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Plenary Session

INNOVATION IN LOCOMOTIVES

Andrea MAZZONE [1]

Summary

- Introduction - State-of-the-Art
  - Introduction to TRAXX 3 MS locomotive,
  - the newest and most powerful MS BoBo loco on the European Market (pulling capability)
  - with Last mile propulsion, Eco Modes, CBM, MDBF 600’000km/loco/year, etc.
- Performance - At the limit
  - More power
  - traction force at the physical limit, slip-slide control – never been so performant
  - efficiency reaching highest level,
  - Question: really necessary?
- Digitalization - Efficiency[2]
  - Predictive M
  - Digital maintenance (paperless, automated)
  - IoT - big data
  - Digital twin
- Automation - The next Revolution
  - GoA2 already existing
  - ATO over ETCS
  - Remote control
  - ATO while driving
  - ATO in yard operations / shunting / Last mile
  - Automated train preparation and stabling
  - GoA4 in only a few years
- Locomotives - Quo Vadis?
  - Changing market requirements (e.g. same day delivery), fierce competition on the road
  - 15 years life time
  - Cargo sprinter
  - Self propelled cargo wagons (the truck on rail)
  - Do we need a locomotive in future?

[1] Bombardier Transportation, Zürich, Switzerland, andrea.mazzone@rail.bombardier.com

SMART: A NOVEL ON-BOARD INTEGRATED MULTI-SENSOR LONG-RANGE OBSTACLE DETECTION SYSTEM FOR RAILWAYS

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Abstract *– A novel integrated multi-sensor on-board obstacle detection (OD) system has been developed within the project "SMART-SMart Automation of Rail Transport", which is funded under the H2020-Shift2Rail-RIA funding scheme. The SMART OD system combines different vision technologies: thermal camera, night vision sensor (camera augmented with image intensifier), multi stereo-vision system and laser scanner in order to create a sensor fusion system for mid (up to 200 m) and long range (up to 1000 m) autonomous obstacle detection, which is independent of light and weather conditions. In this way, SMART will make an important contribution to the long-term vision of an autonomous rail freight system.*

All SMART OD sensors are integrated into the sensor housing to enable easy mount and dismount onto/from different test vehicles in different evaluation tests. In the second project year, the integrated OD system prototype was tested in static as well as in dynamic field tests. The dynamic field tests were performed on Serbian railway test-site in July 2018 in two phases.In the first phase, the SMART on-board integrated OD system was mounted onto the SERBIA CARGO locomotive 444-018 runing without attached wagons from the "Red cross" station to the Niš Marshalling Yard in length of 3.1 km. In the second phase of the dynamic field tests, the SMART on-board integrated OD system was mounted onto the SERBIA CARGO locomotive 444-017 pulling the freight train with 21 wagons on the Pan European corridor X to Thessaloniki in the length of 120 km. Innovative SMART hardware, supported with novel machine learning-based computer vision software, enabled reliable obstacle detection in the range of up to 500m. Achieved initial results represent a good basis for further advancing of SMART software and achievement of reliable aimed long-range (up to 1000 m) autonomous detection of obstacles on the rail tracks ahead of the locomotive.

Keywords – Autonomous obstacle detection, Rail Freight, Multi-sensor on-board system.

1. INTRODUCTION

Reliable and accurate detection of obstacles is one of the challenges of safe autonomous driving. According to the Shift2Rail Multi-Annual Action Plan-MAAP [1] one key challenge, which has so far hindered automation of rail freight systems, is the lack of a safe and reliable on-board obstacle detection system for freight trains within existing infrastructure. Project SMART, which is funded under the H2020-Shift2Rail-RIA funding scheme [2], will contribute to tackling this challenge, and so contribute to the long-term vision for an autonomous rail freight system, by the development, implementation and evaluation of a prototype integrated on-board multi-sensor system for

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reliable detection of potential obstacles on the rail tracks ahead of the locomotive. The obstacle detection solution resulting from these activities should be ready for later integration into the automated freight train described in the MAAP [1]. As such, the SMART project is one of the Shift2Rail Innovation Programme 5 (IP5) projects and it will directly contribute to the expected impact set out in the Shift2Rail work program under the topic S2R-OC-IP5-01-2015 – “Freight Automation on lines and in yards”, to introduce the automation of rail freight operations.

SMART solution for autonomous obstacle-detection on rail tracks ahead of a train, which incorporates multiple sensors, is not a new solution. Different combination of sensors, such as stereo vision, mono cameras, radar and laser, were already used in related work, e. g. [3]. However, the combinations of sensors used to date achieved relatively short range obstacle detection, that is, up to 100 m. In recent years, there is also a tendency to use experience from obstacle detection both in the automotive and the aviation sector for the development of autonomous obstacle detection in railways. While the main principle of obstacle detection in front of a vehicle from the automotive sector can be applied to railway applications, there are also specific challenges. One of the key challenges is long-range obstacle detection. Sensor technology in current land transport research is able to look some 200 m ahead [4]. The required rail obstacle detection interfacing with loco control should be able to look ahead up to 1000 m detecting objects on and near track which may potentially interfere with the clearance and ground profile. The SMART project will advance state-of-the-art by developing a prototype OD system which will integrate a night vision sensor with a thermal camera, multi stereo-vision system and a laser scanner. The SMART OD system will therefore be a novel fully integrated multi-sensor on-board system for mid (up to 200 m) and long range (up to 1000 m) obstacle detection, which can operate in day and night conditions as well as in poor visibility conditions.

2. SMART HARDWARE

SMART OD system combines different vision technologies: thermal camera, night vision sensor (camera augmented with image intensifier), 3 RGB cameras that form two pairs of stereo-vision cameras of different base lines to cover different ranges and laser scanner in order to create a sensor fusion system, which effectively combines data streams from multiple sensors as sensors individually are not yet powerful enough to deal with complex obstacle detection tasks in working conditions, which include day and night operation and operation in poor visibility condition.

All SMART OD sensors are integrated into the sensor housing as shown in Fig. 1 (top). The function of the sensor housing is to enable easy mount and dismount onto/from different test vehicles in different evaluation tests. The front panel of the housing is detachable which provides easy access to the sensors. The sections of the front panel are made from the plan parallel tempered glass which provides protection for the camera sensors while maintaining the visibility. The thermal camera is protected by a circular shape Germanium glass which is transparent for infrared radiation. The used laser scanner has already a protective housing so no additional elements for its protection are introduced. At the top of the housing guiding louvers are introduced to guide the air flow from vehicle movement to the protective glass elements. The air flow speed is increased by in a nozzle like system. Such design solution will enable the functioning of the system during rain and snow as the high speed air flow sweeps the water/snow particles from the glass protective elements. The sensor housing is designed so to enable different mounting locations. Fig. 1 (bottom) shows the integrated OD system mounted on the frontal profile of the SERBIA CARGO Locomotive 444-017 above the frontal foot support directly below the headlights.

3. SMART SOFTWARE

SMART software is based on machine learning setup that provides the OD system with a method to estimate the distance from the monocular camera to the object viewed with the camera, which is possible obstacles on the rail tracks ahead of the locomotive. The applied machine learning is based on Multi Hidden-Layer Neural Network, named DisNet, which is used to learn the change in object appearance in an image (in terms of size) due to the change of the object distance with respect to camera viewing the object [5]. Fig. 2 illustrates the system architecture. The camera image is the input to the state-of-the-art object classifier YOLO (You Only Look Once) [6] trained with COCO dataset [7]. YOLO is a fast and accurate object detector based on Convolution Neural Network (CNN). Its outputs are bounding boxes of detected objects in the image and labels of the classes of detected objects. The objects bounding boxes resulted from the YOLO object classification are further processed to calculate the features-bounding boxes parameters. Based on the these features, the trained DisNet gives as outputs the estimated distance of the object to the camera coordinate system. In Fig. 2, an example of the estimation of distances of two persons on the rail tracks is shown. The final result is the displayed camera image overlaid with the bounding boxes of the detected obstacles and the estimated distances between the objects and the camera mounted on the locomotive.

Fig.1. (top) OD sensors integrated into sensor housing. (bottom) OD demonstrator mounted onto the frontal profile of the SERBIA CARGO Locomotive 444-017 during the dynamic field tests in July 2018

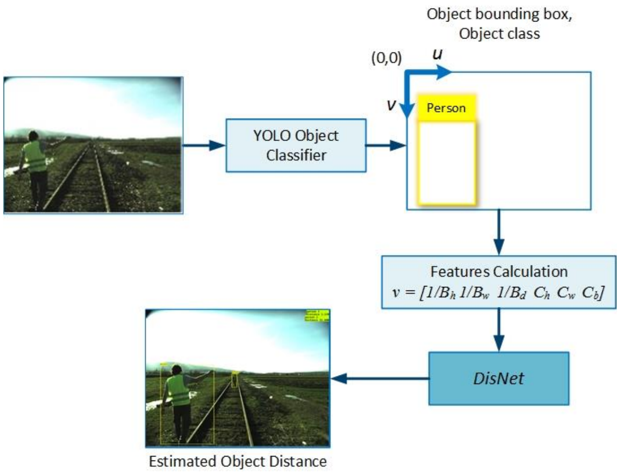


Fig.2. The DisNet -based system used for object distance estimation from a monocular camera

DisNet Training - 2000 features vectors **v** dataset was created by calculation of the parameters of manually extracted objects bounding boxes in RGB images:

B_h=(height of the object bounding box in pixels/image height in pixels);

B_w =(width of the object bounding box in pixels/image width in pixels);

B_d =(diagonal of the object bounding box in pixels/image diagonal in pixels).

Calculated features vectors, **v** have 6 coordinates

$$\mathbf{v} = [1/B_h\ 1/B_w\ 1/B_d\ C_h\ C_w\ C_b] \tag{1}$$

Besides the inverse of the above bounding boxes parameters, additional features are C_h, C_w *and* C_b that represent average height, width and breadth of the particular object class. For example for the class "person" C_h, C_w and C_b are 175 cm, 55 cm and 30 cm respectively. The images used for extraction of features vectors were captured by RGB camera (one of SMART stereo cameras). In order to achieve sufficient discriminatory information in the dataset, different objects, which could be present in a railway scene as possible obstacles on the rail tracks such as pedestrians and bicycles were recorded. The objects positions were recorded also with a 3D laser scanner simultaneously, which was placed inline with the camera, on the same distance from the imaged objects and on the same elevation as the camera.

The input dataset was randomly split into a training (80% of the data), validation (10% of the data) and a test set (10% of the data). For the training of DisNet, a feature vector **v** feed to the network the input and the output, i.e. the ground truth, was the accurate laser scanner object distance measurement in the recorded scene.

4. EVALUATION RESULTS

In the period March 2018-July 2018, the integrated OD system prototype was tested in static as well as in dynamic field tests.

4.1 Static field tests

The sensor data, which were used for the evaluation of a DisNet-based system for object distance estimation, were recorded in the field tests on the straight rail tracks in different times of the day and night on the location of the straight rail tracks. The sensor housing with SMART OD sensors integrated was placed on two tripods, representing so a static test-stand (Fig. 3). During the performed field tests, the members of the SMART Consortium imitated potential static obstacles on the rail tracks located on different distances from the SMART test-stand.

Fig.3. SMART OD demonstrator during static field-tests in March 2018

Some of the results of the DisNet object detection in RGB and thermal camera images are given in Fig. 4. The estimated distances to the detected objects (persons) are given in Table I. Shown results demonstrate long-range distance estimation of up to 500 meters. Also, the results show the advantages of multiple viewing angles due to different positioning of cameras on the test-stand. The multiple perspectives help to detect the person 4 in RGB image, which cannot be seen in the thermal image due to its position behind the person 5. Similarly, person 5 can be seen in the thermal image, but not in the RGB image.

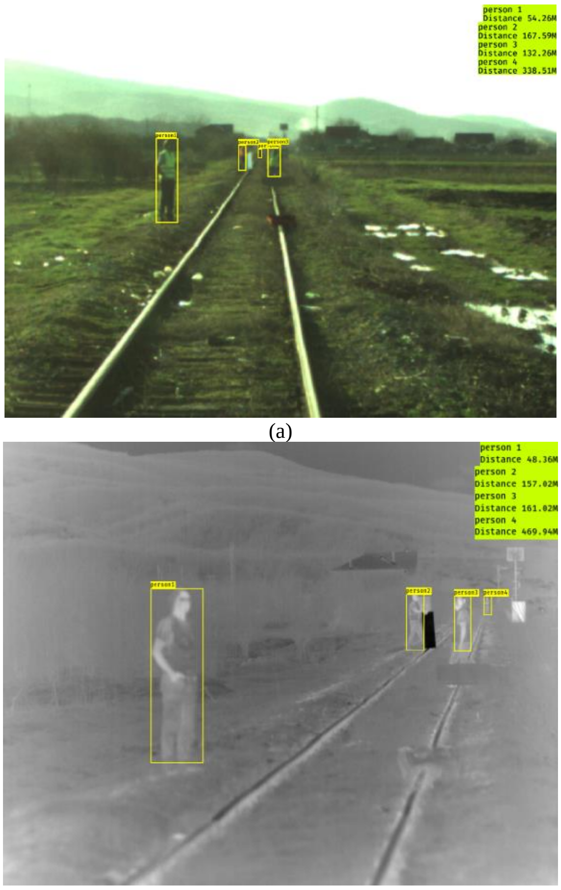
Tab. 1. Estimated distances vs. ground truth (in meters)

Object	***Ground Truth***	***RGB Camera***	**Thermal Camera**
Person 1	50	54.26	48.36
Person 2	100	132.26	161.02
Person 3	150	167.59	157.02
Person 4	300	338.51	not-visible
Person 5	500	not-visible	469.94

A significant error in estimation of the distance of the person at 100m is due to partially extracted person bounding box by YOLO object classifier as the person was ocluded with an unclassified object. In future work, bounding box extraction will be improved by a combination of YOLO, i.e. machine learning, object detection with traditional image processing based object detection. In addition, other visual features will be investigated to improve the accuracy of distance estimation.

4.2 Dynamic field tests

The dynamic field tests were performed on Serbian railway test-sites in two phases. In the first phase, the SMART on-board integrated OD system was mounted onto the SERBIA CARGO locomotive 444-018 runing without attached wagons from the “Red cross” station to the Niš Marshalling Yard in length of 3.1 km. During this field tests the members of the SMART team imitated possible obstacles on the rail tracks, crossing the rail tracks according to previously defined scenario at the safe distance from the train bearing in mind the train speed of 40km/h on the considered traks section. Some of the results of the SMART object detection and distance calculation with RGB cameras are shown in Fig. 5. Figures 5 (a)-(d) show four subsequent frames of the RGB camera video in which two persons crossing the track are reconized out of which one person is pushing the bike, which also was recognised.

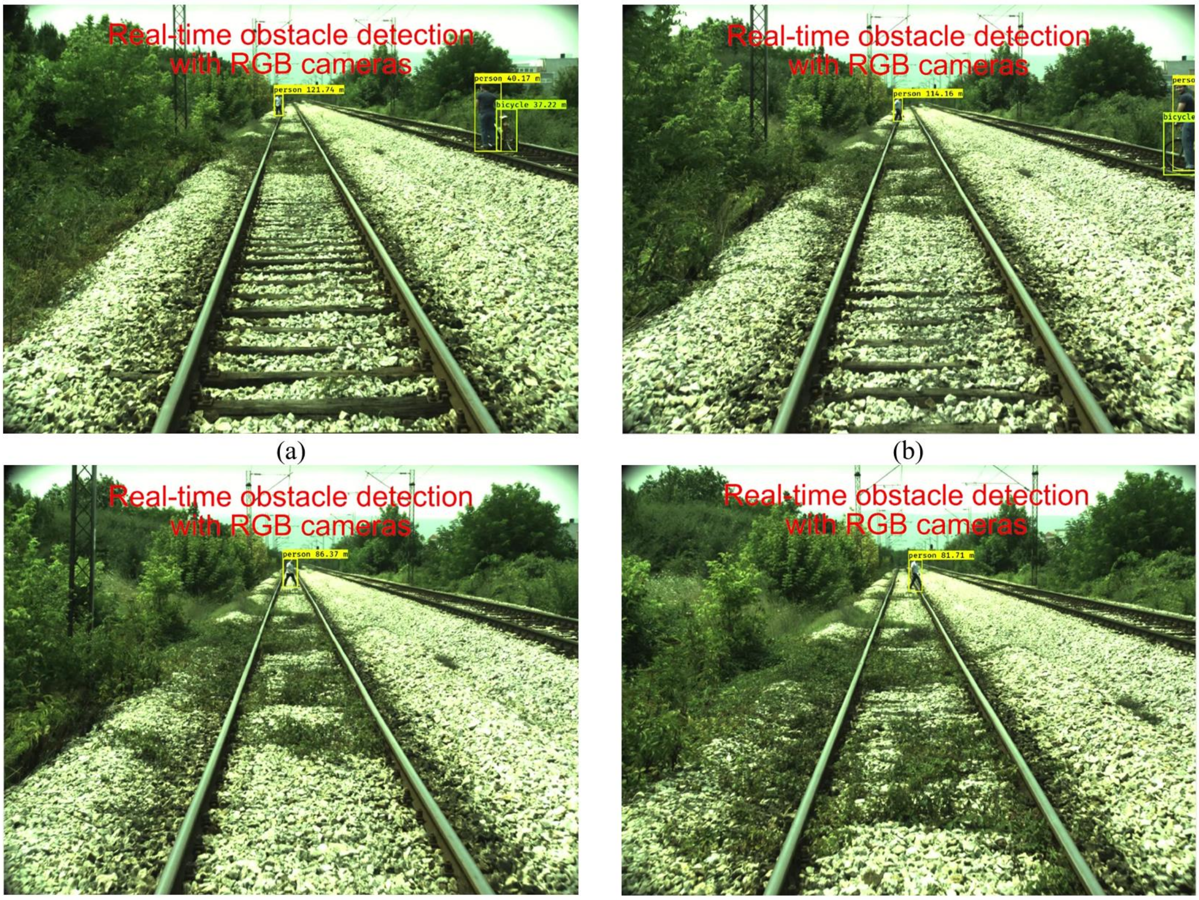


(a)

(b)

Fig.4. DisNet estimation of distances to objects at different distances in a rail track scene captured by RGB camera (a) and thermal camera (b).

Person and the bike were recognised though they are not on the same track as the train. In future work and inteligent reasoning will be included to enable software to understand whether the recognised objects are on the rail trackes ahead of the locomotive or on the parallel rail track. As it can be seen from Fig. 5, person without the bike, who is crossing the rail track, in four subsequent frames was recognised at distances 121,74 m, 114,16 m, 86,37 m and 81,71 m. As the performed tests were dynamic real-world tests where both the train and the person were in movement, the ground trouth distance could not be calculated. However, decreasing of estimated distance in shown four subsequent frames is fully in line with the expected behaviour of the person in the scene, crossing the rail tracks.



(a) (b)

(c) (d)

Fig.5. Four subsequents frames of the RGB camera video overlaid with the bounding boxes of the detected objects as well as with the estimated distances from the locomotive to the objects

(a) (b)

Fig.6. SMART estimation of distances to objects in real-world scenario with RGB camera (a) and thermal camera (b).

In the second phase of the performed dynamic field tests, the SMART on-board integrated OD system was mounted onto the SERBIA CARGO locomotive 444-017 pulling the freight train with 21 wagons on the Pan European corridor X to Thessaloniki in the length of 120 km (Fig. 1 (bottom)). Some of the results of the SMART object detection and distance estimation with RGB and thermal camera are given in Fig. 6. As it can be seen, the distance to person, who accidentely cross the rail track while the train is approaching the crossing, with RGB camera is 248,58 m while the estimated distance to the person at the same location with theraml camera is 122,94 m. A difference in distance estimation with thermal camera with respect to RGB camera is due to incorrectly extracted person bounding box by YOLO object classifier. Namely, with the closer look to the result with thermal camera one can see that the extracted bounding box is much larger then the person. Also, that incorrect result influenced not possible recognition of truck (which was recognised with RGB camera) as large portion of truck image region was considered as the person image region. In future work, bounding box extraction will be improved by a combination of YOLO, i.e. machine learning, object detection with traditional image processing based object detection. However, inspite of recognised problems to be resolved in future, shown initial results of dynamic field tests represent a good basis for further advancing of SMART software and achievement of reliable aimed long-range (up to 1000 m) autonomous detection of obstacles.

