features of the individual blend partner. Desirable outcome is therefore easily obtained [1]. Natural rubber (NR) is widely known to possess good mechanical properties such as high tensile and tear strengths due to its ability to crystallize upon stretching. The elasticity and dynamic properties of NR are also excellent. However, due to the existence of numerous reactive double bonds on the molecular backbone, NR is highly susceptible to degradation by thermal aging and ozone attack [2]. The introduction of chlorine and sulfur dioxide onto the polyethylene linking via condensation or substitution reactions molecule destroys the crystallinity, thereby changing the thermoplastic material into an amorphous polymer, commercially known as chlorosulphonated polyethylene (CSM), which contains 25–43% by weight of chlorine and 1–1.5% by weight of sulfur as SO_2Cl units. Thus, CSM rubber is highly reactive, and reactivity is due to the SO_2Cl groups [3].

Different types of additives used in processing of rubber into products include a vulcanizing agent's accelerator, an activator, antidegradants, fillers, a softener, thickeners, a gel sensitizer, a colorant,etc. Fillers modify physical and, to some extent, chemical properties of rubber composites. It has currently been reported that precipitated silica, widely used as reinforcing filler for most rubbers, could form strong interaction with CR through hydrogen bonds [4].

In the present study, the effect of aging temperature on properties of silica-filled NR/CSM rubber blend composites was investigated as a possible application in suspension of railway vehicles. The mechanical properties as well as the resistance to aging of the blends were focused.

[1] Gordana MARKOVIĆ, Tigar, Nikole Pašića 213, 18300 Pirot, Serbia; gordana1markovic@gmail.com
[2] Milena MARINOVIC-CINCOVIĆ, Institute of Nuclear Science Vinča, Mike Petrovića Alasa 12-14, 11000 Belgrade, Serbia; milena@vinca.rs
[3] Vojislav JOVANOVIĆ, Suzana SAMARŽIJA-JOVANOVIĆ, Faculty of Natural Science and Mathematics, University of Priština, Lole Ribara 29, 38220 Kosovska Mitrovica, Serbia; vojani@sbb.rs
[4] Jaroslava BUDINSKI-SIMENDIĆ, Faculty of Technology, University of Novi Sad, Bulevar Cara Lazara 1, Novi Sad, jarkamer@gmail.com

2. EXPERIMENTAL

The NR/CSM rubber blend compounding recipes are given in Table 1. The cure characteristics of rubber compounds were carried out using an Oscillating Disc Rheometer (ODR) model ALPHA ODR 2000 according to IS0 3417 at 448K.

The tensile properties were determined using the tensile testing machine type Zwick 1445 according to SRPS.G.S2.127. The average value of the mechanical properties was calculated using at least three samples. A cross head speed of 500 mm/min was used and the tests were performed at 298K.

Table 1. Formulation of the composites based on NR/CSM/silica rubber blends.

Compounding (phr)*	1	2	3	4	5	6
NR	80	80	80	80	80	80
CSM**	20	20	20	20	20	20
Silica	0	20	40	60	80	100

*Phr, parts per hundred,**Compounding (phr): Stearine 2, Naphtene oil 10, MgO 4, TMTD 2, Sulphur 1.

Samples of at least 0.12 mm in thickness with flat surface were cut for hardness test. The measurement was carried out according to SRPS.G.S2.125 using durometer of model 306L type. The unit of hardness is expressed in (Shore A).

To determine the deterioration of the mechanical properties of rubber blend composites after aging in Geer's oven, a circulated air oven (Thermolyne-oven series 9000) is used. Place the specimens for aging in the oven after it has been preheated to the operating temperature. Then the oven temperature adjusted to the operating temperature (298, 348, 373, 398 K during 48h). At the termination of the aging interval (48 h), remove the specimens from the oven, cool to room temperature on a flat surface and allow them to rest not less than 16 h or more than 96 h before determination of the physical properties.

3. RESULTS AND DISCUSSION

3.1 Cure characteristics

The cure characteristics: the torque evolution, the scorch time ts_2, optimum cure time t_{c90} and the cure rate index (CRI) of silica reinforced NR/CSM rubber blends are shown in Table 2.