5. CONCLUSION

In this paper, a novel integrated on-board multi-sensor obstacle detection (OD) system, which is under development within Shift2Rail H2020 project SMART, is presented. The hardware and the current software of the system are described. The particular novelty of this paper is the first presenting of the results of dynamic field tests performed at the Serbian railways in July 2018. Successful dynamic field tests proved the reliability of using the developed OD system on the running train. Achieved, good initial results in obstacle detection and distance estimation represent a good basis for further advancing of SMART software and achievement of reliable aimed long-range (up to 1000 m) autonomous detection of obstacles on the rail tracks ahead of the locomotive.

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CHALLENGES OF CONTINUED SERBIAN RAILWAY RESTRUCTURING PROCESS

Branislav BOŠKOVIĆ[1]

Abstract *– Serbian railways are facing with new challenges of continuing the restructuring process. How come that many think this process is over even though it has just begun? What are the possible markers and how to define a further strategy for the restructuring and development of the railway sector in Serbia? Where is the focus in further development in order to get efficient railways in Serbia? What are the chances for the development of the Serbian railway and what kind of changes do these changes require? What measures the Serbian Government must take to finally get an efficient rail system and competitive rail service and railway sector? Do we know really how deep the requires of the restructuring process are and what is the main goal the restructuring of the railway sector? How long does it take in European and regional conditions and why? What kind of support and assumptions are needed to take this process forward? What capacities are required, and what do we really have in terms of human resources, the necessary knowledge, and investments? These are some of the issues discussed in the paper having in mind previous experience of Serbia. Also, by the case of Serbia is illustrated and commented on how to recognize the restructuring phases, the possible and necessary process dynamics, and the sustainability of this process and the railway sector in the transition phase. In the paper was given analyzes, synthesizes and systematization of the transformed path of the restructuring of the Serbian railway sector in order to sublimate the experiences for the continuation of the process, as well as the answer to the question of why the essential steps for this process are yet ahead.*

Keywords – railway reforms, market competition, corridor, case study.

1. INTRODUCTION

European railways are still in the phase of significant changes that began since 1991. The key word for recognizing, understanding and tracking these changes is the "market." The introduction of market relations into a system that was a monopoly required structural changes that affected all parts of the system. Instead of two actors (one company with three activities and the government as the owner and regulator of the sector), there is now a much greater number of actors, stakeholders, and relationships.

That process started in the EU in 1991, was not limited to the specified model but only with deadlines of liberalization of particular market segments. With regard to the directive requirements, on the one hand, and the different positions of the countries (geographical, political, society transition phase, etc.) the network capacity, the characteristic of (monopolistic) companies and the situation in industrial sector, on the other hand, each country had to find its own model of railway sector restructuring. The unique model did not exist, nor could it exist in European conditions characterized by high heterogeneity of railway systems and their development [1].

Market opening in the railway infrastructure requires the set up of several new bodies: the Regulatory body, Safety authority, Licensing body, and Investigation body. In its legal acts, EU has defined a role, jurisdictions, independence of those bodies under market participants and certain procedures, but not there models of organization and position in the system of government. There is still considerable freedom or ambiguity in terms of independence and mutual relationships of these bodies, as well as in relation to other bodies of the railway sector and country [2].

Although the process of establishing the mentioned bodies in Europe has lasted over 15 years, the same process is still characterized by frequent changes and wandering. The process of establishing railway bodies is a particular challenge for small countries with lack of knowledge, financial, human and other resources. It also requires a significant commitment of the Government and budget. If we take into account actual economic crises demand to reduce the budget

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deficit and public administration as a general trend in Europe, then the problem of establishing and stabilizing above mentioned new bodies, and in particular, the building of its authority, becomes even more difficult. This process is highly correlating with the process of railway sector restructuring, in particular with restructuring of incumbents.

2. PHASES OF THE SERBIAN RAILWAYS RESTRUCTURING PROCESS - A CRITICAL OVERVIEW

Railway sector reforms in Serbia started in 2005 by transposing the main EU railway acquis in the new Railway Law. Under the same law, most of the measures implemented provided deadlines in respect of set-up of competent state authorities and institutions (the setup of new bodies, the railway market authorities, by-laws, etc.). However, the restructuring of the monopoly railways company Serbian Railways JSC started only in 2015. In addition to the Government of Serbia, the International Monetary Founds (IMF) and the World Bank (WB) were involved in this process. State railway companies are now at the stage of turbulent changes in all areas of business and operation, and at all levels. The new, and actually "old" actors are now in new roles and in new mutual relations.

The railway sector of Serbia has the following participants and structure of the system today (Fig.1):

a) Railway companies: JSC for Management of Public Railway Infrastructure „ *Infrastruktura železnice Srbije*“; railway undertakings: *JSC for passenger transport „Srbija Voz“, JSC for freight transport „Srbija Kargo“* (all three companies originated by the separation of a vertically integrated company JSC „*Serbian Railways*“), *Kombinovani prevoz d.o.o. and Despotija d.o.o.* (two new private company) being the actors on the railway market. There are 5 more companies registered for the freight transports, but they are not present on the market.
b) Government institutions: *Ministry of Construction, Transport and Infrastructure* (MoCTI) as Ministry in charge for the railway, *Directorate for Railways* (body of the Serbian Government) - being the institutions which comprises in itself the Regulatory body, Safety authority, Licensing body and Designated body; *Center for the investigation of traffic accidents* (Investigation body) which is joint for air, inland waterways and railway traffic.

In the heretofore stream of the railway sector restructuring in Serbia, two phases can be distinguished, and activities for the preparation of the third phase are currently underway. Each of the phases was preceded by a political decision that the Serbian Government had to make and which was always reflected in the adoption of a strategic document.

By the adoption of a new *Railway Law* in 2005, the first time was allowed reforms to the market opening. That is showed by the establishing new institutions (such as *Directorate for Railways*) and to the restructuring the vertically integrated company ,,ŽTP Beograd”. The law was awaiting adoption in the Serbian Parliament for two years. At that time, its adoption was a condition for further investment supported by European banks: the EIB and the EBRD. Implementation of the law was carried out only in the domain of state institutions (the set up of new bodies in the railway market, adoption of bylaws, etc.). There was no restructuring of the ,, ŽTP Beograd”, which only changed its name to the Public Enterprise “Serbian Railways” and then became a joint-stock company with one owner.

In the period from 2005 to 2015, the *Law on Railways* has been amended several times, a new *Law on Interoperability Safety of the Railwa*y has been adopted, numerous bylaws related to the new regulation of railway safety and market relations have been adopted as well, established and strengthened the *Directorate for railways* as a regulatory, licensing and safety body, but there were no practical and essential steps in opening up the market and restructuring the monopoly system.

The second phase of restructuring started in August 2015 with vertical separation of incumbent core activities (infrastructure management, freight transport, and passenger transport) to fully independent companies. This model was adopted even though the model of the holding was a solution “on the table” for a long period. This phase of restructuring was preceded by a political decision with the adoption of a strategic document proposed by the *World Bank (Accelerating the Railways in Serbia - the Roadmap*), and then by *Planet S.A.* consulting company from London *(Serbian Railways Reform Plan 2016-2020*), which mainly elaborated in more detail the proposed plan by WB.

On that occasion, the WB introduced the Action Plan measures under the report *Accelerating the Railways in Serbia - the Roadmap*, which the Serbian Government adopted and implemented as its own act. The Government of Serbia has established the Working Group for the management of the Serbian Railways Reform Process as foreseen by the WB Action Plan. The working group was formed in December 2014 and included representatives of incumbent, some ministries (MoCTI, Ministry of Finance, Ministry of Economy and Ministry of Labor, Employment, Veterans' Affairs and Social Affairs), the Republic Property Directorate and international institutions (IMF, WB, EU delegation). The working group changed the participants (not structure) several times in line with the changes that occurred (reconstruction of the Government of Serbia, new management in companies, etc.).

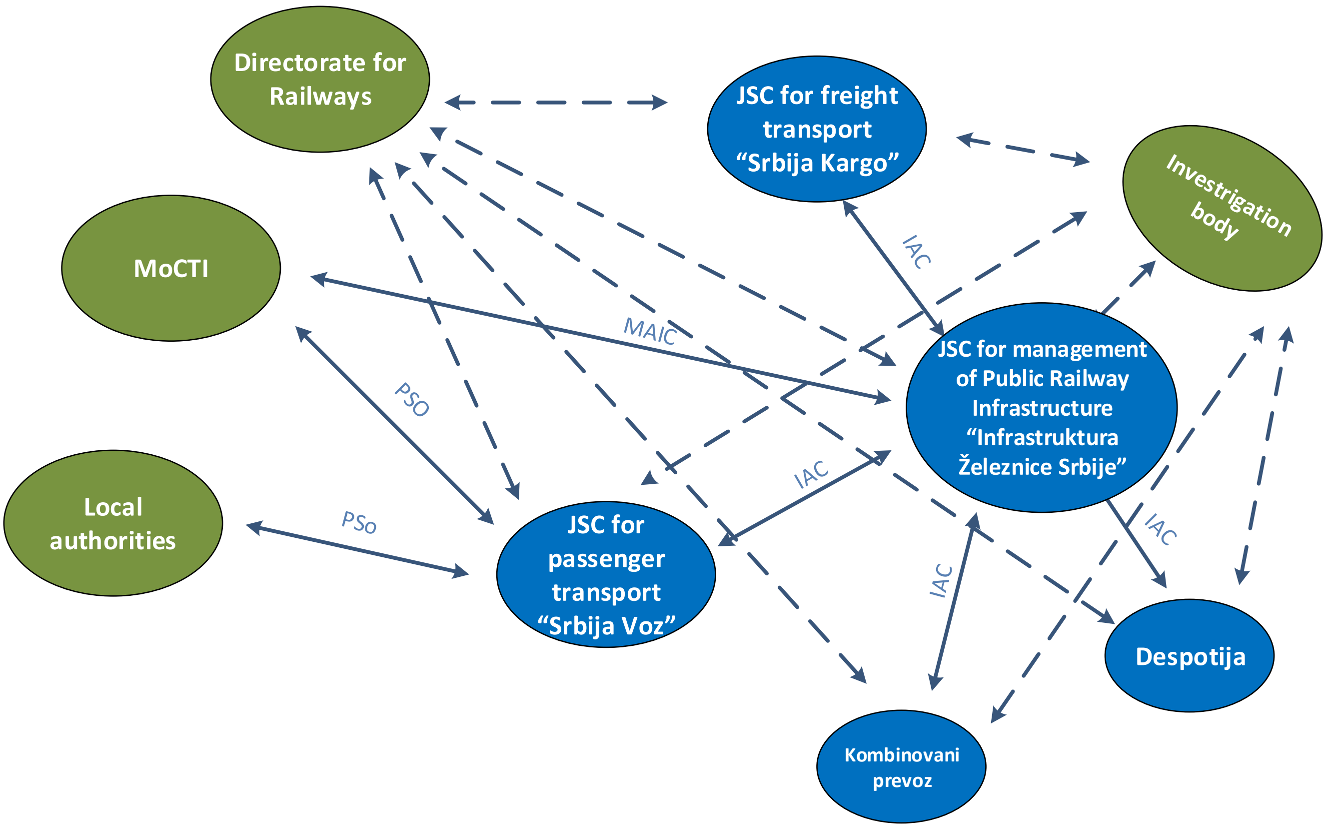

Fig.1. Stakeholders on the railway market with relationships

The period from 2005 to 2015 today can be marked as the wasting time period for the railway sector in Serbia. The restructuring was continuously postponed for some other or better times, which they could not even come in. The main justification was that is first necessary to raise the company to a higher level of competitiveness so then it can start on the market equally. The result of the postponement was, instead of better, an even worse starting point for restructuring: the infrastructure and financial operations of the incumbent company PE “Serbia Railways” have never been worse.

In the same period, project restructuring activity continued to be carried out as an aid to international, and, above all, EU institutions. The projects came one after the other and included different areas starting with the methodology for cost monitoring and finances according to the services provided [3], creating a business rolling plan and a new organizational model [4], modeling the access charges [5], five years rolling plan and multiannual infrastructure agreement [6], strengthening the capacity for the regulatory and safety body [7], to the study of organizational models in the separation of activities and management of costs [8], asset management plan, commercialization of assets and models of contracts between companies [9], etc. However, none of these projects has been implemented. The primary reason was the lack of will on the part of the Government (either as a competent authority or owner), and then with the management of a railway company that passed passively, leaving to the „fate of waiting“ .

At this moment, Serbia almost completely implemented EU legislation (except for the IV package of directives) into its laws or bylaws acts. The latest set of laws from June 2018[1] further improved the legal basis for the market foundations of the Serbian railway sector. So, in a legal sense, Serbia has mostly liberalized the market. However, the functioning of the market is at the very beginning in every way.

What does the Serbian history of restructuring tell us and their experience in choosing the moment of starting the restructuring process and its implementing dynamics? The conclusion is unequivocal: the process has been reluctantly and under pressure of international factors related to the conditions of

[1] In May 2018, the following new laws were adopted: *Railway Law* ("Official Gazette of RS", No. 41/18), *Law on Safety in Railway Transport* ("Official Gazette of RS", No. 41/18) and *Law on Interoperability of the Rail System* ("Official Gazette of RS", No 41/18)

financing of railway infrastructure and rolling stock or previously, the obligations undertaken in the process of EU accession. These two factors almost always work together when it comes to the Southeast Europe area. These circumstances are not a good starting point for the beginning and the course of the restructuring process. Today, we are entirely sure that the period 2005-2015 was a period of missed chances. The best evidence for this is stated, and non-implemented, projects and economic crisis whose beginning is related to 2008. Namely, the Serbian railway sector has met a crisis unreformed, which has proven to be devastating over the past ten years. Now no one is arguing that the restructured railways have overcome the economic crisis since unreformed [10].

3. THE BASIC SETTINGS OF THE THIRD PHASE OF RESTRUCTURING

Two years after the implementation of *World Bank* and *Planet S.A.* action plans, it was engaged a consortium led by the KPMG consulting company to develop new *Action Plan (AP)* for continuing the reforms, entirely based on the Project’s Terms of Reference “Technical Assistance to the Ministry of Construction, Transport and Infrastructure and the State-owned railway companies in Serbia – Comprehensive Railway Reform” and funded by the European Union in IPA framework. This AP shows continuity in view of the previous AP, however in continuing the reform process deals mainly with roles of the Government and the responsible ministry of transport. Now the focus is on reforms leading to efficient railways and a sustainable Serbian rail sector.

The concept and activities proposed in the AP are backed by the analyses of previous experiences, current circumstances present in Serbia, the best EU practices, as well as tried-and-tested models in railway reforms from other countries. However, all of the above has been put into the function of achieving a sustainable and efficient rail sector **in relation to market factors**.

The study has identified eight fields of conceptual measures (*Table 1*). The measures follow five main roles and responsibilities held by the Government of Serbia and MoCTI[2]. They jointly strive to boost the performance, efficiency, and competitiveness of the Serbian railway system. To summarize, they denote a new objective – a sustainable railway sector.

The activities/measures are designed to (1) improve railways’ competitiveness railways in the transportation market, (2) increase competition in the Serbian rail network, and (3) improve institutional solutions to support the foregoing said. Goals set in such a manner called for a change in the regulatory and institutional framework to create prerequisites for their implementation. They also call for a shift from a structure largely regulated based on a certain hierarchy (chain of command) and control to the structure led by business principles and competencies specific for commercial company management.

The AP focuses on the need to improve and establish a legislative and regulatory framework that would ensure sustainability of set targets, as in the absence of a more substantial institutional reform, the increased investment would yield minimal impact on the railway performance. Without reforms, Serbian railways cannot expect an advance in the transportation market just because they remain uncompetitive. It takes a change of attitude and focus to first preserve, and then grow the market share.

What defined the proposed AP in such form or what is the key landmark in defining a further strategy for the restructuring and development of the Serbian railway sector? **The answer to this question must be a marketable landmark.** As a result, the current and perspective flows of passengers and goods on the Serbian railroad network have been focused as a landmark. In conditions of highly-subsidized or unprofitable passenger transport, the focus was placed on reforms that ought to increase the competitiveness of rail freight transport that generates 80% of the railway network transport revenue, and then increase the efficiency and effectiveness of passenger traffic within the public transport obligation. Historical trends, as well as today’s reality, indicate that more than 80% of freight transport is generated on Corridor X. This fact indicates that Corridor X is a chance that must not be missed for railway transit network and country such as Serbia, a key factor that will determine the future comprehensive reform of the Serbian railway sector. In other words, **the competitiveness of Corridor X in both railway and transportation markets will define the fate of the Serbian railway sector and determine competitiveness and the size of incentives for other industries in Serbia**.

A comprehensive reform process should be regarded as a priority in strengthening the competitiveness of Serbian railways and human resources that support and facilitate them. The Government of Serbia should promptly decide, as the next step, on the reform action plan with setting clear

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[2] The five roles of the Government and the ministry responsible for transport are as follows:

1) the policy maker responsible for defining the national transport strategy and the owner (shareholder in state-owned companies);
2) the railway sector regulator responsible for creating the structure and regulating the railway sector;
3) the client – responsible for managing railway contracts;
4) the mediator (the facilitator) in the international railway integration;
5) the one responsible for establishing administrative apparatus in the railway sector.

and strict deadlines for the so-called “soft” measures and needed investments, all of which should enable Serbia to increase the competitiveness of Corridor X and really use the opportunity to attract the flow of goods, primarily from China and Turkey, to Central Europe.

Tab. 1. The reform conceptual measures (fields of action)

No.	Conceptual measure	No. of Action	No. of Activities
1.	Harmonization with the EU regulations and improving financial discipline in the railway sector	5	12
2.	Introduction of performance contracts for management of railway companies	6	7
3.	Improved PSO and MAIC management and obtaining a value for money	10	19
4.	MoCTI as moderator of international integration of Serbian railway sector	1	5
5.	Development of effective and efficient railway network in Serbia	2	6
6.	Improved management of the fixed assets and the rolling stock	1	1
7.	Setting up of state-level capacity for improving the competitiveness of the railway	3	7
8.	Enhancing competence of the Regulatory Body	1	4

In the next two chapters, **two key elements for the success of the reform process of Serbian railways are considered in depth: the competitiveness of Corridor X and the need to strengthen the capacity and competence of the ministry responsible for transport.**

4. CORRIDOR X AS A CHANCE AND REQUIREMENTS GENERATOR FOR SERBIAN RAILWAY REFORMS

The importance of Corridor X for the business operations on the Serbian rail market is extremely high. Not only that the Serbian railway is highly dependent on international traffic (as can be seen in table 2), given that transit plays the lead role. The transport on Corridor X is also crucial for the other railways in Southeast Europe (Macedonia, Greece, and Croatia) because it makes far more than half of the share of total transport and income of the freight transport.

However, Corridor X is in direct competition with the Corridor IV which can be seen at first glance on the Fig.2.

Corridor IV had offered a stable alternative to circumvent the former Yugoslavia due to previous political instability in the Balkans in 90thin years. At the same time, Corridor IV is the shortest land route between Turkey/Greece and Central Europe that runs entirely across the EU territory. The new bridge (Vidin-Kalafat) linking Bulgaria and Romania across the Danube further shortens the distance along Corridor IV. Seeing that EU investments continue to focus on Corridor IV (6,8 billion EUR were recently made available to Romania for supporting Corridor IV transport infrastructure), Serbia must adapt to the existing geopolitical situation and position itself in line with China’s and Russia’s strategic plans for Central Europe to overcome the harm inflicted by the political turmoil of the 1990s.

Tab.2. The importance of (international) freight transport for SEE countries

Country	Transit tone-km (millions)	% of the international freight traffic in a total volume of the freight traffic	% of freight traffic revenues in total traffic revenues
Croatia	1.987	78	67,87
Serbia	2.457	90	79,82
FYROM	379	98	81,03
Greece	33	86	27,58
Bulgaria	909	32	52,13
Romania	1.881	33	72,97

Source: Eurostat and UIC 2016

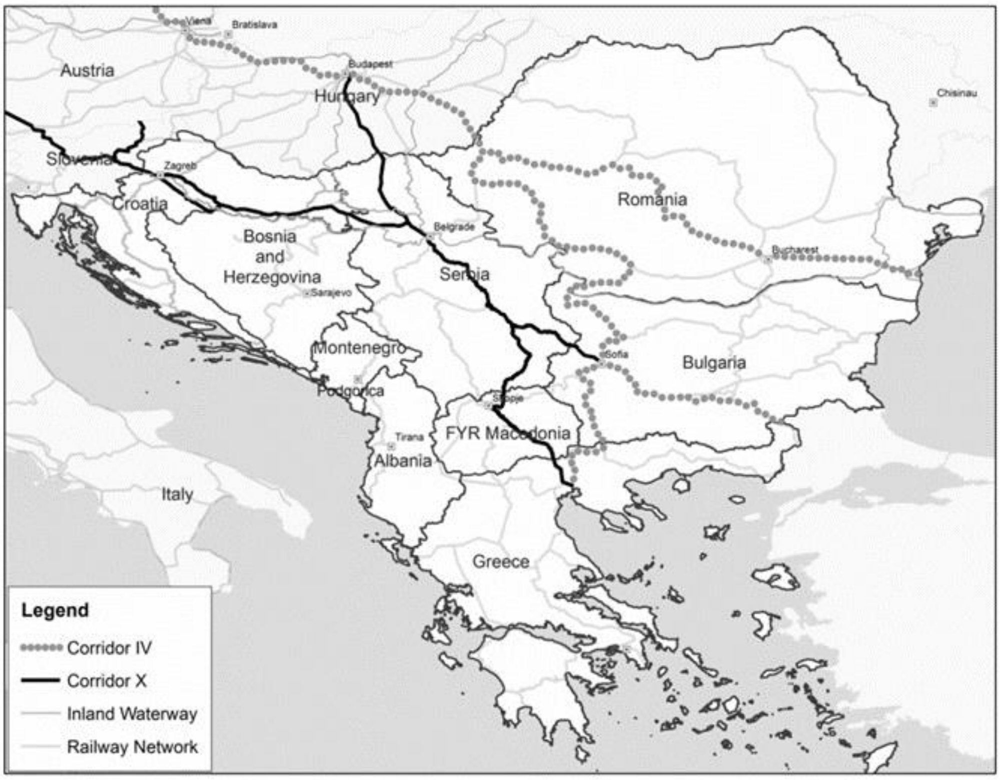

Fig.2. SEE countries and railway corridors X and IV

The Chinese state and economy have designated the Port of Piraeus as the new logistics center for goods heading towards Central Europe. Chinese investments represent an unexpected chance for Serbia to catch up in developing Corridor X and make a comeback as an important partner in the European transportation market. In conditions of high competition between Corridor X and Corridor IV, the travel time of goods, or more specifically the difference in the time of travel, will determine the volume of freight in the railway network of Serbia. In doing so, the fact that Corridor IV runs entirely across the EU territory having no stops at border crossings for customs and inspection and other control, a major handicap for Corridor X, must not be neglected.

Infrastructure is a key element in China's policy towards the Balkan region. The development of a network of infrastructure facilities in the region is a component of Beijing's plan to eventually link China and Europe, link East and West. In September 2013, the new China's president Xí Jìnpíng announced his initiative for building The Silk Road Economic Belt to boost cooperation and to improve traffic connectivity, so as to open the strategic regional thoroughfare from the Pacific Ocean to the Baltic Sea. Undoubtedly, the new Silk Road project will facilitate the distribution of Chinese products and enhance Chinese economic presence in Europe.

Chinese state-owned shipping companies, along with several East Asian corporations, have marked the Port of Piraeus as a new logistics hub of Europe. China Ocean Shipping Company (COSCO) in 2009 won the 35-year concession for the two of three port terminals and in January 2016 formally acquired a 67% share for 370 million EUR. Furthermore, the company has announced another 350 million EUR investment in the next five years, increasing the port capacity from 1 million to 7 million TEU [11].

The loss of competitiveness of Corridor X in relation to Corridor IV due to the high percentage of transit traffic as well as to the poor development of Western Balkan countries' industries would be and is already irreplaceable for the Serbian railway sector and also a handicap for the economy of Serbia in general.

Although investments are foreseen for the modernization and reconstruction of Corridor X, which in Serbia alone exceed EUR 1.5 billion, infrastructure investments alone will not suffice. Investments in the bare track will not be enough to allow Corridor X to compete with Corridor IV on the key parallel section of corridors X and IV from Thessaloniki to Budapest.

In total, the travel time from Thessaloniki to Budapest on Corridor X can be as high as three days. On average, it lasts 49 hours, half of the time spent at the borders. Average commercial speed is 22 km/h, and average running speed is around 35 km/h.

At the same time, a significant portion of the Corridor IV railway infrastructure is a single track with operating speeds between 60 and 70 km/h. Notwithstanding the EU membership, the countries on this stretch of the Corridor IV still face an issue with the border procedures. The waiting time on the Greece /Bulgaria border is around 3,5 hrs, Bulgaria/Romania around 2,5 hrs and Romania/Hungary up to 2 hrs.

Corridor X, although 300 km shorter than Corridor IV from Thessaloniki to Budapest, is currently not a viable option for the long-distance freight transport. Extended travel times, inadequate maintenance, slow speeds and on-going development of road infrastructure parallel to railways have contributed to the decline in the freight transport. Furthermore, waiting time on the borders is on average eight hours. Each train is stopped twice per border, where it goes through numerous customs and operational procedures. Further organizational problems, such as extra services for transfer between border stations, lack of coordination and communication between the operators and legislative differences boost the waiting further.

In order to take a share of the transit flows from the Piraeus port for Central Europe by Corridor X and the railway's additional reforms must be implemented. These are the so-called “soft measures,” referred to above. The biggest time savings can come from a better border crossing procedure followed by all other operational procedures and measures. Altogether, it is possible to cut the border waiting times by up to 16 hours, and travel time by 4 hours, by implementing “soft” measures for a relatively small fraction of cost of the planned investment.

Therefore, the focus of the AP is on the so-called “soft” measures that involve no significant financial burden but require extensive work and qualified human resources. Particular attention is dedicated to finding solutions for strengthening state-level human resources (MoCTI), as they are necessary capacities for carrying out actions and activities from the defined AP. This activity is termed as a *condition sine qua non*.

5. STRENGTHENING HUMAN RESOURCES ON THE STATE LEVEL

Increasing the efficiency of the rail sector and the liberalization of the rail market require significantly stronger capacities and human resources at the level of the ministry responsible for transport than it was during the period of the monopoly organized railway sector. In addition to the five key activities carried out by modern ministries responsible for transport in the world (given in footnote 2), the implementation of reform activities requires a strengthening of human and organizational capacities at the Government level for several years. Mainly because the tasks that come with the continuation of the restructuring are primarily from the field so-called „soft“ measures, and they require the hard work and human resources of MoCTI both regarding knowledge and skills, as well as looking at the number of employees. The largest number of these activities are currently present in minimum level at the MoCTI, such as:

- Providing procedures and methodologies for contracting and contract management for PSO and MAIC, as well as monitoring performance indicators;
- Planning and budgeting of public expenditures by which will be more precisely allocate costs to the railway policy individual goals;
- Implementation of internal control and audit;
- Management of infrastructure costs and investments in accordance with the specific objectives and criteria which needed to be determined;
- Establishment of measures that support the implementation of the third and fourth railway packages;
- Creating a policy and legal framework for opening a market for passenger transport;
- Development of a program for increasing the efficiency of the railway sector and, in particular, infrastructure manager (objectives and priorities for investing and maintaining railways, closing railway lines, offering lines for PPP/concessions to third parties or local authorities, etc.)

For the predicted scope and content of the reforms, three variants of organizing form human resources are possible for the continuation of the process of restructuring of the railway sector of Serbia. Which model will be adopted will depend on, apart from MoCTI preferences, from external circumstances among which the most important is the speed of the EU integration process. Each model has, as an outcome, different capacities of both human resources and organizational. Each of the three variants requires a specific preparatory period for its implementation.

If the reform process were to take place without any sudden leaps or relatively gradually, then the establishment of a Permanent Working Group for Railway Reform (PWG) should start in the initial period. According to this model, instead of the current Working Group (WG) for the restructuring of the railways, the Government's decision should establish a permanent WG, since the next phase of restructuring requires a more permanent commitment and higher capacity of the ministry responsible for transport than needed by the previous activities. The PWG structure should correspond to the structure of the measures and activities that need to be implemented according to the proposed Action Plan.

The second variant (model) is the creation of a special organizational unit within the MoCTI that would exclusively deal with the reform of the railway sector.

The third model is the formation of a special reform body outside the ministry in charge, but under the coordination of MoCTI, This body would be responsible for analyzing, generating and supervising the implementation of reform measures in the railway sector as well as for coordinating and supervising the implementation of the reform activities of other stakeholders. This is a model that would satisfy the speedy entrance/admission of Serbia into the EU and a lot of challenging demands that the Serbian rail sector will be faced on.

Especially for the continuation of the reform process, the human resources recruitment is important. When deciding on the recruitment of human resources in the public administration in relation to the restructuring of the railway, the following should be taken into account:

- Employees, suitable candidates regardless of their education should have knowledge and skills in the field of law, strategic thinking, with a good understanding of entrepreneurship;
- Detailed knowledge of rail operations should not be considered as a prerequisite;
- Candidates should have competencies related to PSO, contract management expertise for PSO and multi-annual contract for maintenance and usage of infrastructure (MAIC).

Also, it is necessary to enable the contracting of external advisory services provided by independent experts, which is needed at this stage of the reform. Here, I will refer to one of the conclusions of the Planet S.A. consultant and the WB's recommendation [12] that in the forthcoming period each reform decision should be justified by the previous research. This is also the case with the European Commission and other EU bodies whose decisions and the various laws adoption are always preceded by a research project.

6. CONCLUSION

All things considered, long periods of railway backlogged maintenance accumulation has created a new reality for Corridor X. The European Union has initiated a strong development of the neighboring routes/corridors, and Corridor X is becoming an increasingly irrelevant factor in the international trade. Luckily, Chinese investments in Greece present an unexpected opportunity to catch-up with the development and re-establish itself as an important partner in the European transport market.

However, the railways and their governments on Corridor X should react rapidly to speed up short-term soft measures and liberalization roadmap reforms. Serbia has a central position on Corridor X, with the largest percentage of the total length of Corridor X, and has the greatest responsibility not only towards itself but also towards neighboring countries/railways to make Corridor X competitive. There is not enough time to concentrate on needed investments, given: (i) the short window of opportunity that requires fact action; (ii) the current situation of rail investment policy in Serbia outlined above; (iii) the advanced state of investments and EU funding for Corridor IV. All these prove that the competitive difference for Serbia should be given by soft measures.

Without accelerated reforms, without the human capacity for reforms and capability for reforms in the railway's sector in Serbia, it will be impossible to catch up with China`s strategic plans towards middle Europe.

The Governments of Serbia have a short window of opportunity to make the sweeping structural reforms on all fields: both in infrastructure and legislation, procedures and operations and they need to do it by 2020.

Main targets should be: the improved borders crossing procedure on both levels (state level and railways level) and joint border crossing railways stations.

Rapid implementation of soft measures should be accompanied by institutional reform strengthening measures:

- new body for railway reform on the state level,
- strong Railway Market Oversight Authority (Regulatory Body),
- legislative reform according to the Transportation Treaty,
- increased competition between railway companies,
- better management of railway companies insured via a better organizational structure and introduction of performance indicators for managers,
- increased capacities and capabilities for public administration involved in the reform sector.

A political decision at the level of the Government of Serbia is necessary for the implementation of the previously described measures. Strengthening and improving reform capacities at the level of the Government and the relevant ministries are not ordinary activities when it comes to the rail sector. The long-term management of the railway sector development from the level of the public enterprise has left a profound mark, and there is still strong resistance to the relocation of reform management to the level of the Government and the competent ministry. This resistance exists both at the level of state-owned companies and at the level of the Government or the ministry responsible for transport.

Therefore, these institutions responsible for the reforms are facing new challenges in the process of restructuring the railway sector. Essential restructuring of the railway sector is only to begin now because the current course and content can be assessed as predominantly with formal character by which we meet the requirements of the EU integration process in creating towards a market environment.

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Rolling stock

COMPARATIVE ANALYSIS OF FATIGUE STRENGTH OF AN Y25LS-K BOGIE FRAME BY METHODS OF UIC AND DVS 1612

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Abstract *– This paper contains the results of the fatigue analysis of the Y25Ls-K bogie frame. Fatigue analysis have been made using the Finite Elements Method in the Department of Railway Engineering at the Technical University – Sofia and the fatigue tests of the bogie frame have been carried out in the Testing laboratory VUZ in Czech Republic. The software product SolidWorks has been used. The comparative analysis is based on the EN 12663, ERRI B12/Rp 17 and 60, DVS 1612-2014 standards. The assessment is made by different methods: Moore-Kommers-Jasper (MKJ) diagram, Goodman-Smith diagram and the method proposed in DVS 1612.*

Keywords – bogie, FEM, calculations, fatigue.

1. INTRODUCTION

In the present work, a comparative analysis of different methods for estimating the probability of the occurrence of cracks in the welds caused by fatigue of the material in metal constructions (MKJ diagram, Goodman - Smith diagram, ERRI and DVS 1612-2014 [1-5]) is presented. The object of the study is a Y25Ls-K bogie designed for freight wagons developed by Transvagon AD. The strength analysis of the object was done in the Department of Railway Engineering at the Technical University of Sofia, taking into consideration the normative documents [6-8]. Based on these, 19 load cases describing the behavior of the structure during operation were determined.

2. ANALYSIS OF NORMATIVE DOCUMENTS

Modern methods for simulation and modeling (including the Finite Element Method) allow theoretically with great precision to create complex mechanical products with parameters close to the optimal ones. One of the serious problems in the field of railway wagon bogies is the presence of failures due to insufficient dynamic strength. The main regulatory documents related to the railway equipment [9] are: UIC - ERRI B 12 / RP 17 and ERRI B 12 / RP 60 [1.2]; EN 12663-1, EN 12663-2 [3, 4] - for wagons; EN 13749: 2011 [6] - design of bogies. Standards EN 1993-1-1: 2005, EN 1993-1-9: 2005 and EN 1999-1-3: 2007 [10-12], provide general rules for designing and testing the fatigue of steel structures. DVS 1612 - national standard in Germany. ERRI B 12 / RP 17 addresses issues related to static and dynamic tests as well as a static fatigue test of the material. Goodman-Smith and MKJ diagrams are used [1,2,5,9].

When working with the MKJ diagram (Fig.1.a), the permissible stresses are a function of the asymmetry coefficient of the cycle R (1) and depend on the material characteristics: R_p - yield limit; R_m - tensile strength; and the area where the calculated stress is located [1,2,5,9,13].

$$R = \frac{\sigma_{\min}}{\sigma_{\max}} \tag{1}$$

if R>1 or R<-1, then the reciprocal value of the coefficient obtained is taken into account when determining the permissible stresses.

When evaluating fatigue using the Goodman-Smith diagrams (Fig.1.b), permissible stresses σ_{lim} are a function of the mean stresses σ_m [1,2,3,9,13,14,15, 16]:

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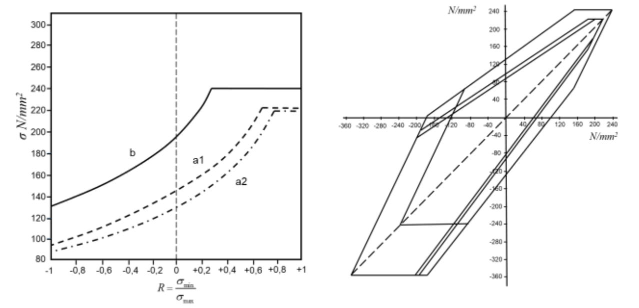

a) b)

Fig.1. a) MKJ-diagram. b) Goodman-Smith diagram.

$$\sigma_m = \frac{\sigma_{\max} + \sigma_{\min}}{2}, \quad (2), \quad \sigma_a = \frac{\sigma_{\max} - \sigma_{\min}}{2} \quad (3)$$

where: σ_a is a stress amplitude [1,2,3,9,14,15, 16, 17].

According to DVS 1612 [5] evaluation of the fatigue strength is done using MKJ-diagrams. Relative to ERRI B 12/R17 [1,2] diference is in the number of permissible stress curves (Fig.2.), which are defined by formula (4).

$$\sigma_{zul}(R_\sigma) = 150\left(1,04^{-x}\right)\left[\frac{2(1-0,3R_\sigma)}{1,3(1-R_\sigma)}\right] \quad (2)$$

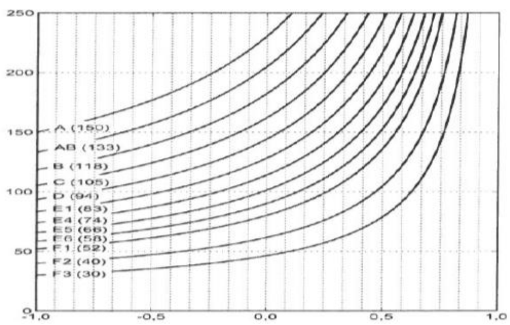

Fig.2. MKJ-diagrams for steel S355 in DVS 1612 [5]

The fatigue strength evaluation in DVS 1612 [5] for complex mechanical structures shall be subject to the following conditions:

- for stress components

$$\frac{\sigma_{\parallel}}{\sigma_{\parallel,zul}} \le 1 \quad (5), \quad \frac{\sigma_{\perp}}{\sigma_{\perp,zul}} \le 1 \quad (6), \quad \frac{\tau}{\tau_{zul}} \le 1 \quad (7)$$

- for comlpex stresses

$$\left(\frac{\sigma_{\parallel}}{\sigma_{\parallel,zul}}\right)^2 + \left(\frac{\sigma_{\perp}}{\sigma_{\perp,zul}}\right)^2 - \frac{\sigma_{\parallel}\sigma_{\perp}}{\left|\sigma_{\parallel,zul}\sigma_{\perp,zul}\right|} + \left(\frac{\tau}{\tau_{zul}}\right)^2 \le 1,1 \quad (8)$$

3. METHODOLOGY FOR FATIGUE STRENGTH ANALYSIS

In this study the following methodology for fatigue strength analysis was used [18]:

1. Load cases are determined.
2. Design documentation (drawings) is analysed.
3. Structure elements are classified into „n" groups according to the material used.
4. Material properties R_p and R_m are determined for all materials used according to European or national standards.
5. Determine "m" number of groups depending on the design features of the node under consideration (type of welds).
6. A computational model for stress-strain analysis is developed.
7. Verification calculations are performed.
8. The results obtained for stresses are generally selected in $m_x n$ databases obtained according to:
   - structure features –"m" databases;
   - the types of materials used – "n" databases.
9. A standard and method to be used is selected.
10. For each database the asymmetry factor according to formula (1) or the mean stresses according to (2) are determined depending on the chosen method;
11. The permitted stress σ_{lim} is determined depending on asymmetry factor (9) or the mean stress (10) depending on the chosen method.
    - using MKJ-diagrams

$$\sigma_{lim} = f(R) \quad (9)$$

- using Goodman-Smith diagram.

$$\sigma_{lim} = f(\sigma_m) \quad (10)$$

12. Safety factors S are calculated according to (11) for all stress values obtained:

$$S = \frac{\sigma_{zul}}{\sigma_u} \quad (11)$$

13. The evaluation criterion is given with the condition (12):

$$S = \frac{\sigma_{zul}}{\sigma_u} \ge 1 \quad (12)$$

If the safety factor is less than one, the test area is of insufficient strength and it is advisable to take constructive measures for local or radical strengthening.