However, in CSM, the rubber-filler interaction is relatively high because CSM contains chlorine atoms which could interact strongly with the silanol groups on silica surface. The degree of filler dispersion in CSM is there-fore higher than that in NR.

Table 2. Rheometric characteristics of NR/CSM/silica rubber blends.

Sample	1	2	3	4	5	6
M_l (dNm)	5	5	5	5	5	5
M_h (dNm)	27	29	31	34	35	35
ΔM (dNm)	22	24	26	29	30	30
t_{s2} (min)	7	7	7	8	9	9
t_{c90} (min)	8	8	8	9	9	9
CRI	1	1	1	1	0	0

It is widely known that the double bonds in NR are more reactive to vulcanization reaction than those in CSM and the non-rubber content in NR could also accelerate cure, NR therefore possesses significantly shorter scorch time and optimum cure time, compared to CSM.

3.2 Mechanical properties

There have been several methods developed to monitor the aging condition of rubbers. Tensile strength and elongation at break testing are two parameters often found to be the most direct and useful indicators of the remaining mechanical properties [5]. The results of thermal aging test are represented in Figs. 1–4.

Fig. 1 shows tensile strength curves for NR/SBR rubber vulcanizates filled with different silica loading at room temperature 298K and with different aging temperature at 348, 373 and 398 K. From these figures it is clear that at the beginning of the tension test for small content are come close for each type of filled compounds at different aging temperatures, while as tensile strength values increase from each other. Also, the shapes of curves were not change due to the thermal aging.

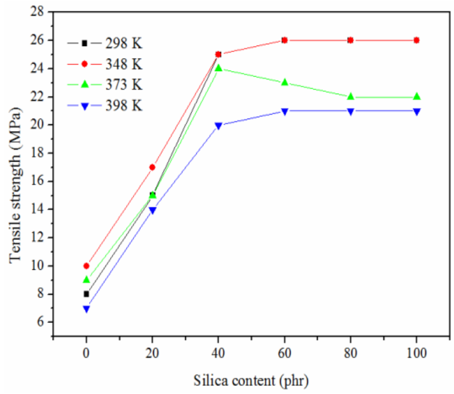


Fig. 1. Variation of the tensile strength versus silica content for filled NR/CSM rubber blend vulcanizates under different aging temperatures.

Figs. 2 and 3 show the effect of aging temperatures on the 300% modulus and the elongation at break under different silica loading for NR/CSM (80:20) rubber blend vulcanizates, respectively. It can be found that due to thermal aging both the 300% modulus and elongation at break decreases. This is due to the oxidative degradation developed very rapidly leading to this marked decrease. This phenomenon is more pronounced as the aging temperature increases. It is evident from these figures that unfilled vulcanizates has low resistance (300% modulus) towards aging as compared with the loaded samples. This detectable resistance was increased with increasing silica loading up to 40phr, which may be attributed to the fact that silica stopped the oxygen uptake of sulfur-cured rubber and slower reaction of rubber degradation can be noted.

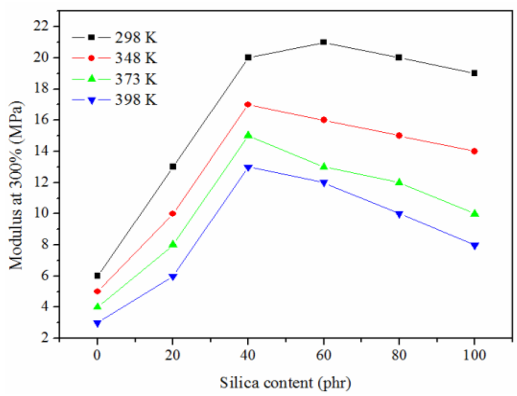


Fig. 2. Variation of the modulus at 300% elongation versus silica content for filled NR/CSM rubber blend vulcanizates under different aging temperatures.