For the purposes of this study, following load cases were determined (Tab.1.) [6, 7, 8, 19]:

Tab.1. Load cases

Load case	Load						Twist	Brake force	
	Vertical			Transverse	Longitudinal				
[kN]	sidebearer F_{z2}	pivot F_{zc}	sidebearer F_{z1}	F_y			g^+	Fbz	Fbx
1	-	F_z	-	-	-	-	-	-	-
2	-	$(1+\beta)F_z$	-	-	-	-	-	-	-
3	-	$(1-\beta)F_z$	-	-	-	-	-	-	-
4	-	$(1-\alpha)(1+\beta)F_z$	$\alpha(1+\beta)F_z$	$0,1(F_z+m^+g)$	-	-	-	-	-
5	$\alpha(1+\beta)F_z$	$(1-\alpha)(1+\beta)F_z$	-	$-0,1(F_z+m^+g)$	-	-	-	-	-
6	-	$(1-\alpha)(1+\beta)F_z$	$\alpha(1+\beta)F_z$	$0,1(F_z+m^+g)$	-	-	$+5\ {}^{0}/_{00}$	-	-
7	-	$(1-\alpha)(1+\beta)F_z$	$\alpha(1+\beta)F_z$	$0,1(F_z+m^+g)$	-	-	$-5\ {}^{0}/_{00}$	-	-
8	$\alpha(1+\beta)F_z$	$(1-\alpha)(1+\beta)F_z$	-	$-0,1(F_z+m^+g)$	-	-	$+5\ {}^{0}/_{00}$	-	-
9	$\alpha(1+\beta)F_z$	$(1-\alpha)(1+\beta)F_z$	-	$-0,1(F_z+m^+g)$	-	-	$-5\ {}^{0}/_{00}$	-	-
10	-	$(1-\alpha)(1-\beta)F_z$	$\alpha(1-\beta)F_z$	$0,1(F_z+m^+g)$	-	-	-	-	-
11	$\alpha(1-\beta)F_z$	$(1-\alpha)(1-\beta)F_z$	-	$-0,1(F_z+m^+g)$	-	-	-	-	-
12	-	$(1-\alpha)(1-\beta)F_z$	$\alpha(1-\beta)F_z$	$0,1(F_z+m^+g)$	-	-	$+5\ {}^{0}/_{00}$	-	-
13	-	$(1-\alpha)(1-\beta)F_z$	$\alpha(1-\beta)F_z$	$0,1(F_z+m^+g)$	-	-	$-5\ {}^{0}/_{00}$	-	-
14	$\alpha(1-\beta)F_z$	$(1-\alpha)(1-\beta)F_z$	-	$-0,1(F_z+m^+g)$	-	-	$+5\ {}^{0}/_{00}$	-	-
15	$\alpha(1-\beta)F_z$	$(1-\alpha)(1-\beta)F_z$	-	$-0,1(F_z+m^+g)$	-	-	$-5\ {}^{0}/_{00}$	-	-
16	-	Fz	-	-	$0,05x(F_z+m^+g)$	$-0,05x(F_z+m^+g)$	-	-	-
17	-	Fz	-	-	$-0,05x(F_z+m^+g)$	$0,05x(F_z+m^+g)$	-	-	-
18	-	$1,2F_z$	-	-	-	-	-	F_{bz}	F_{bx}
19	-	$1,2F_z$	-	-	-	-	-	$-F_{bz}$	$-F_{bx}$

Materials used have following properties: steel S355J2, thickness $3 \leq t \leq 16$ mm, $\boldsymbol{R_p}$= 355 MPa, $\boldsymbol{R_m}$= 470 MPa. Steel S355J2, thickness $16 \leq t \leq 40$ mm, $\boldsymbol{R_p}$= 345 MPa, $\boldsymbol{R_m}$= 470 MPa. Material GE240, $\boldsymbol{R_p}$= 240 MPa, $\boldsymbol{R_m}$= 450 MPa.

Fig.3. Finite elements mesh of calculation model

A computational model for stress-strain analysis has been developed. In this model the finite elements mesh is compressed (1 374 520 nodes and 843 616 elements), maximum size of finite elements is 15 mm (Fig.3), which shows a very good mesh density of the analysed structure.

4. RESULTS ANALYSIS

The results obtained for the stresses σ_u are selected by choosing the nodes of the welds. Various databases were obtained depending on the type of welding and the material used.

During the work with MKJ and Goodman-Smith diagrams, we identified a problem with respect to the determination of the minimum and maximum stresses, which determine the asymmetry factor R (1) or the mean stresses σ_m (2) depending on the selected evaluation method. For the purpose of objectivity and comprehensiveness of the study, the following approach is applied to each node of the welds: The principal stresses (σ_1, σ_2, σ_3) [20] are determined under all load cases; the stress with maximum value ($\sigma_{\max}$) is selected; all normal stresses from the stress tensors (σ_x, σ_y, σ_z from formula (13)) are projected in the direction of the highest main stresses; the minimum stress (σ_{min}) is then selected for all load cases [1, 2, 3, 14]. The procedure is repeated for each of the nodes in the welding area.

$$\sigma_{ij} = \begin{bmatrix} \sigma_x & \tau_{yx} & \tau_{zx} \\ \tau_{xy} & \sigma_y & \tau_{zy} \\ \tau_{xz} & \tau_{yz} & \sigma_z \end{bmatrix} \tag{13}$$

When working with german standard DVS 1612, the stress tensors (13), obtained for different load cases, should be projected in the weld plane [21]. The highest stresses are then taken for assessment: perpendicular $\sigma\perp$, parallel $\sigma\parallel$ and tangential τ to the weld. The evaluation criterion is given with conditions (5,6,7,8).

The analysis of the obtained results shows that in all evaluation methods the same areas with insufficient dynamic strength are obtained.

In evaluation with MKJ-diagrams from DVS 1612 [5], because of welds type, two curves (line C- and line D) were used. In this case 21 nodes have safety factor less than one. (Fig.4., tab. 2.).

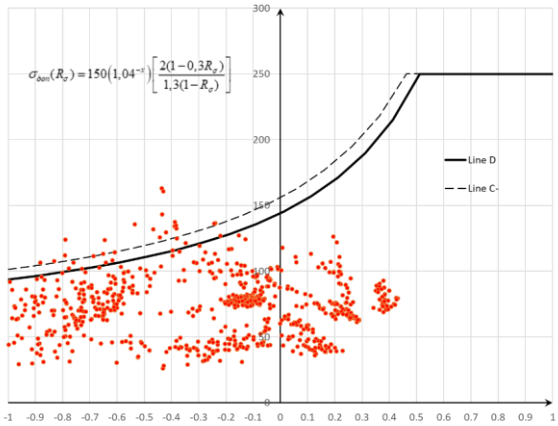

Fig.4. Results by MKJ-diagrams DVS 1612-2014 [5]

Tab. 2. Results of the analysis

Node	case up	up	down	case down	R	zul (MKJ)	S (MKJ)	σa	σm	zul (G-S)	S (G-S)
1012625	17	62.1	-143.2	16	-0.43	122.9	0.86	102.7	-40.5	48.1	0.77
1012153	17	72.5	-135.5	16	-0.54	117.9	0.87	104.0	-31.5	56.3	0.78
1013670	18	163.1	-71.1	19	-0.44	113.5	0.70	117.1	46.0	126.9	0.78
1012491	17	124.0	-97.9	16	-0.79	107.7	0.87	110.9	13.0	96.9	0.78
1013412	18	160.6	-69.0	19	-0.43	113.8	0.71	114.8	45.8	126.7	0.79
1012627	16	123.8	-80.0	17	-0.65	113.1	0.91	101.9	21.9	105.0	0.85
1012492	17	106.5	-93.9	16	-0.88	104.8	0.98	100.2	6.3	90.7	0.85
966824	17	112.0	-88.7	16	-0.79	107.7	0.96	100.4	11.7	95.6	0.85
966940	17	61.5	-131.8	16	-0.47	121.2	0.92	96.7	-35.1	53.0	0.86
966823	17	107.7	-89.5	16	-0.83	106.4	0.99	98.6	9.1	93.3	0.87
1012885	19	137.4	-53.2	18	-0.39	116.0	0.84	95.3	42.1	123.3	0.90
1012628	16	111.3	-76.5	17	-0.69	111.5	1.00	93.9	17.4	100.9	0.91
1012490	17	106.6	-80.9	16	-0.76	108.8	1.02	93.7	12.8	96.7	0.91
1012156	16	113.3	-73.7	17	-0.65	112.9	1.00	93.5	19.8	103.0	0.91
967184	19	134.8	-51.7	18	-0.38	116.2	0.86	93.2	41.5	122.8	0.91
1013413	18	134.2	-52.3	19	-0.39	115.9	0.86	93.2	41.0	122.3	0.91
1012291	17	114.3	-69.6	16	-0.61	114.6	1.00	91.9	22.4	105.4	0.92
1013669	18	132.6	-50.7	19	-0.38	116.2	0.88	91.6	41.0	122.3	0.92
966847	16	91.9	-91.4	17	-0.99	101.5	1.10	91.7	0.3	85.2	0.93
1012289	16	54.5	-129.6	17	-0.42	123.6	0.95	92.0	-37.5	50.8	0.93
1012191	17	79.4	-102.2	16	-0.78	108.2	1.06	90.8	-11.4	74.6	0.94
1012465	17	84.0	-95.7	16	-0.88	104.9	1.10	89.9	-5.8	79.7	0.95
1012589	16	55.7	-125.8	17	-0.44	122.4	0.97	90.8	-35.1	53.0	0.95
1012193	13	84.0	-94.0	16	-0.89	104.4	1.11	89.0	-5.0	80.5	0.96
1012556	17	101.9	-74.3	16	-0.73	109.9	1.08	88.1	13.8	97.6	0.96
1012626	16	108.3	-66.8	17	-0.62	114.3	1.05	87.6	20.7	103.9	0.96
966942	16	106.5	-68.4	17	-0.64	113.2	1.06	87.4	19.1	102.4	0.96
1012306	16	79.1	-98.7	17	-0.80	107.4	1.09	88.9	-9.8	76.1	0.96
967686	18	124.9	-47.5	19	-0.38	116.3	0.93	86.2	38.7	120.3	0.96
1012851	18	136.2	-33.1	19	-0.24	134.5	0.99	84.6	51.5	131.9	0.97
1013703	19	136.4	-32.6	18	-0.24	134.9	0.99	84.5	51.9	132.3	0.97
966941	16	102.9	-68.4	17	-0.66	112.3	1.09	85.6	17.3	100.7	0.98
1012305	6	81.0	-93.5	17	-0.87	105.3	1.13	87.2	-6.3	79.3	0.98
1012557	17	99.2	-71.0	16	-0.72	110.4	1.11	85.1	14.1	97.8	0.99
967912	18	121.4	-42.3	19	-0.35	118.1	0.97	81.8	39.5	121.0	1.00

In evaluation with Goodman-Smith diagram 37 nodes have safety factor lower than one (Fig. 5, tab. 2.), with 90% reliability. When reliability value is 50%, only two nodes (No 1012625 and 1012153) have safety factor less than one (tab.2.).

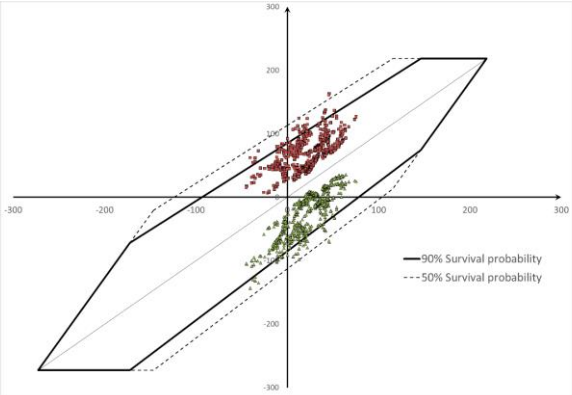

Fig.5. Results by Goodman-Smith diagram

The results of insufficient dynamic strength for a part of the welds obtained in theoretical study were not confirmed in the actual tests of the bogie frame [22]. The main reasons for this are:

- The theoretical studies were made taking into account the most unfavorable tension combinations σ_{max} and σ_{min}.

- The bogie frame test is carried out in accordance with [6-8], and there is a constant alternation of each of the load cases from a table 1.

5. CONCLUSION

The analysis of the results shows that all theoretical methods used for evaluation give the same areas of insufficient dynamic strength. This indicates that if the frame is tested at the worst stress combinations σ_{max} and σ_{min} (10^7 cycles), it would likely show insufficient dynamic strength. There is, therefore, a discrepancy between the theoretical methods and the test method for bogies. This requires the development of a new methodology for the theoretical analysis of material fatigue in the welding area, which corresponds exactly to the test method for bogie frames.

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ASSESSMENT OF THE FATIGUE BEHAVIOR OF REPAIRED ALUMINUM CARBODY STRUCTURE

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Abstract *– Aluminum carbody structures vs. steel structures have an increasing share in rail vehicle passenger fleet. New trams for Belgrade city transport with aluminum carbody structure after approximately three years of service, suffered from cracks. The first repair made by manufacturer was only partially successful. Two years after repair some cracks reappeared. This paper deals with some specificity of the aluminum structures repair process. The issue of the aluminum structures fatigue is compared with the fatigue of common carbody steel structures. Stress measurements in the repaired welding zone after second repair and reinforcement are presented. The test was performed with fully loaded tram under typical service conditions. Assessment of the future fatigue behavior is made based on the analysis of measured data.*

Keywords – carbody, aluminum, cracks, fatigue, repair.

1. INTRODUCTION

The strength of aluminum alloy and steel structures has many important differences. Among them, the significantly lower fatigue strength in the welded zones, in the case of aluminum alloys, requires special attention.

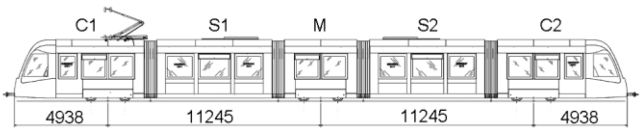

Fig.1. 5- module articulated tram

In the year 2011/2012, the Belgrade City Transportation company has acquired 30 articulated five-module low-floor trams (Fig.1) with aluminum alloy carbody structure. Modules C1, M and C2 rests on the bogies, while modules S1 and S2 are articulated connected between C and M modules. After less than three years of service, in the carbody structure appeared fatigue cracks.

2. MECHANICAL CHARACTERISTICS OF ALUMINUM ALLOYS WELD ZONES

Rail vehicles structures require aluminum alloys suitable for extrusion, eldable, with good mechanical properties after welding and with good corrosion resistance in welding zones. Two groups of alloys dominates in rail vehicle structures: AlMgSi (international alloy designation 6000) and AlMgZn (7000).

Static mechanical characteristics of both groups for base metal (examples are listed in table 1) are comparable to carbon steel S235 or S275. However, immediately after welding, in the heat-treated zones mechanical characteristics significantly drop, and after few months of ageing process partially recover. AlZnMg alloys recover mechanical properties up to 80-90% of the original metal, and AlMgSi alloys only to 50-60%.

Fatigue characteristics of welded joints of aluminum alloys are also significantly lower than corresponding characteristics of steel welds. Table 2 gives examples for steel and table 3 for corresponding aluminum alloy welding.

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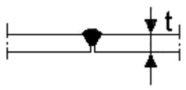
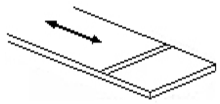
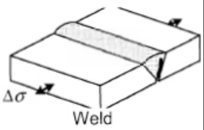
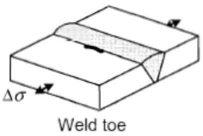
Tab. 1. Mechanical characteristics of representative Al alloys (heat-treated and artificially aged - T6)

Alloy		AlMgSi1 (6082)	AlZn4,5Mg1 (7020)
Base metal	R_{p02} (N/mm^2)	235	270
	R_m (N/mm^2)	275	330
	A_5 min (%)	9	10
Welded zone	R_{p02} (N/mm^2)	50-60% of base metal	80-90% of base metal
	R_m (N/mm^2)		

Tab.2. Fatigue category examples of steel welds [1]

Detail category	36	71
Construction detail		
Description	But welds made from one side only	But welds made from one side only when full penetration checked by appropriate NDT

Tab.3. Fatigue category examples of Al-alloy welds [2]

Detail category $\Delta\sigma$–m_1	18-3,4	45-4,3 / 40-4,3
Construction detail Initiation site		
Type of weld	Partial penetration	Welded one side only, full penetration without backing
Joint part		Flats, solids
Quality level acc. to EN ISO 10042		
Internal	D	B / C
Surface and geometric	D	B / C

First number of detail category denotes reference fatigue strength (at $2{\cdot}10^6$ cycles). Welded joints of aluminum alloys have reference fatigue strength 50 to 60% of the corresponding steel welded joints. This makes aluminum alloy carbody structures more susceptible to fatigue cracks, which requires a special care in construction design.

3. CRACK APPEARANCE HISTORY

Figure 2 shows the carbody structure of first tram module C1.

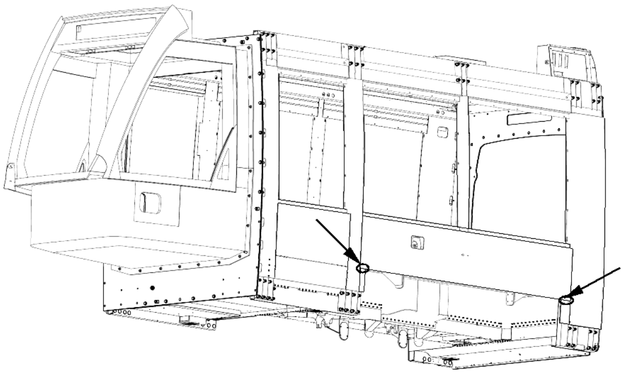


Fig.2. Carbody structure of the module C1 with initial crack positions

The first cracks arise in the corners of the cuts for bogies, along horizontal welds, marked in the figure 2 with arrows. In some units initial cracks appeared after only 20.000 service kilometers. In the next phase, the cracks propagated along vertical weld connecting vertical posts with horizontal profiles (figure 3).

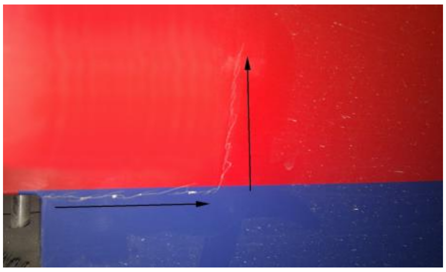


Fig.3. Crack propagation from bogie space corner

Later, some cracks appeared in the lower corners of the windows and in some cases along horizontal welding connecting small post between windows with horizontal profiles (figure 4).

Fig.4. Cracks along window welds

The manufacturer made analysis of all three types of cracks. Analysis suspected following causes of the crack appearance:

- high vibrations as consequence of the bad infrastructure,
- welding quality failures and
- lower weld thickness caused by esthetical outside weld grinding.

It can be remarked that new trams circulates mainly on renewed tracks along with other old steel structure trams that do not have problems with cracks.

First reparation performed by manufacturer included corrective action consisting of:

- corrective welding at all places where vertical cracks appeared and all places where window post horizontal cracks appeared, including added backing,
- in the corners of the bogie space, in the whole fleet the 4 mm plates were replaced with 6 mm plates. A rib supporting a plate was added,

Less than two years after first reparation, cracks in the corners of the bogie space as well as few in other locations reappeared.

In order to better understand the causes of this and some other problems, manufacturer performed test ride with measurements of different accelerations, strokes in primary and secondary suspension etc.

Based on the test results, manufacturer blamed absence of transition curves, which causes occasional impacts on rotational stoppers between carbody and bogie frame, important crack appearance cause.

However, the number of the hard curve entrance impacts is too low to provoke typical fatigue cracks.

The manufacturer increased the stroke of the longitudinal stoppers of the rotary movement of the carbody and made repair of repeated cracked welded joints. In the bogie opening corners this time were used plates with 10 mm thickness with prepared shaped overlap in order to achieve full penetration. The proposal to round the shape of plates in the corners and to make repair in the whole fleet, not only on affected places, was from manufacturer rejected.

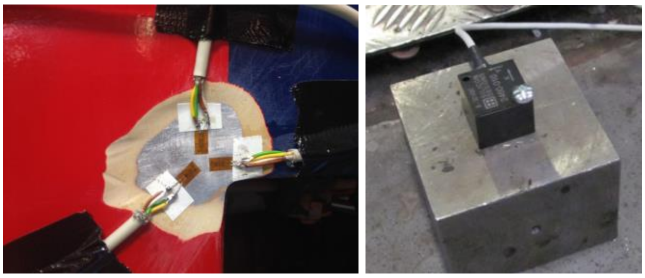
After that, a new test was carried out with a maximum loaded tram. Measurements of different accelerations and relative movements in primary and secondary suspension were done, focused on curve transition performance.

The authors of the paper used this opportunity to make measurement of the stresses in the primary crack appearance zone (corners of the bogie space).

4. STRESS MEASUREMENTS IN THE CRACK APPEARANCE ZONE

At one corner of bogie cut in the lateral side of carbody, in the immediate vicinity of the repaired weld, was performed measurement with strain gauges in $0/45^o/90^o$ rosette arrangement (Figure 5a). At two other corners the measurement was made with strain gauges placed perpendicular to weld. The strain gauges HBM 6/120LY13 for aluminum measurement with 6 mm base were used.

Three–axial acceleration measurements were performed with SD2460-010 pickup placed on the floor with the aim to correlate the appearance of high stresses to acceleration amplitudes. In this way, stress causes like curve passing, acceleration, braking, vertical or lateral track irregularities could be identified.



a) strain – gauges b) accelerometer

Fig.5. Measurement sensors

The aquisition was performed using HBM Quantumx MX840a device and Catman DAQ software.

For the test ride the tram was loaded with sacs filled with sand, simulating maximum design load. Test was performed along all parts of Belgrade tram network where new trams circulate: depot "Sava" – Blok 45 - Banovo brdo – Ustanička - depot "Sava". The total length of the tracks where the test were performed was 34 km. Test run included accelerating, driving with normal service speed, braking and stopping on all stops, to obtain stress history under normal service conditions.

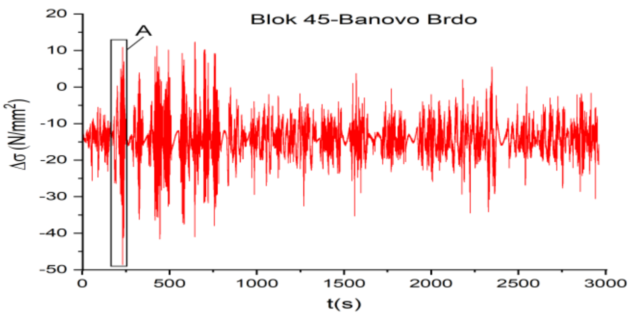


Fig.6. Measured stress, worse track

Figure 6 shows the example of stress measurements between stops Blok 45 and Banovo Brdo. It can seen that the first part of the track is in a worse state, giving larger stress spans.

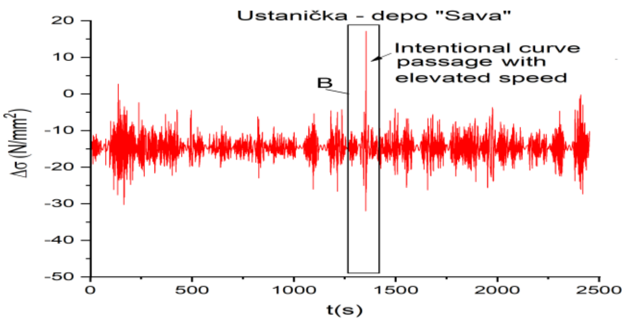


Fig.7. Measured stress, better track

Figure 7 shows the example of the stress measured between stops Ustanička and depot “Sava“. The smaller average stress spans are consequence of better track quality. There is one exception. In order to test effect of longer stroke to rotational stoppers of carbody, intentionally passing of the curve to Resavska street was at speed of approximately 18 km/h instead of regular 10-12 km/h (detail B).

Figure 8 shows the detail B of the curve passing, where on the exit from the curve the singular stress span reached 50 N/mm^2.

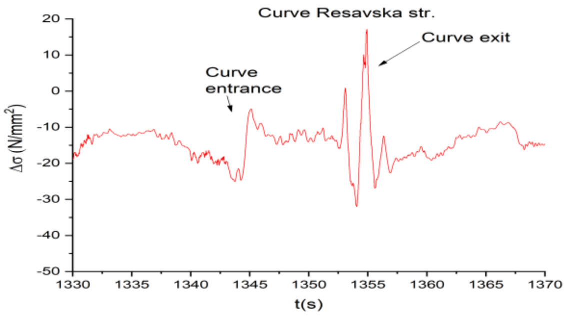


Fig.8. Detail B (curve Resavska str.)

In the same scale figure 9 shows detail A from figure 6 corresponding to straight track passing in Jurija Gagarina street. It can be seen that stress continuosly pulsate with spans from 30 to 60 N/mm^2. Correlation with acceleration measurements shows that these stress alterations origin from roll movement caused by track twist i.e by carbody torsion.

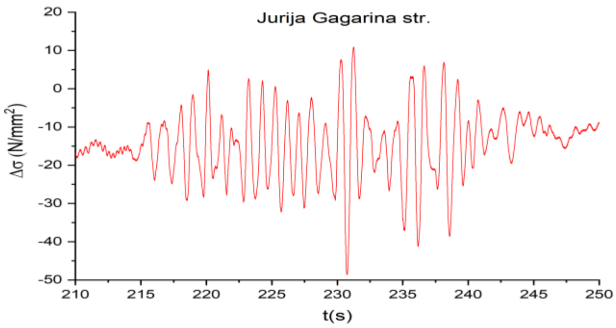


Fig.9. Detail A (J. Gagarina street)

5. CRACK FREE LIFE PERIOD ASSESSMENT

In order to assess fail free life period, expecting after repair of weld cracks, the stress span evaluation was performed. First step was to select one of the different methods of cycle counting that can be applied.

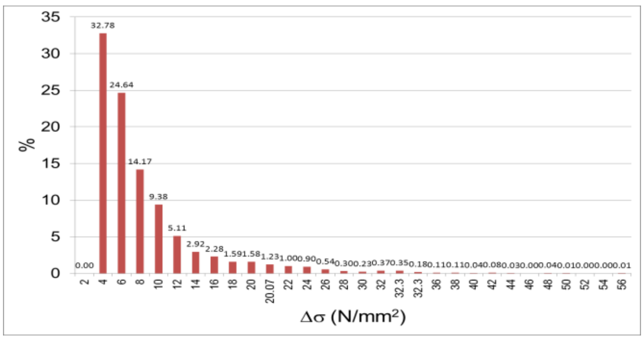


Fig.10. Stress distribution hystogram

In the cases of long stress histories obtained from measured strains in actual structures in [2] is recommended to use Rain-flow method. This method [3] was applied to analyze measured stresses.

Figure 10 shows resulting distribution histogram of the stress ranges. The data are extrapolated on 30-year service life and presented in S-N diagram in figure 11. Calculation of accumulated damage according to Palmgren-Miner damage hypothesis gave value 3.3.

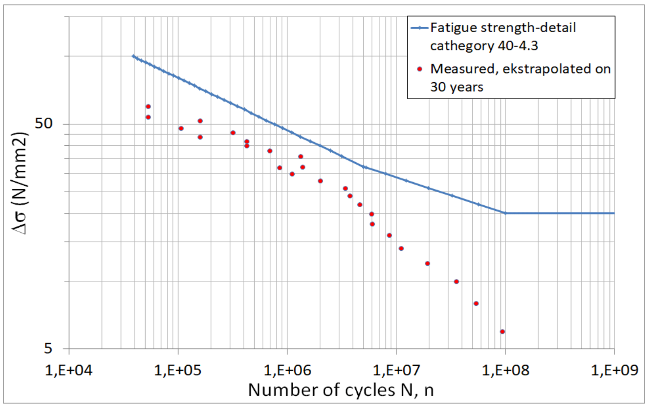


Fig.11. Extrapolated S-N diagram basd on test

6. CONCLUSION

Stress analysis made using results obtained from service like test revealed that the majority of high stress ranges originate from roll movement i.e. from carbody torsion. Result of calculation of accumulated damage based on Rain-flow method cycle count and Palmgren-Miner linear damage hypothesis indicates possible repetition of cracks after estimated mean service time of approximately nine years. However, several parameters can influence this estimation. Having in mind that the test was performed with full load, under average load a longer period to new crack initiation can be expected. Deterioration or renovation of tracks in such a long period is also parameter that shall be additionally taken in account. Supposed welding quality is also an influencing parameter, etc.

ACKNOWLEDGEMENT

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IMPROVING OF ABSORPTION POWER OF TUBE COLLISION ENERGY ABSORBER BY USING POLYURETHANE FOAM

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Abstract – *Tendencies to increase the speed in the railway transport lead to intensive work on active and passive safety improvement of railway vehicles with the aim to reduce possibilities of collision to a minimum. Frequently, we have collisions in the main railway stations during shunting and forming trains at speed higher than allowed. Consequences of these collisions are damages of the vehicles structure and sometimes parts of infrastructure that require time for repairs. These reduce the availability of the vehicles and causes loss of profit and increase of maintenance costs. Subject of this paper is experimental investigation of absorption characteristics of foam filled tube collision energy absorber which works on the principle of shrinking the seamless tube through special cone bushing. This type of absorber is intended for mounting in a line with standard buffer. Tube is filled with high density polyurethane foam with the aim to increase deformation resistance during collision. Using shrinking process energy absorption occurs by elastic-plastic deformations of the tube, friction between the tube and the cone bushing and compression resistance of high density polyurethane foam. This type of absorber gives gradually increase of the deformation resistance and higher absorption power in comparison with empty seamless tube. Experimental researches were realized on the hydraulic testing machine in the laboratory conditions. During tests, reaction force on defined stroke was measured. Results of the experimental investigations of foam filled tube collision energy absorber and empty tube collision energy absorbers were compared.*

Keywords – Passive Safety, Foam Filled Tube, Experimental Investigations, Collision Energy Absorber.

1. INTRODUCTION

This paper presents experimental investigations of characteristics of improved type of tube collision energy absorber filled by high-density polyurethane foam. Base for improving of absorption characteristics is seamless tube shrinking absorber that works on the principle of shrinking the seamless tube passing through a special cone bushing [1-5]. Shrinking the tube, as a shape of deformation, is possible to combine with more other shapes of deformation with the aim of getting better absorption characteristics with compact-unchanged dimensions of absorber. Shrinking tube absorber characterizes gradual increase of the deformation resistance (force), without any peaks at the beginning of deformation process. Force increases to its maximal value and remains at this value to the end of the deformation process. There is many ways to absorb collision kinetic energy on railway vehicles. Very limited space in the front part of the vehicle structure requires compact dimensions of absorber. On the other side, absorber must have required absorption power. Serious challenge for designers and researchers presents connection of these two conditions. Axial crushing analysis of empty and foam-filled concentric cylinder tubes is one of more ideas for collision energy absorption is [6, 7]. These types of energy absorbers use folding of the tube as primary deformation process. This shape of deformation characterizes jagged flow of the force during energy absorption. Jagged effect may cause start of deformation of vehicle structure before the fully utilization of absorption power of energy

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absorber. Impact of high-density polyurethane foam on increasing of absorption power presented in papers. Low velocity impact of empty and foam filled circumferentially grooved thick-walled circular tubes are presented in the paper [8]. Experimental results show that foam filling in dynamic loading, though effective from the energy absorption perspective, is not as effective as in the case of quasi-static loading. In addition, experimental investigations of crushing response of square aluminum tubes filled with polyurethane foam and aluminum honeycomb were presented in the paper [9]. Influence of the shape of deformation and polyurethane foam on absorption characteristics was analyzed. Experimental and numerical results of crushing of foam-filled aluminum tubes were presented in the papers [10, 11]. Results of these investigations clearly indicated that the energy absorption of a foam-filled tube is significantly higher than that of the empty tube. Next to these results also indicated that the friction coefficient between the foam and the tube has negligible influence on the energy absorption. Folding process as a way of deformation process in the mentioned research papers also characterizes jagged effect. Consequences of this type of deformation were explained above. This undesirable effect leads to choose shrinking process of deformation as a most acceptable for tube deformation for purpose of collision energy absorption on the railway vehicles.

Experimental investigations of absorption characteristics of empty and foam-filled circular steel seamless tubes under axial loading were realized in this paper. Polyurethane foam of high density was made by mixed of two chemical components (isocyanate and polyol) in precisely determined concentrations and with exactly defined technology. The foam was formed directly in the seamless tube and in this way connection with the tube wall is obtained. Quasi-static tests were performed on empty and foam filled tubes. Results obtained by these experimental investigations were analyzed and main differences are presented.

2. EXPERIMENTAL INVESTIGATIONS

Working principle of this type of absorber is shown in the Fig. 1. The same deformation process was used for empty (Fig. 1 left) and foam filled tube (Fig. 1 right). Shrinking absorber works on the principle of shrinking the seamless tube passing through special cone bushing. During deformation, tube diameter reduces from 75 mm to 68 mm, at the stroke of ≈ 90 mm. Using shrinking process energy absorption occurs by: *elastic-plastic deformations of the tube, friction between the tube and the cone bushing and compression resistance of high density polyurethane foam*.

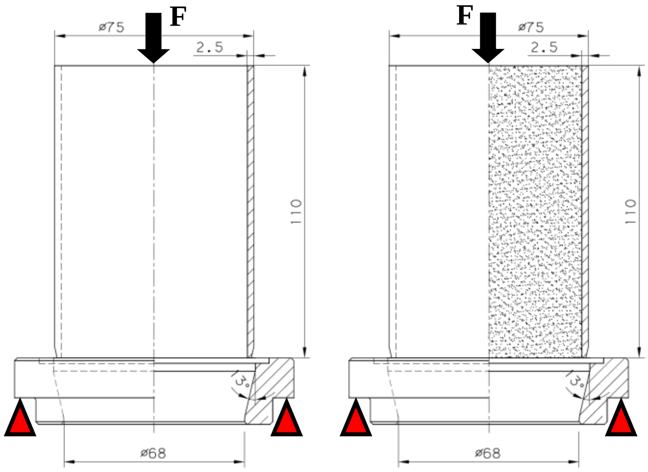

Fig.1. The working priciple

Experimental, quasi-static, investigations of the empty and foam filled seamless tubes were realized on the servo-hydraulic testing machine Zwick Roell HB250 that can be realized maximal force of 250 kN, Fig. 2.

Fig.2. Testing machine Zwick Roell HB250

Tests were realized at speed of the head of the machine of 1 mm/s. During tests, the values of the force were measured on defined stroke.

The following samples were used for tests, Fig. 3:

a) Seamless tubes (Item 1) from quench and tempered carbon steel in grade C45E with dimensions ∅75/2.5x110 mm,

b) Cone bushing (Item 2) from quench and tempered carbon steel in grade C45 with dimensions ∅75/68/13°x25 mm,

c) Steel tubes (Item 3) and

d) Steel covers of the tubes (Item 4).

Items 3 and 4 were used as auxiliary tools for filling the tubes with polyurethane foam. During expansion of polyurethane foam, chemical process produces high-pressure on the tubes wall as well as on the covers of the tubes, so it is necessary to perform this process in strongly controlled environment. In this way is possible to get foam of defined density with adequate structure, Fig. 4.

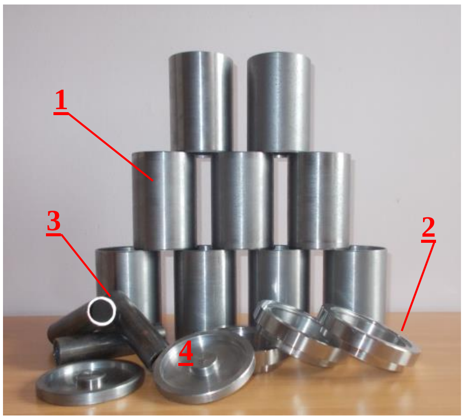

Fig.3. Samples

Fig.4. Filling the tube with foam

Fig. 5 shows seamless tube filled by polyurethane foam ($\rho \approx 115$ kg/m^3).

Fig.5. Filled tube

3. RESULTS AND DISCUSSION

During experimental investigations three samples of empty and three of foam-filled tubes were deformed. Characteristics force vs. stroke diagrams obtained by experimental investigations of empty tubes is shown in Fig. 6. This diagram characterizes gradual increase of the force until the maximal value is reached. The force remains approximately constant to the end of the deformation process at the stroke of ≈ 90 mm.

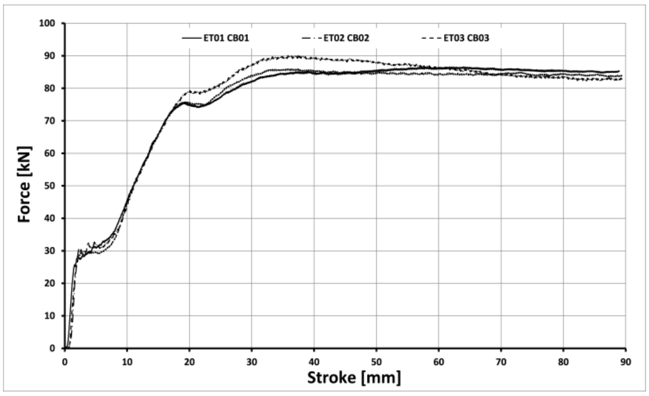

Fig.6. Force vs. stroke diagram – empty tubes

Fig. 7 shows force vs. stroke diagram obtained by experimental investigations of foam-filled seamless tubes.

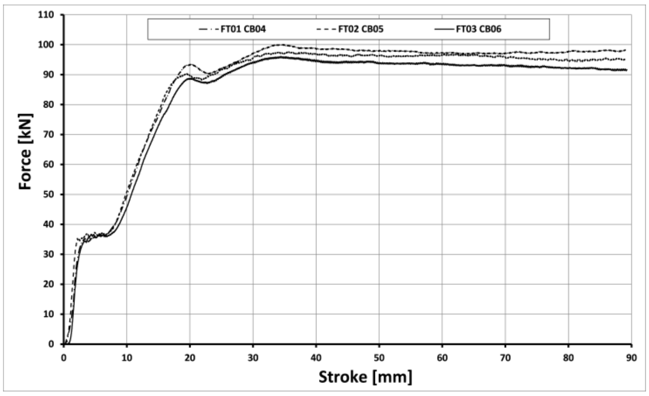

Fig.7. Force vs. stroke diagram – foam filled tubes

This diagram shows the same flow of the force as previous one, but with larger force values at the whole stroke. With the aim to present clearer relation between force vs. stroke curves of the empty and the foam-filled tubes, Fig. 8 shows average values of empty and foam filled tubes.

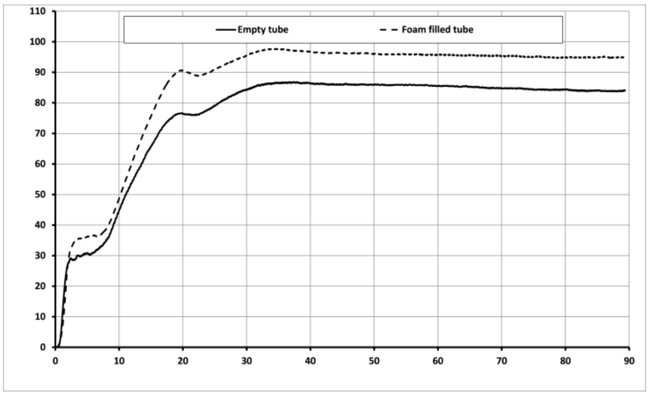

Fig.8. Comparison vs. stroke diagram – empty and foam filled tubes

Characteristic parameters that can be used for evaluation of this type of absorber are shown in the Table 1. Absorbed energy “W” is calculated as a work of force at defined stroke (amount of absorbed energy is equal to area under curve):

$$W=F_{av}\ x\ h$$

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

Tab.1. Characteristics parameters

	F_{max} [kN]	F_{av} [kN]	h [mm]	W [kJ]
Empty tube	86.86	73.87	≈ 90	**6.65**
Foam filled	97.79	83.38	≈ 90	**7.50**

The aim of this analysis was to compare two types of energy absorption elements. Since it was performed using scaled model, as expected, scaled values of force and absorbed energy were obtained. Using foam-filled tube, amount of absorbed energy is approximately 13 % higher compared to empty tube shrinking absorbers, at the defined stroke.

4. CONCLUSION

The use of foam-filled tube for collision energy absorption gives opportunity for increase of absorption power with the compact dimensions of absorber. Shrinking tube absorber filled by high-density polyurethane foam leads to better absorption characteristics. Improved type of shrinking absorber may absorb higher amount of collision energy compared to empty tube shrinking absorber. Most important is to keep gradual increase of the force at the beginning of the deformation process, without any peaks, and to get constant value of the force after reaching the maximal value. This is significant for gradual introduction force in the vehicle structure and to proper energy absorption, which begins at the buffer and goes through crash energy absorber in the front part of the vehicle structure.