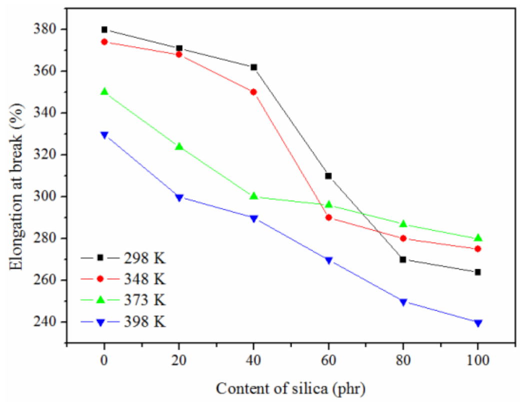


Fig. 3. Variation of the elongation at break versus silica content for filled NR/CSM rubber blend vulcanizates under different aging temperatures.

As silica is highly polar filler whereas NR is considered as a non-polar elastomer, and CSM is considered as a polar elastomer [6] (which is 20 phr presented in blend), the rubber-filler interaction is therefore relatively low. On the contrary, the hydroxyl and silanol groups on silica surface could form hydrogen bonds towards each other resulting in a strong filler-filler interaction. Disagglomeration of silica is therefore more difficult to take place leading to poor filler dispersion.

It can be found that silica filled NR/CSM rubber blend compound (80/20/40) has more resistance to thermal degradation compared with other filled compounds due to the high rubber–filler interaction and the presence of SO_2Cl groups in the CSM rubber.

Fig. 4 shows the variations of hardness versus aging temperatures for NR/CSM with different silica loading.

It can be first observed that the measurements are generally very consistent demonstrating that the use of the hardness test is both sensitive and repeatable enough to detect the thermal degradation. It is clear that the hardness value increases as aging temperatures increases. This is due to the high crosslinks formation and the oxidizing skin which results from oxygen uptake at the surface of the specimen [7]. So, the increase in aging temperature results in increasing the hardness of all types of vulcanizates. This increase in hardness as aging temperature increase is nearly representing a linear relationship. At a give silica loading, hardness of NR/CSM filled vulcanizates is clearly greater than those in unfilled rubber blend vulcanizates due to the high rubber–filler interaction.

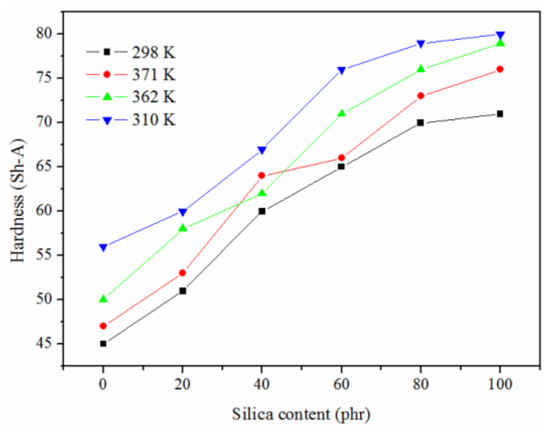


Fig. 4. Variation of the hardness versus silica content for filled NR/CSM rubber blend vulcanizates under different aging temperatures.

4. CONCLUSIONS

From the current investigation of thermal aging behavior of NR/CSM rubber blends composites filled with different silica loading as a possible application in suspension of railway vehicles the following conclusions were derived from the experimental results.

(1) Due to the thermal aging the 300% modulus, the tensile strength and elongation at break for NR/CSM/silica filled composites decrease. This is due to the oxidative degradation

developed very rapidly leading to this marked decrease. This phenomenon is more pronounced with the increase of aging temperature.

(2) The silica filled NR/CSM rubber blends composites have more resistance (tensile strength and 300% modulus) towards aging as compared with the unfilled rubber blend. This detectable resistance was decreased with increasing aging temperature. This may be attributed to the fact that filler-filler interactions are predominately and the oxygen accelerates uptake of sulfur-cured rubber and the reaction is accompanied by a rapid degradation of rubber.

(3) CSM rubber is more resistance to thermal degradation compared with nr rubber due to the high rubber–filler interaction and the presence of SO_2Cl group.

As silica loading increase the hardness values increase as a result to increase in cross linking which make the rubber blend vulcanizates more rigid. At given silica loading, hardness of rubber blend vulcanizates is clearly greater than unfilled due to the rubber–filler interaction.

ACKNOWLEDGEMENT

Financial support for this study was granted by the Ministry of Science and Technological Development of the Republic of Serbia (Project Numbers 45022 and 45020).

REFERENCES

[1] A. Das., A.K. Ghosh, D.K Basu., Kautschuk Gummi Kunststoffe, 58 (2005) 230–238.
[2] M.T. Ramesan., R. Alex., N.V. Khanh, Reactive &Functional Polymers, 62 (2005) 41–50
[3] G. Marković M. Marinović-.Cincović,V.Jovanović, S. Samaržija-Jovanović, J. Budinski-Simendić, Composites: Part B 55 (2013) 368–373
[4] E.V. Bystritskaya, AL Pomerantsev, O.Y. Rodionova. Polym Test 19 (2000) 221–9.
[5] G.R. Hamed, J. Zhao. Rubber Chem Technol 72 (1999) 721–30.
[6] G. Marković, M. Marinović-Cincović, V. Jovanović, S. Samaržija-Jovanović, J. Budinski-Simendić, J Elastomers Plast 4(44) (2012) 335–51.
[7] G. Marković, M. Marinović-Cincović, B. Radovanović, J. Budinski-Simendić, Curing and mechanical properties of chlorosulphonated polyethylene rubber blends, Chem. Ind. Chem. Eng. Q. 13(4) (2007) 186-191.

INDEX OF AUTHORS

A

ATANASKOVIĆ, Predrag 213
ATMADZHOVA, Dobrinka 65, 69

B

BABIĆ, Branko 197
BABIĆ, Ranko 249
BANIĆ, Milan 21
BARIŠIĆ, Darko 133
BIŽIĆ, Milan 145, 157
BLAGOJEVIĆ, Aleksandar 275
BLANUŠA, Vladimir 169
BOGDANOVIĆ, Borisav 257
BOJKOVIĆ, Nataša 173
BOŠKOVIĆ, Branislav 185, 201
BRANOVIĆ, Irina 149
BUDINSKI SIMENDIĆ, Jaroslava 279
BURSAĆ, Marko 73, 97

C

CEROVIĆ, Nataša 185

Č

ČURĆIĆ, Radmila 275

Ć

ĆIRIĆ, Ivan 53
ĆOJBAŠIĆ, Žarko 53
ĆURČIĆ, Nebojša 197

D

DIMANOSKI, Kire 61
DIMITRIJEVIĆ, Jelena 161, 225

Đ

ĐORĐEVIĆ, Boban 189
ĐORĐEVIĆ, Dragan 177, 217
ĐORĐEVIĆ, Života 149
ĐORIĆ, Danijela 185
ĐUKIĆ, Marko 57
ĐURĐANOVIĆ, Dragan I

DŽ

DŽUDOVIĆ, Mirjana 141

E

EVLOGIEVA, Zornitsa 49, 245

G

GEORGIEVA, Kalina 25, 33
GRENČÍK, Juraj 233

I

IONTCHEV, Emil 65
IVANOVIĆ, Dragan 101

J

JAKOVLJEVIĆ, Živana 17
JANKOVIĆ, Slađana 149
JANOŠEVIĆ, Dragoslav 241
JEREMIĆ, Dušan 73, 97
JEROSIMIĆ, Ljuban 117
JEVTIĆ Nenad 237
JOKANOVIĆ, Dragana 141
JOVANOVIĆ, Dragan 165
JOVANOVIĆ, Dragutin 197
JOVANOVIĆ, Predrag 101
JOVANOVIĆ, Slobodan 165
JOVANOVIĆ, Vesna 113, 241
JOVANOVIĆ, Vojislav 279

K

KALINČÁK, Daniel 5, 265
KASALICA, Sandra 73, 97
KHAIRALLAH, Fadi 9
KORUNOSKI, Igor 61
KOSTIĆ, Dragutin 93, 237
KOVAČEVIĆ, Miloš 181
KRASTEV, Mario 193
KRASTEV, Oleg 29, 193
KRIVOKAPIĆ, Milutin 257