The next step of this research will be experimental investigations of the polyurethane foam-filled tube with different values of densities with the aim to show influence of the foam density on increase of deformation resistance.

ACKNOWLEDGEMENT

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CORRAIL®1000 – AN OPTICAL SENSOR FOR CONTACTLESS AND SLIP FREE SPEED MEASUREMENT FOR RAIL VEHICLES

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Abstract – *Methods of measurement that are subject to wheel slip do not come up to modern measurement requirements due to their material (wheel/rail) dependent inherent measuring errors. Microwave-based methods are exposed to the problem of measuring against changing surfaces on the track bed, and GPS systems suffer from frequent signal failures in tunnels, narrow valleys or forests. The optical, contact-free CORRail®1000 speed sensor provides a track-bed-independent, direct measurement of train speed relative to the surface of the rail. The principle behind this is known as "Spatial Filtering Velocimetry". This paper focuses on how the CORRail®1000 has been evaluated during field tests by HaslerRail and its partners. This report will reveal that HaslerRail has succeeded in proving CORRail®1000's suitability for railway use and in demonstrating the advantage of using this technology for ERTMS / ETCS odometry systems. In particular, this paper shows the advantages of the CORRail®1000 in comparison with current Doppler Radar sensors.*

Keywords – Speed measurement, optical sensor, slip and slide, ERMTS / ETCS.

1. INTRODUCTION

1.1 Motivation

Methods of measurement that are subject to wheel slip do not come up to modern measurement requirements due to their material (wheel/rail) dependent inherent measuring errors. Microwave-based methods are exposed to the problem of measuring against changing surfaces on the track bed, and GPS systems suffer from frequent signal failures in tunnels, narrow valleys or forests.

HaslerRail has developed an optical, contact-free speed sensor which provides a track-bed-independent, direct measurement of train speed relative to the surface of the rail. The principle behind is known as "Spatial Filtering Velocimetry".

In a field test campaign, the goal was to prove that the sensor was ready to be integrated on railway vehicles as part of an ETCS odometry system.

The described field test campaign in this paper reflects the results of the latest test campaign performed in April/May 2017. This test campaign can also be interpreted as the final iterative step of an acceptance process which was started in 2010 with a simple CORRail®1000 prototype.

1.2 CORRail – Theory of operation

The basic operation of this velocimetry is to observe the optical image of a moving object through a spatial filter in the form of parallel slits (Fig.1) [1]. The illuminating light is scattered by an object, moving with velocity v_0 in direction x_0. A lens system creates an image of the object onto a grating, the transmittance of which is periodic in the direction of the moving object. The light passing through the spatial filter is received by a photodetector.

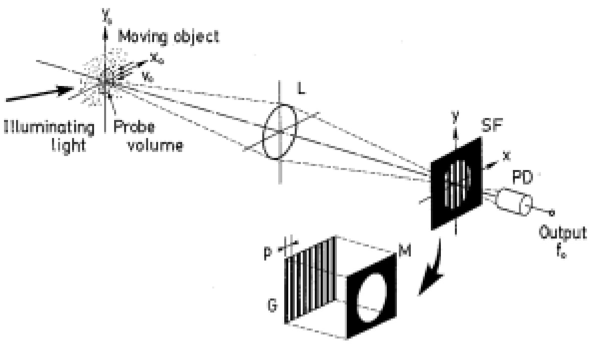

Fig.1. Principle using a spatial filter

The total intensity of the light arriving at the photodetector varies periodically, because of the image movement with constant velocity v and the periodic transmittance having a pitch p (Fig.2) [2].

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Thus, the photodetector provides a periodic signal containing a period $T_0 = p/ v_0$

The ratio of the AC to the DC component (i.e. the degree of modulation) of this signal depends on the size of the object image passing onto the transmission grating.

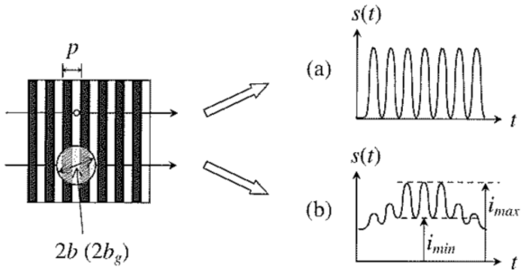

Fig.2. Output signal vs. object diameter

By measuring the frequency $f_0 = 1/T_0$ of this signal, the object velocity is determined from

$$|v_0| = p \cdot f_0 / M \qquad (1)$$

where M is the optical magnification of the lens system.

In order to be able not only to extract the length of the velocity vector, but also its direction, the system needs to be extended by a second channel. The properties of this second channel have to be defined such that its signal has a phase difference of π/2 with respect to the first channel.

Thus, a second transmission grating with the appropriate alignment and an additional photodetector is added.

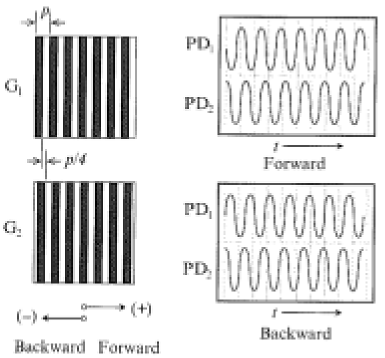

Fig.3. Sense of motion (forward/backward)

The sign of the velocity is determined by observing which channel leads onto the other (Fig.3) [2].

The purpose of the aforementioned lens system is to form an image of an object onto the grating. As the optical magnification M has a direct influence on the measured velocity, this lens system needs to be designed such that this magnification factor remains constant despite the variable distance between the sensor and the object of measurement.

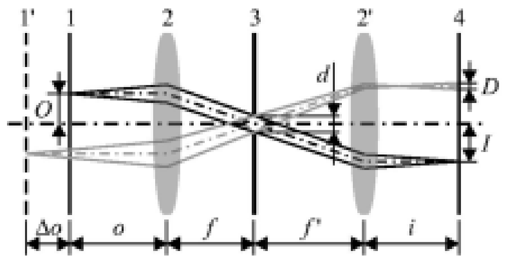

Fig.4. Double telecentric lens system

Fig.4 [3] depicts the lens arrangement of a double telecentric imaging system. Using such an arrangement results in parallel chief rays not only in the object space, but also the image space.

This leads to an optical magnification M that is invariant to the object distance.

1.3 Definitions

Since the CORRail sensor evaluates the frequency returned by a spatial filtering velocimeter this measurand can be classified according to DIN 1319-2, 3.8.2. [9]

DIN 55350-13 [8] strongly advises against utilizing the term accuracy in combination with quantitative figures and suggests employing the term “uncertainty of measurement” instead:

Uncertainty of measurement *(quantitative)*

Metric for the uncertainty attached to a measurement result. This is the quantitative correspondent to the qualitative term “accuracy”.

Systematic error *(quantitative)*

Difference between the expected value of the indication and the true value of the input quantity, as defined by [8]. This is the quantitative correspondent to the qualitative term “trueness”.

Standard deviation *(quantitative)*

[9] recommends quantitatively expressing precision in the context of measurement systems by the standard deviation. Thus, the standard deviation serves as quantitative correspondent to the qualitative term “precision”.

Before the field test campaign, the CORRail sensor was calibrated on HaslerRail`s roller test bench (ATE) proving the CORRail system meets the specification stated in [10]. Further, the availability of the CORRail sensor is checked during the calibration routine by monitoring the Measuring Valid Bit, which is sent with each speed-reading. Over the entire calibration routine the availability must be >99.8%. This value will be the benchmark for the field test campaign described in this paper.

All measurement values taken from the ATE are derived from national standards. The ATE`s uncertainty of measurement is significantly less compared to the CORRail sensor. In the table below the uncertainty of measurement of the ATE and the

CORRail system are compared.

Tab.1. Uncertainty of Measurement

Accuracy	ATE	CORRail
Systematic error - Trueness -	10^{-6} km/h	1 km/h…100 km/h < 0.2 km/h 100 km/h…500 km/h < 0.2 %
Statistical error 1σ - Precision -	10^{-3} km/h	1 km/h…100 km/h < 0.2 km/h 100 km/h…500 km/h < 0.2 %

2. METHODS AND MATERIALS

The field test setup consisted of five railway vehicles: Two SBB ICBt control cars, one SBB Re460 locomotive and two DB ICE BR401 control cars. The result in this test campaign came from only one DB BR401 TK509 control car. On all of those vehicles, a CORRail®1000 Speed Sensor was mounted and connected to a TELOC event recorder, which had additional interfaces in order to record context data such as: Reference speed, ETCS speed, outside temperature, traction control, brake application, GPS position and more. This event recorder was connected to a mobile gateway which allowed the automated transfer of data to an off board infrastructure where the data was processed with EVA+.

Whereas accuracy (systematical and statistical error) was determined on the test bench, the field test aimed to prove robustness under real operational conditions.

To compile a confusion matrix the following values were calculated based on CORRail Speed, the CORRail`s Measurement Valid Bit and the reference speed (ZWG-speed):

True positive:
Measurement valid AND no difference to reference speed.
True negative:
Measurement invalid AND difference to reference speed. (mostly wrong since it cannot be detected if there is no change in speed)
False positive:
Measurement valid AND difference to reference speed (this mostly indicates errors in the reference speed)
False negative:
Measurement invalid AND no difference in speed (mostly happens if the speed of the vehicle does not change)

The CORRail®1000 Speed Sensor`s availability was calculated as follows:

***Availability* [%]** = 100 – Driving Time / total Event Time of Measurement Valid

It was observed that referring to speed differences for availability was not optimal for the following reasons:

1. If there is no change in the vehicle speed, errors did not result in a speed difference, the error was hidden and the result appeared to be counted as a false negative.
2. The reference speed contains errors. Visual control of the occurred differences showed that they were mostly caused by an error in the reference speed.
3. Latency: The recorded speeds had different latencies, which resulted in differences during acceleration.
4. Resolution: Since the reference speed was limited in terms of its resolution a quantification noise of approximately 2 km/h was observable (Fig 5).

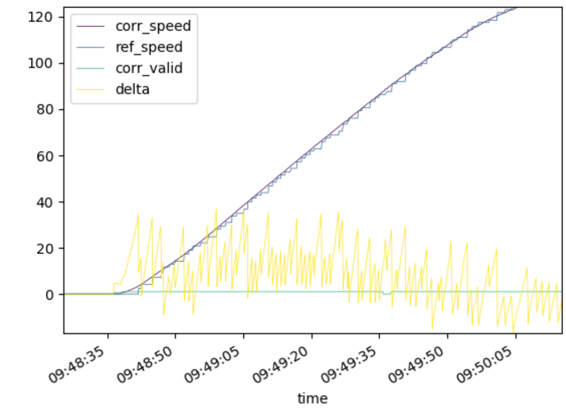

Fig.5. Quantification noise (delta x10)

The speed difference > 5km/h and > 7km/h was recorded as a digital signal on the event recorder and used for the above calculation. 5km/h was used due to the difference distribution under normal conditions (Fig 6). These differences occurred due to the above mentioned reasons.

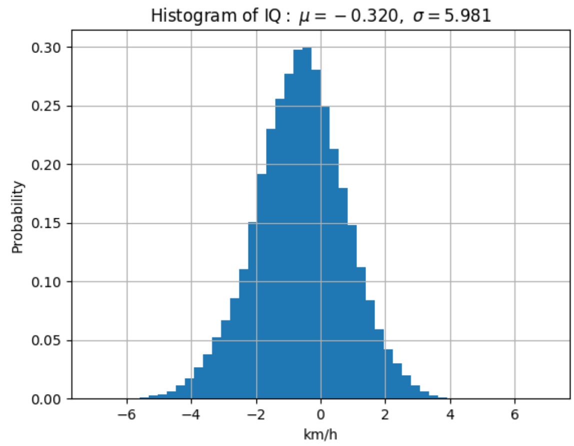

Fig.6. Difference distribution under non-error conditions

In the result, driving times below 10min a day were rejected. Since lower driving times normally contained only maneuvering sections where not all signals where recorded, this would have led to wrong calculations in terms of the availability.

3. RESULT

During the entire field test campaign (09.02.2017 until 10.02.2018) on board the DB BR401 TK 509 control car, a total mileage of app. 380`000 km was achieved. After one year the CORRail®1000 Speed Sensor did not show any indications of degradation (e.g. soiling).

A detailed statistical analysis was performed using the data recorded in the time range from the 14.04.2017 to the 16.05.2017. During this period, the DB BR401 TK509 was in motion for app. 347 hours and a mileage of 45`463 km was achieved.

Each day, the availability was calculated (Fig 7). The overall availability of the entire period was calculated with 99.5 %. The outliers are exceptional days with very low mileage and high percentage of maneuvering

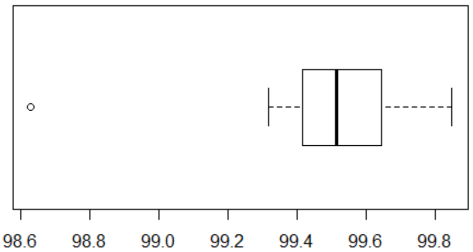

Fig.7. Availability distribution

4. DISCUSSION

The metric of the trial campaign was a good way to assess the CORRail®1000 Speed Sensor over a long period of time and to compare it in terms of its availability, whereas the benchmarking of the sensor`s uncertainty of measurement was not possible due to the characteristic of the reference speed.

The availability's threshold of > 99% was accepted as a given value which was specified by potential customers. The general availability provides limited information about the quality since it does not reveal if the failures were short or long. On a railway vehicle long lasting errors have a higher impact than short ones. This has not been considered in the result. The observation period neither contained the roughest weather conditions nor an equal balanced distribution of different normal weather conditions. Extreme cases will have to be studied in detail.

5. CONCLUSION

An availability of 99.5% makes the CORRail®1000 Speed Sensor a viable sensor for ETCS odometry systems. It makes it more valuable since common issues for other sensors (e.g. radar sensor) are reduced due to a different physical measurement principle.

Furthermore, the test campaign demonstrated that the CORRail®1000 Speed Sensor is a maintenance friendly system. Its patented splashguard prevents the sensor from soiling and guarantees a high availability as well as a high accuracy over hundreds of thousands of kilometers.

The test campaign also showed that the CORRail®1000 Speed Sensor is not subjected to changes of the reference`s surface (c.p. calibration shift of radar sensors due to different track beds), since the CORRail®1000 Speed Sensor uses only the rail head as reference.

In a potential further test campaign the aspect of a more accurate "true speed" (reference speed) should be considered in order to qualify the CORRail®1000`s accuracy as well.

ACKNOWLEDGEMENTS

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LIGHTWEIGHT DESIGN OF HIGH SIDED OPEN FREIGHT WAGON SERIES Eamno

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Abstract *– This paper is dedicated to lightweight design of high sided open freight wagon series Eamno, type 159. Design strength was calculated in Department of Railway Engineering at Technical University Sofia and tested at the Bulgarian National Transport Research Institute (NTRI) in 2015. In the same year German railway administration commissioned the wagon. The results of carried out strength calculations show, that the wagon's construction has very high strength and stiffness. The conclusion from calculations is that wagon construction could be optimized in order to reduce wagon's own weight and in that way to increase maximal payload capacity of the wagon by keeping the wagon body strength in prescribed limits. The result of the pre-calculations is that the construction of Eamno 159 is oversized due to massive mid solebar, bolsters and transoms. Those elements of wagon underframe have immense impact on own weight of entire wagon body. This motivated the authors to conduct the preliminary optimization of wagon design. The paper presents the preliminary optimization of wagon Eamno 159 with a goal of weight reduction in order to increase the wagon maximal payload. The optimization of wagon geometry was performed by topological optimization with ANSYS 19.1 software package.*

Keywords – lightweight design, freight wagon, FEM, topology, optimization.

1. INTRODUCTION

Lightweight design is, according to Albers [1], a development strategy, which aims to realize a required function with a system minimized mass under predefined boundary conditions. Lightweight design is generally not self-perpetuating, but has to be justified with superior goals – cost and benefits.

The object of this study is wagon Eamno 159, which is designed for in-house transportation of heavy bulk goods. The manufacturer of wagon is Bulgarian rolling stock manufacturer TRANSWAGON Plc., from city of Bourgas, Bulgaria. The companies design department developed the design documentation of the wagon in 2016 and strength calculations were carried out in 2017. The wagon was not tested, because it is a modification of the wagon series Eamnos 158, which was also designed in the company. Construction strength of Eamnos 158 was calculated in Department of Railway Engineering at Technical University Sofia and tested at the Bulgarian National Transport Research Institute (NTRI) in 2015. In same year German railway administration commissioned the wagon.

The results of carried out strength calculations show, that the wagon's construction has very high strength and stiffness [2].

The design optimization of the wagons like Eamno 159 is rarely done by the manufacturers of freight wagons even if there is higher potential for reducing the own weight. Most of wagon manufacturing companies and wagon owners are perfectly satisfied when the wagon pass the strength calculation and tests and finally is commissioned. Especially if the wagon is produced in smaller series, the design optimization is not done. Also for the manufacturers is such optimization time and money consuming and in most cases is done by external engineering offices. Other reason for avoiding the optimization is that most manufacturers are producing conventional wagons

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with traditional technologies already proven in service.

Obvious, there is enough potential for application of lightweight techniques in order to reduce the own weight of the wagon. This motivated the authors to conduct the optimization of wagon design.

2. VALIDATION OF WAGON DESIGN

Eamno 159 is designed for axle load of 25 t, has 4 axles and gauge G2. Its own weight is approx. 24 t, and maximal payload approx. 76 t. The material used is steel S355J2 according to EN 10025-2. Distance between pivots is 6500 mm and wagon length without buffers is 10 300 mm. Maximal speed for Eamno 159 is limited to 25 km/h, which means, that is used only for in-house transportation. The wagon has no side doors or end swing doors. The 3D model of Eamno's wagon body is shown in Figure 1.

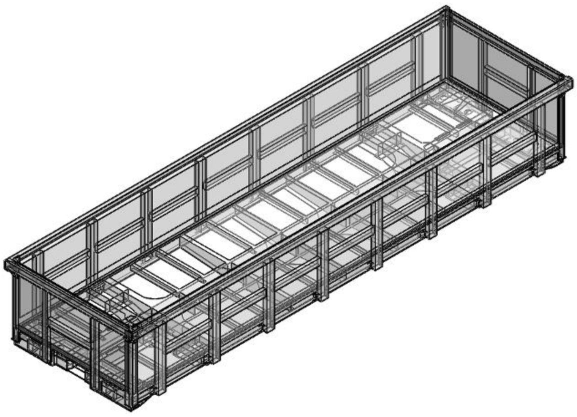

Fig.1. 3D model of Eamno's wagon body

The first step in lightweight design of the wagon body was to assess the strength of the current design.

The numerical analysis of wagon strenght was performed in ANSYS Workbench software. The material used in simulation for all the design elements of the wagon is S355J2 for which the material properties were taken from EN 10025-2. As the wagon body is simmetrical according to the vertical plane which passes trough the center of pivots and the load applied during the analysis is simetrical only a half of the model was used to reduce the time necessary for calculations.

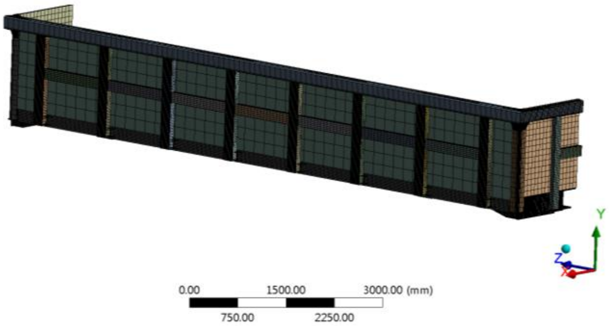

Fig.2. Finite element model of Eamno's wagon body

The meshing was performed with 3D [4] higher order elements in order to exactly capture the geometry of some of the design elements as well to increase the accuracy of simulations. Maximum mesh skewness of the model was 0.82 which proved mesh quality and thus provided confidence in simulation results. The model consists of 762991 nodes which form 184035 finite elements. A mesh size sensitivity test was performed to obtain confidence in accuracy of finite element simulations. It was assumed that the simulation results are insensitive to mesh size if the difference in equivalent stress and total deformation in two adjunct meshes is below 5%. The model finite element mesh iz shown on Figure 2.