L

LAZAREVIĆ, Luka 137, 181
LEERMAKERS, Bas XVII
LUČANIN, Vojkan 1
LUKOVAC, Vesko 89

M

MADIĆ, Miloš 129
MAKSIĆ, Goran 81
MANDIĆ, Dragomir 101, 205
MARIĆ, Siniša 213
MARINOVIĆ CINCOVIĆ, Milena 279
MARKOVIĆ, Gordana 279
MARKOVIĆ, Petar 237
MIHAYLOV, Emil 49, 65
MIKIĆ, Tatjana 117
MIKOLAJČÍK, Martin 5, 265
MILČIĆ, Dragan 229
MILKOVIĆ, Dragan 1, 17
MILOŠEVIĆ, Miloš 21, 261
MILTENOVIĆ, Aleksandar 21
MIŠKOVIĆ, Žarko 1
MITROVIĆ, Mladen 113

MITROVIĆ, Slobodan 237

N

NAUMOVIĆ, Aleksandar 213
NEDELJKOVIĆ, Branka 209
NEŠIĆ, Dragan XVII
NIKOLIĆ, Boban 129
NIKOLIĆ, Vlastimir 53
NIKOLOV, Vasko 37

P

PAMUČAR, Dragan 89
PAREZANOVIĆ, Tanja 189
PAVLOVIĆ, Ivan 53
PAVLOVIĆ, Jovan 241
PAVLOVIĆ, Nenad 253
PAVLOVIĆ, Zoran 221
PEJČIĆ TARLE, Snežana XI, 173, 189
PEŠIĆ, Jovica 261
PETKOVIĆ, Dušan 161, 225
PETROVA. Vanushka 245
PETROVIĆ, Dragan 145, 157
PETROVIĆ, Emina 53
PETROVIĆ, Jelena 113
PETROVIĆ, Marija 85
PETROVIĆ, Marijana 173
PETROVIĆ, Nikola 113, 189
PETROVIĆ, Predrag 85
PETROVIĆ, Živojin 85
PLANIĆ, Slaviša 165
POPOVIĆ, Milan 141
POPOVIĆ, Zdenka 137, 181, 271
POROJANOVA, Nikolina 121
PURGIĆ, Sanel 25, 29

R

RADENKOVIĆ, Goran 161
RADOVIĆ, Zorica 209
RADULOVIĆ, Saša 257
RAJILIĆ, Snježana 81, 149
RAJKOVIĆ, Dragan 153
RAKIPOVSKI, Erdinč 229
REDŽOVIĆ, Vladimir 77
REMUS, Tomasz 125
ŘEZNÍČEK, Rudolf 265
ROSIĆ, Slobodan 93
RÜGER, Bernhard 13, 45
RUMAN, František 233

S

SAMARŽIJA JOVANOVIĆ, Suzana 279
SCHÖBEL Andreas 105
SIMIĆ, Goran 17
SIMIĆ, Tatjana 117
SLAVCHEV, Svetoslav 25, 33
STAMENKOVIĆ, Dušan 21, 205
STANKOVIĆ, Ivan 253
STEVANOVIĆ HEDRIH, Katica 41
STOILOV, Valeri 25, 33
STOILOVA, Svetla 109, 267
STOJADINOVIĆ, Nikola 201
STOJIĆ, Gordan 81
STOEV, Veselin 109

T

TANASKOVIĆ, Jovan 1, 17
TJUPA, Ljubiša 261
TOMIĆ, Miša 21
TOMIĆ, Vojislav 129, 261
TOMOVIĆ, Nena XI, 189
TRIČKOVIĆ, Goran 73, 97

U

UL HAQ, Asad I

V

VALKOVA, Snejana 121
VASILJEVIĆ, Marko 81
VASIN, Ljubislav 89
VELKOV. Kiril 29, 193
VESKOVIĆ, Slavko 81, 149
VEŠOVIĆ, Vujadin 197
VICENTIĆ, Ivana 271
VIDUKA, Zvonimir 133
VILOTIJEVIĆ, Milica 137
VRTANOSKI, Gligorche 61
VUKMIROVIĆ, Slobodan 85
VUKŠIĆ POPOVIĆ, Marija 257
VULEVIĆ, Ana 217

Z

ZELJKOVIĆ, Milan 169

Ž

ŽIVKOVIĆ, Aleksandar 169

Government of the Republic of Serbia
Ministry of Education, Science and Technological Development

SERBIAN RAILWAYS JSC
ŽELEZNICE SRBIJE

MIN
Lokomotiva a.d.

STADLER

STRAIL®

ALTPRO d.o.o.
RESEARCH - DEVELOPMENT - PRODUCTION

MINDIV

DIV
BETONSKI PRAGOVI

THALES

OPEN TRACK

ЖЕЛЕЗНИЦЕ СРБИЈЕ

МЕДИЈА ЦЕНТАР

www.zeleznicesrbije.com

Making Rail Travel Fun!

ALTPRO d.o.o.