European standard EN 12663-2:2010 [3] specifies static load cases and conditions for their application on freight wagon constructions. According to the standard the static loads are applied on initial design of high sided open wagon Eamno given in table 1. Examined were all 16 load cases prescribed in EN 12663-2. Figure 2 shows the boundary conditions and loads for load case

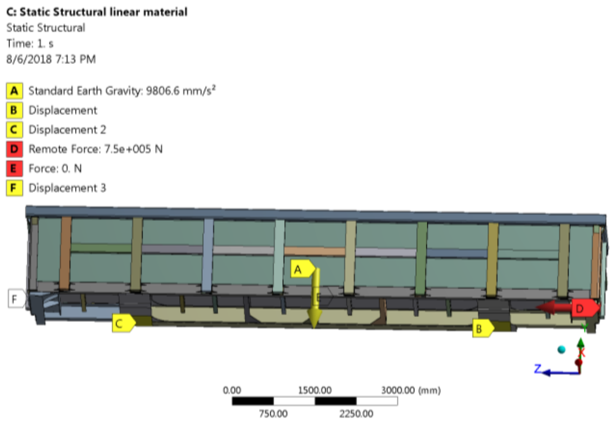

Fig.3. Loads and boundary conditions in case of HLC2 load case

In table 1 the mass m_1 = 15 t equals to underframe own mass, mass m_2 = 4,5 t equals to bogie mass and mass m_3 = 76 t equals to mass of maximal vertical payload.

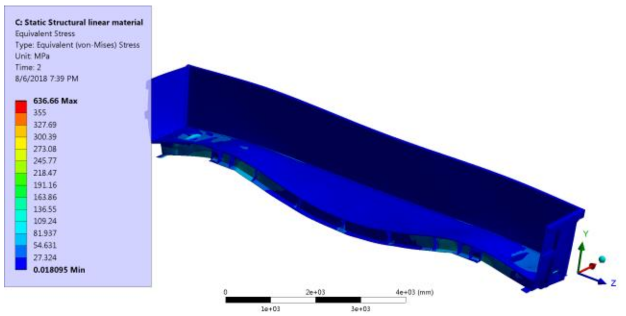

Fig.4. Equivalent stress of Eamno's wagon body for a CHLC2 load case

The table 1 also sumirises the results of numerical calculations. The maximal registered stress value is 653,2 MPa (Figure 4). Out of 16 load cases only in 2 of them the stress values were higher than 323 MPa which is the pemisible stress acording to the standard EN 12663-2:2010 in the vicinity of the welds. For the parent metal the permissible stres, according to the noted standard is 355 MPa [3]. The higher stress values are a consequence of local stress concentrations (Figure 5) in analysis and they are a conseguence of singularuty problem of finite element method.

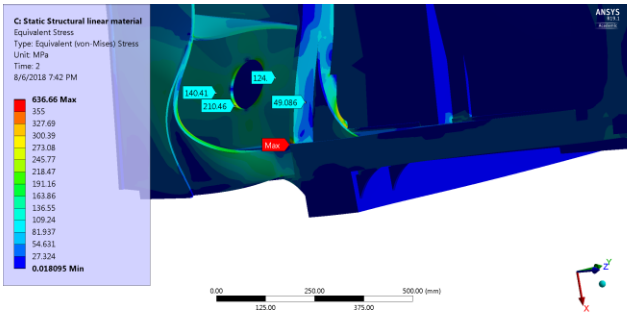

Fig.5. Stress concentration for a CHLC2 load case

The noted situation can be overcomed by application of plastic material model but such solution was rejected as the topology optimization can be only conducted with the linear material model. Furthermore, according to the Annex 1 of EN 12663-2:2010 [5] the acceptance criteria for ductile materials is satisfied, thus the wagon body can be validated according to the currently applicable standards. The values of other calculated parameters are up to 10 time higher (torsional stiffness) or lower (deflection of underframe) than permissible values.

The results of the finite element simulations show that the construction of Eamno 159 is oversized due to massive mid solebar, bolsters and transoms. Those elements of wagon underframe have immense impact on own weight of entire wagon body. It can be concluded that wagon design could be optimized in order to reduce wagon's own weight and in that way to increase maximal payload capacity of the wagon by keeping the wagon body strength in prescribed limits.

Tab.1. Load cases applied on wagon body and preliminary results

Load case	**Description**	**Stress value [MPa]**
	Longitudinal static loads	
HLC1	Compressive force at buffer axis height 2000 kN (Table 2 of [3])	272,6
HLC2	Compressive force 50 mm below buffer centre line 1500 kN (Table 3 of [3])	653,2
HLC3	Compressive force applied diagonally at buffer level 400 kN (Table 4 of [3])	118,7
HLC4	Tensile force at coupler axis level 1500 kN (Table 5 of [3])	195,9
	Vertical static loads (Table 6 of [3])	
VLC1	Vertical load 76 t distributed at the whole width and length	186,3
	Exceptional static loads (lifting and jacking)	
LLC1	Lifting at one end of the vehicle $1{,}0*g*(m_1+m_2+m_3)$ (Table 7 of [3])	238,6
LLC2	Lifting the whole vehicle at 4 lifting positions $1{,}0*g*(m_1+2m_2+m_3)$ (Table 8 of [3])	312,9
LLC3	Lifting the whole vehicle at 4 lifting positions with one lifting point displaced 10 mm vertically $1{,}0*g*(m_1+2m_2+m_3)$ (Table 8 of [3])	274,7
	Superposition of static loads (Table 9 of [3])	
CHLC1	Compressive force at buffer axis height 2000 kN and vertical load $1{,}0*g*(m_1+m_3)$	274,0
CHLC2	Compressive force 50 mm below buffer centre line 1500 kN and vertical load $1{,}0*g*(m_1+m_3)$	636,7
CHLC3	Compressive force at buffer axis height 2000 kN and minimum vertical load $1{,}0*g*m_1$	272,7
CHLC4	Tensile force at coupler axis level 1500 kN and vertical load $1{,}0*g*(m_1+m_3)$	197,7
CHLC5	Tensile force at coupler axis level 1500 kN and minimum vertical load $1{,}0*g*m_1$	196,2
	Special static loads (Points a), b) and c), Subchapter 7.3.3. of [3])	
SLC1	Force of 100 kN applied at four centre posts of each side wall outwards in the horizontal direction at a level of 1,5 m above the floor	240,5
SLC2	Horizontal force of 25 kN applied towards the outside of the wagon at the middle of the upper side wall rails	39,5
SLC3	Denting on the upper rails of the side walls by applying a vertical force of 40 kN	150,8

3. TOPOLOGY OPTIMISATION

Topology optimization is a mathematical method that optimizes material distrubution or fluid flow within a defined 3D design space, for a given set of loads, boundary conditions and constraints with the goal of improving properties of mechanical parts or fluid flow. Usually topology optimisation is associated with decrease of mass of mechanical parts and assemblies.

As it was already concluded that there is a potential of decrease of mass of wagon Eamno 159. Topology optimization was performed for two critical load cases HLC2 and CHLC2, where equivalent stresses had the highest values. The ANSYS software allows combination of multiple load cases in order to perform topology optimization, as well as weighting between the load cases. In this study the weighting option was not used as both load cases are equally important in order to validate the wagon design. It is important to point out that software currently allows the topological optimization with linear analysis.

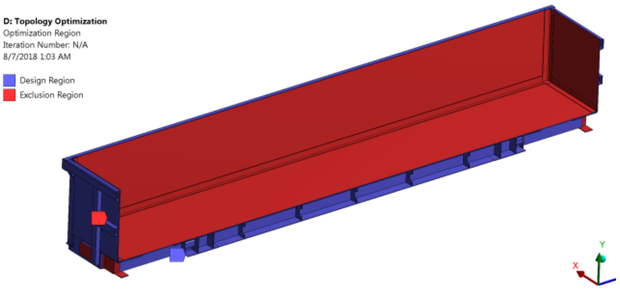

Fig.6. Optimisation region for a topology optimisation

The first step in topology optimization was to define an optimization region i.e. the 3D region where change of material layout is possible. All surfaces where loads or boundary conditions were applied were excluded from optimization region. Furthermore, all other functional surfaces which are necessary for performing of basic function (carrying the load), connection to other wagons and connection to bogies were also excluded from the optimization region, as shown in Figure 6.

The second step in topology optimization procedure was to define an optimization goal. As already noted the primary goal of the study was to decrease the mass of the Eamno wagon body, so a 20% reduction of mass was adopted as a goal of analysis.

The results of performed analysis are shown on figures 7 and 8. The topology optimization showed that there is potential to reduce side profiles as well as underframe elements to achieve the 20 % reduction of mass of wagon body.

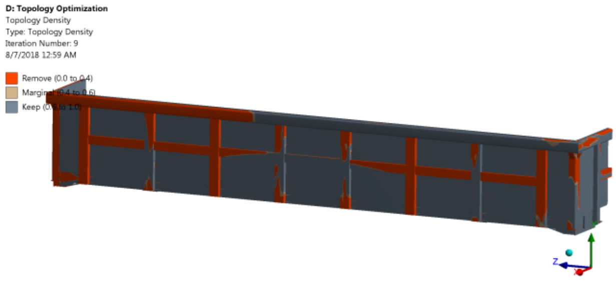

Fig.7. Result of topology optimisation

Fig.8. Result of topology optimisation

Further analysis should include in topology optimization all load cases necessary for validation of wagon design according to the standard EN 12663-2, as well as verification of wagon body redesign in static structural analysis for all load cases.

4. CONCLUSION

The reduction of the weight of freight wagons is a prerequisite for improving the competitiveness and effectiveness of rail freight as it allows trains to carry more freight as well as to decrease the impact on infrastructure due to lower dynamic forces.

The results of carried out strength calculations on Eamno 159 wagon body show that the wagon's body is oversized. By performing the topology optimization, it is possible to reduce the wagon own mass by up to 20%. Further research should focus on verification of results of topology optimization by defining the redesigned wagon body and performing the validation according to the requirements of EN 12663-2 standard.

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COMPARISON OF BRAKE PERFORMANCES OF FREIGHT WAGONS WITH THE CLASSIC BRAKE AND COMPACT FREIGHT CAR BRAKE

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Marija VUKŠIĆ POPOVIĆ [4]

Abstract *– Contemporary design of the freight wagons requires lightweight and compact design of all subassemblies and components (e.g. bogies, brake systems etc.). Because of that several manufacturers of railway brake systems have developed a compact brake system having all major components located within bogie. This system despite the more complex construction than standard have more advantages (lower mass, reduced air consumption, higher efficiency of brake rigging etc.) This paper presents results and conclusions obtained by testing of two freight wagons of the same type equipped with classic brake system and compact freight car brake system (CFCB). The testing included brake performance test i.e. stationary test and slip brake test.*

Keywords – railway, bogie, brake, testing.

1. INTRODUCTION

Development of the freight cars goes toward lightweight design (the minimum tare mass) and to the increased speed. Consequently, manufacturers started to develop compact brake systems for freight cars, in which the complete system is located within bogies. Such systems have lower mass and take up less space in comparison with standard brake systems. Obligatory application of the composite brake shoes type K accelerated development and introduction of the compact brake systems, because their higher friction coefficient, compared to cast iron shoes, made possible massive use of one-sided braking shoes.

In this paper we presented brake performance obtained by calculations and tests of the two rail cars type Falns equipped with standard brake and compact freight car brake (CFCB).

1.1. Compact freight car brake characteristics

The CFCB makes the operation of freight cars increasingly economical and efficient [1]. Due to its modular design, the CFCB is reduced in weight, simple to install and reduces costs. It offers low maintenance and low air consumption while being highly efficient and delivering low life-cycle costs. This leads to an increased performance, which brings benefits to both, vehicle manufacturers and the operators.

The main advantages of CFCB are:

- Optimum kinematics
- Modular design (block force is adjustable by changing the internal ratio, without changing installation space or interface to the bogie and reduced installation time)
- Low noise (use of steel-rubber-steel sleeves)
- Low LCC
- Low air consumption
- Can be equipped with bogie-mounted and car body-mounted manual parking brake
- Low weight (4-axle wagon weight is decreased for cca. 1 t)
- Preassembled and ready to install
- High efficiency (brake rigging efficiency is cca. 0.95 and does not change between two maintenance inspections and it is independent of brake cylinder pressure
- Low maintenance (there is no maintenance between the revisions).

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2. TEST WAGONS

Figure 1 shows analyzed freight wagon type Falns.

Fig.1. Wagon type Falns

Main characteristics of wagon are [2], [3]:

- Vehicle mass (empty): 20800 kg
- Vehicle mass (loaded): 90000 kg
- Number of axles: 4
- Bogie type: Y25
- Axle distance within bogie: 1800 mm
- Wheel diameter: 920 mm
- Maximum speed: 120 km/h

One wagon is fitted with a classic braking system and the other with a CFCB (Fig. 2). [1]

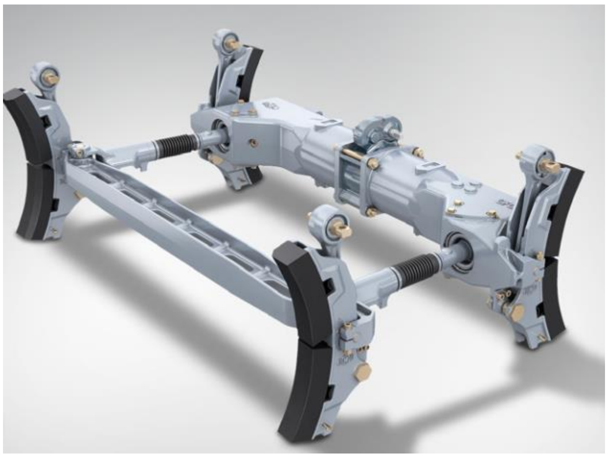

Fig.2. CFCB Knnor Bremse

Tab.1. Brake cylinder pressure

			Classic brake	CFCB
Brake cylinder pressure	bar	Empty wagon	1.36	1.09
		Loaded Wagon	3.80	3.60
Brake block force	kN	Empty wagon	8.36	7.31
		Loaded Wagon	29.41	28.84

Both wagons brakes are with automatic change of brake force vs. wagon mass and equipped with composite brake shoes type K.

Wagon with CFCB system had the maximum brake cylinder pressure adjusted to 3.6 bar unlike 3.8 bar regularly used with standard freight brakes. Lower pressure causes reduction of wear of the shoes.

On the basis of the calculation, the following parameters of the brake system were selected (Tab. 1).

3. COMPARISON OF BRAKE PERFORMANCE

3.1. Brake rigging efficiency

One of the basic difference between the classic and the compact brake is rigging efficiency. In the calculations its value for classic brakes is selected as 0.83 and corresponds to mean rigging efficiency between two inspections [5], while for CFCB this value is considered to be perpetual and equals 0.97.

For tested wagons brake rigging efficiency was determined based on the brake cylinder pressure and the measurement of force between the shoe and the wheel (Fig.3).

Fig.3. Brake shoe force tranducers

The values of the measured efficiency are shown in Table 2 and the graphical diagram of the development of the brake force is shown in Figure 4.

Tab.2. Brake rigging efficiency

			Classic brake	CFCB
Calculated brake force (η=1)	bar	Empty wagon	10.07	8.45
		Loaded wagon	35.43	33.58
Measured brake force	kN	Empty wagon	8.69	8.32
		Loaded wagon	32.96	32.20
Effieniecy		Empty wagon	0.86	0.97
		Loaded	0.93	0.96

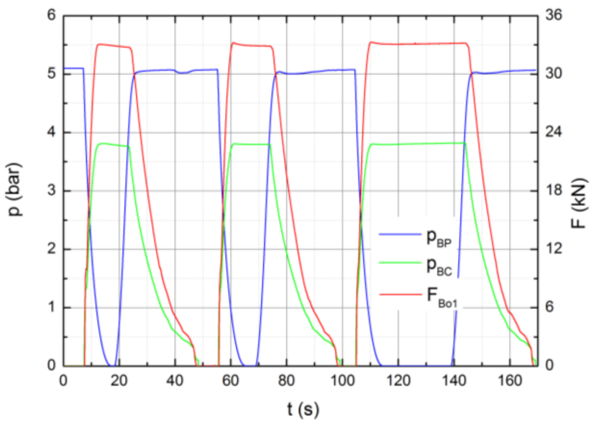

Fig.4. Brake shoe force, axle 4, loaded wagon, with classic brake

3.2. Brake weight

Braking performance of rail vehicles can be expressed via braked weight. Brake weight is the basic braking performance parameter expressed in integer numbers of tons.

Brake weight of these wagons was determined based on the slip test according UIC 544-1.

The first test results do not fulfill the minimum braking performance from CR TSI WAG 2013, table C.3 for the wagon equipped with the variable relay valve.

With nominal cylinder pressure 1.36 bar resulted in following results:

s_{corr}=395 m, λ=138% for 100 km/h and

s_{corr}=505 m, λ=147% for 120 km/h.

where are:

s_{corr} – corrected stopping distance

λ - brake weight percentage.

Also, at nominal designed cylinder pressure of 3.8 bar in the partially loaded condition with m=59.7 t, first two tests resulted in following results:

s_{corr}=405 m, λ=120.5% for 100 km/h

s_{corr}=575 m, λ=126.5% for 120 km/h

Measured brake weight percentages were above allowable values according to EN 14198.

Brake cylinder pressure was decreased by using relay valve to 1.2 bar for empty wagon and 3.4 bar for loaded wagon.

With new values of brake cylinder pressure was performed slip test and the following results were obtained (Table 3) where:

m – wagon mass

v – initial speed

s_{corr} – corrected stopping distance

λ – brake weight percentage

B – brake weight

B_{uic} – rounded brake weight that will be marked on the wagon.

Tab. 3. Brake weight – classic brake

Brake regime	M [t]	V [km/h]	$s_{corr,2}$ [m]	λ [%]	B [t]	B_{UIC} [t]
P	20.8	100	432.1	112.3	23.4	23
		120	616.8	116.6	24.3	24
	59.70	100	491.6	97.5	58.2	58
		120	682.3	103.6	61.8	62
	89.85	100	699.3	65.6	58.9	59

Table 4 presents test results for the wagon with compact brake.

Tab.4. Brake weight – compact brake

Brake regime	M [t]	v [km/h]	$s_{corr,2}$ [m]	λ [%]	B [t]	B_{UIC} [t]
P	20.84	100	474.6	101.3	21.1	21
		120	650.3	109.6	22.8	23
	59.8	100	476.1	101.0	60.4	60
		120	668.4	106.1	63.5	63
	90.05	100	698.8	65.6	59.1	59

As an illustration, diagrams for two recorded tests are shown in figures 5 and 6. In the graphics, following designations are used:

p_{BP} - brake pipe pressure

p_{BC} - brake cylinder pressure

v - speed

s - distance traveled

The stopping distance was derived from the traveled distance data for each individual test, as a path traveled between the starting moment of pressure fall in main brake pipe to the moment when the speed reaches zero.

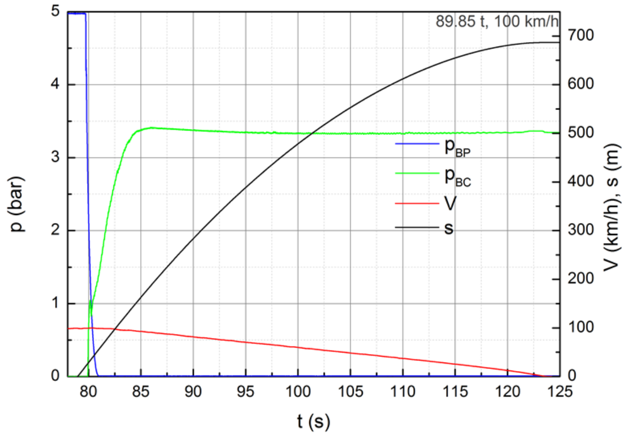

Fig.4. Slip test, wagon with classic brake

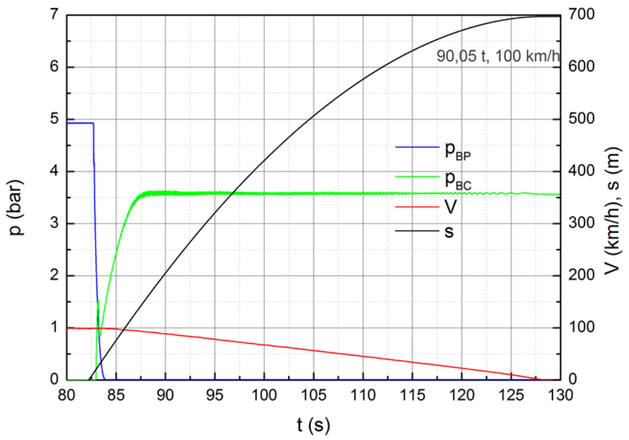

Fig.5. Slip test, wagon with compact brake

4. CONCLUSION

Based on the results, it can be concluded and confirmed that due to the construction of the braking system, brake rigging efficiency of CFCB is greater than classic brake.