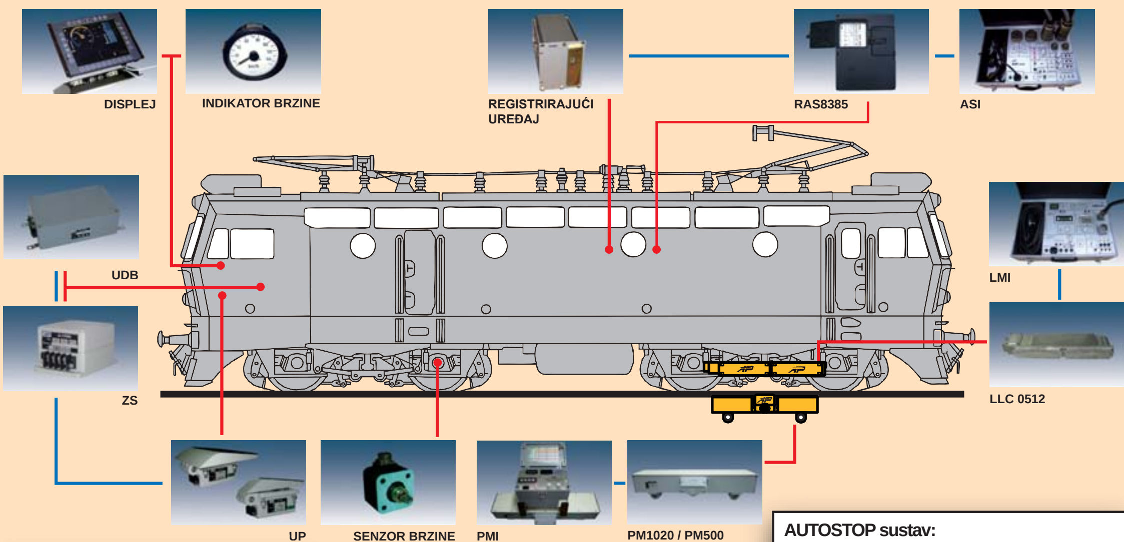
ISTRAŽIVANJE - RAZVOJ - PROIZVODNJA

INFRASTRUKTURA

SIGNALNO-SIGURNOSNI UREĐAJI

VOZILA

SIGURNOSNI UREĐAJI ZA VOZILA

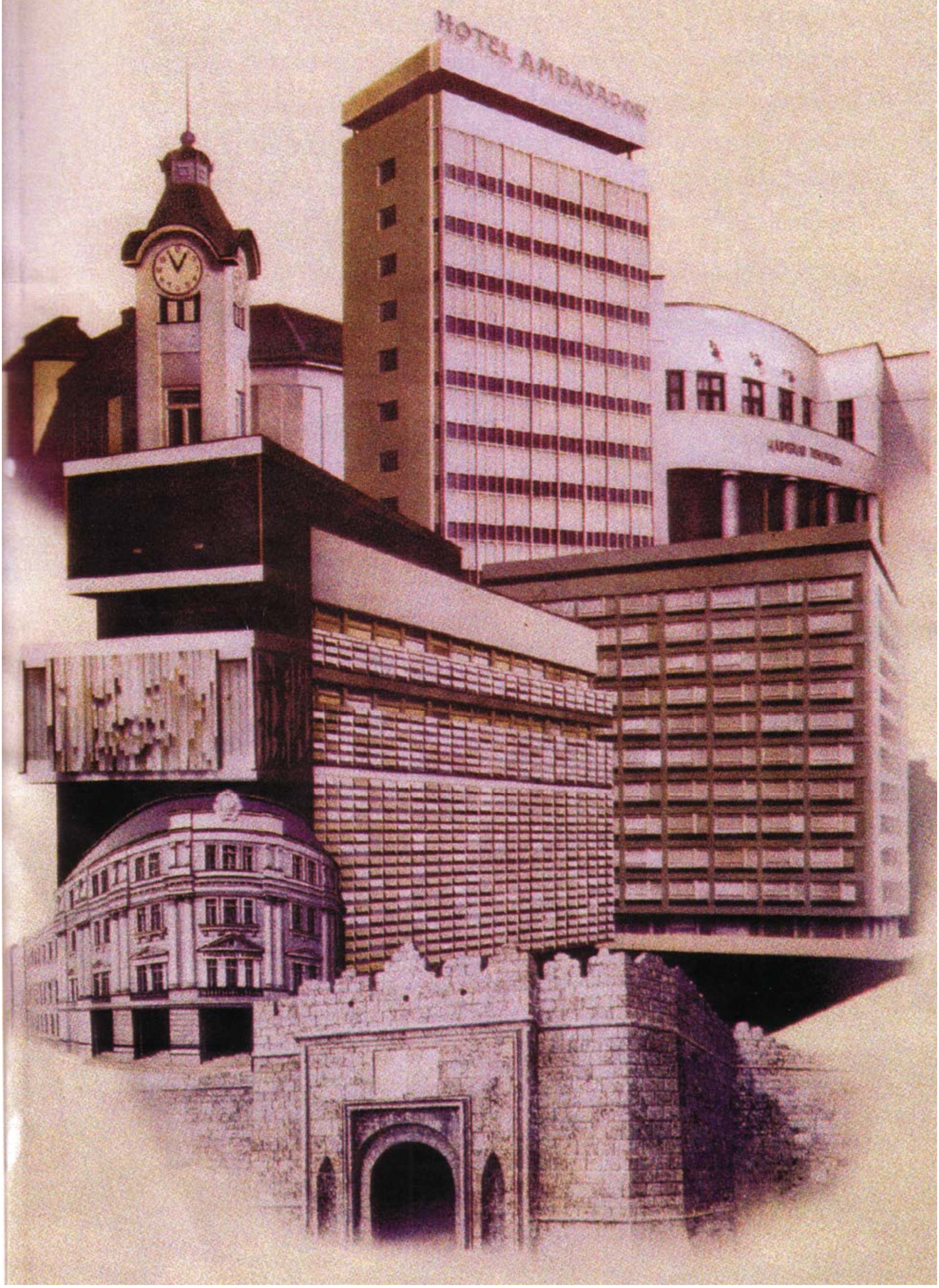


Sustav budnosti (SIFA):
Unificirani digitani budnik - **UDB**
Zvučni trotonski signalizator - **ZS**
Nožni prekidač - široki **UP1-D** i uski **UP1**

Izrada projekata sustava za različita vozila

AUTOSTOP sustav:
Centralni uređaj - **RAS8385**
Lokomotivski magnet- **LLC0512**
Pružni magnet- **PM500 i PM1020**
ASI - uređaj za testiranje RAS8385
PMI, LMI - ispitni uređaji za magnete

Velika cesta 41, 10020 ZAGREB - ODRA, HRVATSKA
Tel: +385 1 6011 700 * Fax: +385 1 3666 078 * E-mail: altpro@altpro.hr * Web: www.altpro.com


HOTEL AMBASADOR