In addition, by using composite brake shoes, it is mandatory to determine the brake performance by testing, due to the variation in the value of the coefficient of friction of these shoes. The conducted testing showed that it is necessary to perform the adjustment of the braking system in order to obtain satisfactory results.

This could be done by changing the pressure in the brake cylinder or the brake rigging ratio. If there is need for changing brake rigging ratio, compact brake system has the advantage, because it is possible to be done more simpler, only by changing the internal ratio without changing installation space or interface to the bogie.

Because of all these advantages, all leading braking equipment manufacturers have developed and upgraded their compact brake systems and their massive use is expected, primarily on new wagons.

ACKNOWLEDGEMENT

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

POWER MEASUREMENT ON TRACTION VEHICLES BASED ON SMART SENSORS

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Abstract *– A detailed description of the acquisition system used to measure the consumption of electric power of traction vehicles with an electric drive that uses smart sensors, based on standard ISO/IEC/IEEE 21451-4, is given . Unlike existing acquisition systems, the designed system based on smart sensors provides numerous advantages, especially in terms of the automatic configuration of the measuring system. Since the configuration of the acquisition system is automatic, significant savings are made, as well as avoiding the damage that often arise due to human error in the process of manual configuration and calibration of the measuring system. The basic parameters of the elements for the algorithmic approach in measuring the average power are analized in order to minimizes the error of an approximate discrete calculation of power consumption.*

Keywords – traction vehicles, power measurement, smart sensors, ISO/IEC/IEEE 21451-4.

1. INTRODUCTION

Classic traction control systems did not take into account the efficiency of staff work, in order to use traction power reasonable. More recently the transport organization devotes considerable attention to this issue because the savings achieved by driving optimization on the criterion of rational use of electricity, particularly visible in freight service. According to experimental research, up to 20% of energy savings achieved by efficient use of particular traction regimes. More manufacturers offer systems for measuring and calculating the electricity consumed on the vehicle. These closed systems are of invariable intent and cannot be modified or upgrading out of the realized solution. Therefore, it is of great importance to have deep knowledge of certain characteristics of modern measuring systems of this purpose. In this paper, such a system is described based on a developed technical solution and includes: realization of the metering mode with a detailed description of the acquisition system, smart sensors as its base subsystem, interface, conversion module as well as algorithm for digital implementation of vehicle power measurement.

2. IMPLEMENTATION OF POWER MEASUREMENT BASED ON SMART SENSORS

The prototype of the acquisition system on a traction vehicle, shown on Fig. 1, is designed to enable efficient power measurement and data transfer to the Control center. This system consists of several important elements:

- Smart sensors for measuring voltage and current of the traction motors;
- Microcontroller, used as smart sensor interface, analog to digital conversion and power calculation;
- Small single-board computer, used for localization and communication with the Control center over the cloud.

In the text below, each of these elements is described in more detail.

2.1. Smart sensors

Measurement of power is carried out indirectly by measuring currents and voltages of the traction motors.

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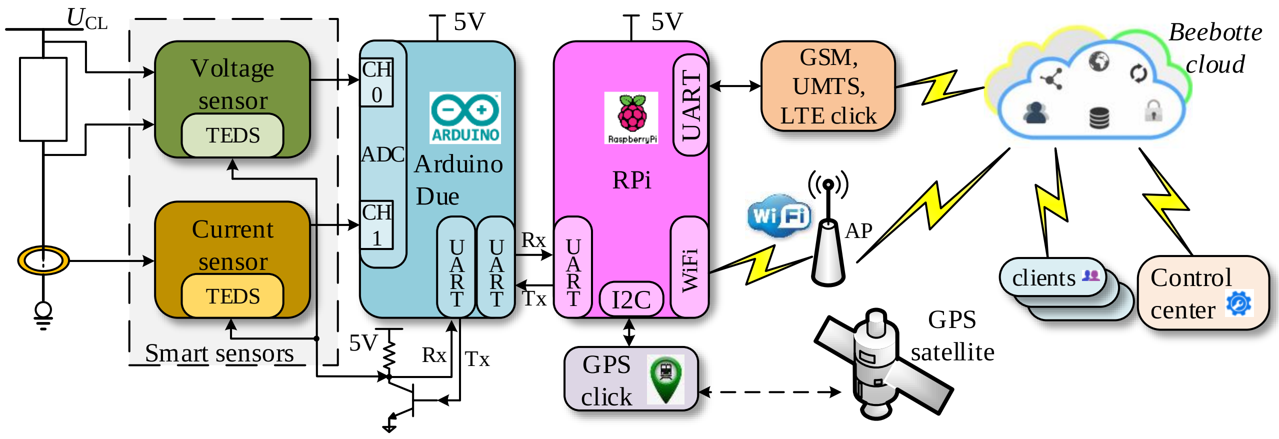

Fig.1. Prototype of the acquisition system on a traction vehicle

For the purpose of measurement of these physical quantities on the developed prototype, smart sensors are used. Smart sensors have been developed according to Standard ISO/IEC/IEEE 21451-4 [1].

For voltage measurements on prototype acquisition system, the LV 100-800 Hall-effect transducer produced by LEM [2] has been selected. Current measurement is carried out using Rogowski coil with integrator, ESCT-RC060-100A/0.333V, produced by Eastron [3]. The voltage and current transducers have been adjusted to produce galvanic isolated voltage signals within the range of (0V, +3.3V) suitable for analog inputs of microcontroller, as shown in Fig.2.

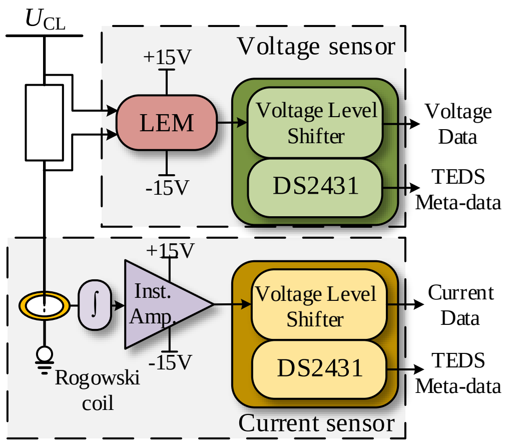

Fig.2. Smart voltage and current sensors

Both voltage and current sensors are connected with microcontroller through the mixed-mode interface (MMI) for analog sensor data and digital meta-data transmission according to ISO/IEC/IEEE 21451-4 specifications. Sensor meta-data are stored using an additional memory module DS2431 [4] in the form of Transducer Electronic Data Sheet (TEDS). By means of TEDS, which contains self-identifying parameters, smart sensors provides a relatively simple mechanism to extend the benefits of plug-and-play concept to the traditional analog sensors. Upon detection of smart sensor, microcontroller reads TEDS meta-data and knows what type of sensor is connected to corresponding analog channel.

2.2. Smart sensor interface

Microcontroller (Arduino Due in Fig.1) controls the transmission of TEDS data, manages the analog-to-digital conversion and allows communication with single board computer through UART interface. Arduino Due [5] prototyping board is based on the Atmel SAM3X8E, 32-bit ARM Cortex-M3 CPU.

The transmission of TEDS data is done using a 1-wire protocol. Protocol implementation is performed using UART interface. The Tx output of the UART interface is used for sending, and the Rx input for receiving TEDS data. However, in order to connect the Tx and Rx lines to a bidirectional 1-wire interface, it is necessary to add a transistor, as shown in Fig. 1.

The most important task for microcontroller is to implement algorithm for calculating consumed electrical energy while eliminating higher harmonics. This task requires high sampling rate of at least 10kHz per channel, so this microcontroller board is used since it provides 12-bit ADC with programmable gain and 1MHz sampling rate. Calculated energy consumption data is periodically sent via second UART interface to the single-board computer.

2.3. Localization and data transfer

In this prototype solution, for the localization and data transfer purposes a computer on the board - Raspberry Pi (RPi) [6] is used. The computer has a Raspbian operating system based on Debian Linux distribution. Programming languages often used for software development on this computer are C ++, Java and Python. For the development of this prototype system, Python language is used.

The basic role of RPi computer is to periodically retrieve data on consumed electrical energy from the Arduino Due microcontroller, as well as to provide data of the vehicle position and speed via the GPS click module [7]. These data is stored locally on the computer's memory card and transmitted to the control center and possibly to other clients when the communication network is available.

For connection to the communication network, the RPi is equipped with a WiFi interface that is used when the vehicle is within the range of WiFi access points. It is possible to connect a GSM/UMTS/LTE click module [7] on the RPi, which can be used for the connection on the local mobile network when the WiFi network is not available.

In the implementation of this prototype, data transfer is performed using Cloud services. There are a number of Cloud platforms available for development of such applications. One of them is Beebotte Cloud [8] that has been selected in this implementation for the ease of use and low cost of service. The use of the Cloud for the data transmission ensures control of data access rights and eliminates the need for data distribution servers, which facilitates the implementation and eventual future expansion of the system.

3. POWER CALCULATION PRINCIPLES

Bearing in mind the voltage and current conditions in the catenary, it is necessary to take into account the presence of higher current and voltage harmonics at the entrance to the traction vehicle.

Voltage signal $u(x)=\sum_{r=1}^{R} U_r \cos(rx+\varphi_u(r))$ where U_r represents harmonic r-th order magnitude for $r\in(1,\ldots,R)$, $x=2\pi f\ t$. Current signal $i(x)=\sum_{q=1}^{Q} I_q \cos(qx+\varphi_i(q))$ where I_q represents harmonic q-th order magnitude for $q\in(1,2,\ldots,Q)$, $R<Q$. The maximum harmonic order is determined based on the characteristics of the filter in the measurement system.

Instantaneous power $p(x)=u(x)i(x)$ can be presented as:

$$p(x)=\sum_{\substack{1\le r\le R\\1\le q\le Q}} \frac{U_r I_q}{2}\cos\big(x(r+q)+\varphi_u(r)+\varphi_i(q)\big) + \sum_{\substack{1\le r\le R\\1\le q\le Q}} \frac{U_r I_q}{2}\cos\big(x(r-q)+\varphi_u(r)-\varphi_i(q)\big) \tag{1}$$

Trapezoidal integration gives approximatively expression for average power, where P and W approximate power:

$$P=\frac{1}{2\pi}\int_0^{2\pi} p(x)\,dx \approx \frac{1}{N}\sum_{n=0}^{N-1}\frac{p(x_n)+p(x_{n+1})}{2} = \frac{1}{2N}\sum_{n=0}^{N-1}u(x_n)i(x_n)+\frac{1}{2N}\sum_{n=0}^{N-1}u(x_{n+1})i(x_{n+1})=W \tag{2}$$

Then it can be written as:

$$W=\frac{1}{2N}\sum_{n=0}^{N-1}2u(x_n)i(x_n)-\frac{1}{2N}u(x_0)i(x_0) \tag{3}$$

If f represents the fundamental frequency of the voltage and current signal, $f_s=1/T_s$ sampling frequency and if n-th sample of voltage and current is taken in the moment $nT_s = n/f_s$ then $x_n=2\pi\frac{f}{f_s}n=n\gamma$, $\gamma=2\pi\frac{f}{f_s}$, and it can be written:

$$\begin{aligned} W=&\sum_{\substack{1\le r\le R\\1\le q\le Q}}\frac{U_r I_q}{2N}\Big\{2\sum_{n=0}^{N-1}\Big[\cos\big(n\gamma(r+q)+\varphi_u(r)+\varphi_i(q)\big)\\ &+\cos\big(n\gamma(r-q)+\varphi_u(r)-\varphi_i(q)\big)\Big]\\ &-\cos(\varphi_u(r))\cos(\varphi_i(q))\Big\}=\\ =&\sum_{\substack{1\le r\le R\\1\le q\le Q}}\frac{U_r I_q}{2N}\Big\{\sum_{n=0}^{N-1}\cos\big(n\gamma(r+q)+\varphi_u(r)+\varphi_i(q)\big)\\ &-\cos(\varphi_u(r))\cos(\varphi_i(q))\Big\}\\ &+\sum_{\substack{1\le r\le R\\1\le q\le Q}}\frac{U_r I_q}{2N}\sum_{n=0}^{N-1}\cos\big(n\gamma(r-q)+\varphi_u(r)-\varphi_i(q)\big) \end{aligned} \tag{4}$$

If in each sum with distinguish all the assemblies for which $r = q$ an approximate term for the average power than can be written as:

$$\begin{aligned} W=P+&\sum_{\substack{1\le r\le R\\1\le q\le Q}}\frac{U_r I_q}{2N}\Big\{\sum_{n=0}^{N-1}\cos\big(n\gamma(r+q)+\varphi_u(r)+\varphi_i(q)\big)\\ &-\cos(\varphi_u(r))\cos(\varphi_i(q))\Big\}\\ &+\sum_{\substack{r\ne q\\1\le r\le R\\1\le q\le Q}}\frac{U_r I_q}{2N}\sum_{n=0}^{N-1}\cos\big(n\gamma(r-q)+\varphi_u(r)-\varphi_i(q)\big)=P+E \end{aligned} \tag{5}$$

Where E represents error of approximation. A procedure for eliminating the error of approximation, depending on the number of samples (N) in one power calculation cycle, as well as the elements for determining the frequency of selection are exposed in the rest of this section. For that purpose the following identities are used:

$$\begin{aligned} &\sum_{n=0}^{N-1}\cos\big(n\gamma(r+q)+\varphi_u(r)+\varphi_i(q)\big)\\ &=\frac{\sin\left(\frac{N\gamma}{2}(r+q)\right)}{\sin\left(\frac{\gamma}{2}(r+q)\right)}\cos\left(\frac{N-1}{2}\gamma(r+q)+\varphi_u(r)+\varphi_i(q)\right)\\ &\sum_{n=0}^{N-1}\cos\big(n\gamma(r-q)+\varphi_u(r)-\varphi_i(q)\big)\\ &=\frac{\sin\left(\frac{N\gamma}{2}(r-q)\right)}{\sin\left(\frac{\gamma}{2}(r-q)\right)}\cos\left(\frac{N-1}{2}\gamma(r-q)+\varphi_u(r)-\varphi_i(q)\right) \end{aligned} \tag{6}$$

The term for the approximation error gets the following form:

$$E=\sum_{\substack{1\le r\le R\\1\le q\le Q}}\frac{U_rI_q}{2N}\left[\frac{\sin\left(\frac{N\gamma}{2}(r+q)\right)}{\sin\left(\frac{\gamma}{2}(r+q)\right)}\cos\left(\frac{N-1}{2}\gamma(r+q)+\varphi_u(r)+\varphi_i(q)\right)\right. \tag{7}$$
$$\left.-\cos(\varphi_u(r))\cos(\varphi_i(q))\right]$$
$$+\sum_{\substack{r\ne q\\1\le r\le R\\1\le q\le Q}}\frac{U_rI_q}{2N}\frac{\sin\left(\frac{N\gamma}{2}(r-q)\right)}{\sin\left(\frac{\gamma}{2}(r-q)\right)}\cos\left(\frac{N-1}{2}\gamma(r-q)+\varphi_u(r)-\varphi_i(q)\right)$$

The integer sum $r+q=k$ can take a value from $k\in(1,2,\ldots,R+Q)$, and integer subtraction $|r-q|=k$ can take a value from $k\in(1,2,\ldots,Q\text{-}1)$. Therefore, the expression for the error E due to discretization can be presented in the following way:

$$E=\sum_{k=1}^{R+Q}\frac{\sin\left(\frac{N\gamma k}{2}\right)}{2N\sin\left(\frac{\gamma k}{2}\right)}\left\{U_rI_{k-r}\left[\cos\left(\frac{N-1}{2}\gamma k+\varphi_u(r)+\varphi_i(k-r)\right)\right.\right. \tag{8}$$
$$\left.-\frac{\sin\left(\frac{\gamma k}{2}\right)}{\sin\left(\frac{N\gamma k}{2}\right)}\cos(\varphi_u(r))\cos(\varphi_i(k-r))\right]$$
$$+\sum_{k=r-q}U_rI_{r-k}\cos\left(\frac{N-1}{2}\gamma k+\varphi_u(r)-\varphi_i(r-k)\right)$$
$$+\sum_{k=q-r}U_rI_{r+k}\cos\left(\frac{N-1}{2}\gamma k-\varphi_u(r)+\varphi_i(r+k)\right)$$

The members in parentheses of the above expression are marked S_{r+q}^k, S_{r-q}^k and S_{q-r}^k, respectively:

$$S_{r+q}^k=\begin{cases}\sum_{r=1}^{k-1}U_rI_{k-r}\left[\cos\left(\frac{N-1}{2}\gamma k+\varphi_u(r)+\varphi_i(k-r)\right)-\frac{\sin\left(\frac{\gamma k}{2}\right)}{\sin\left(\frac{N\gamma k}{2}\right)}\cos(\varphi_u(r))\cos(\varphi_i(k-r))\right], & 1<k\le R\\ \sum_{r=1}^{R}U_rI_{k-r}\left[\cos\left(\frac{N-1}{2}\gamma k+\varphi_u(r)+\varphi_i(k-r)\right)-\frac{\sin\left(\frac{\gamma k}{2}\right)}{\sin\left(\frac{N\gamma k}{2}\right)}\cos(\varphi_u(r))\cos(\varphi_i(k-r))\right], & R<k\le Q\\ \sum_{r=k-Q}^{R}U_rI_{k-r}\left[\cos\left(\frac{N-1}{2}\gamma k+\varphi_u(r)+\varphi_i(k-r)\right)-\frac{\sin\left(\frac{\gamma k}{2}\right)}{\sin\left(\frac{N\gamma k}{2}\right)}\cos(\varphi_u(r))\cos(\varphi_i(k-r))\right], & Q<k\le Q+R\end{cases} \tag{9}$$

$$S_{r-q}^k=\sum_{r=k+1}^{R}U_rI_{r-k}\cos\left(\frac{N-1}{2}\gamma k+\varphi_u(r)-\varphi_i(r-k)\right),\ 1\le k\le R-1$$

$$S_{q-r}^k=\begin{cases}\sum_{r=1}^{R}U_rI_{r+k}\cos\left(\frac{N-1}{2}\gamma k-\varphi_u(r)+\varphi_i(r+k)\right), & 1\le k\le Q-R\\ \sum_{r=1}^{Q-k}U_rI_{r+k}\cos\left(\frac{N-1}{2}\gamma k-\varphi_u(r)+\varphi_i(r+k)\right), & Q-R<k\le Q-R\end{cases}$$

Now error E can be expressed as:

$$E_k=\frac{\sin\left(\frac{N\gamma k}{2}\right)}{2N\sin\left(\frac{\gamma k}{2}\right)}\left(S_{r+q}^k+S_{r-q}^k+S_{q-r}^k\right) \tag{10}$$

Having in mind that sin $(Z\pi)$ = 0 number of samples in one measurement period should be chosen such as:

$$N=Z\frac{f}{f_s} \tag{11}$$

On the other side, it is necessary that sampling frequency fulfill next condition:

$$\frac{f}{f_s}\ll\frac{1}{R+Q} \tag{12}$$

In practice stands:

$$f_s=(15-30)\cdot(R+Q)\cdot f \tag{13}$$

Therefore, expression in denominator of the equation (10) will differ zero and there will be no aliasing effect in the border region of the frequency range.

4. CONCLUSION

The paper presents the basic elements of a measuring system for the power consumption of traction vehicles based on of synchronous current and voltage sampling at the vehicle's entrance. The types of measuring sensors are analyzed, their upgrades to the level of smart sensors, standards and protocols that determine the working domains of these sensors, as well as systems for positioning and data transfer. The basic parameters that define the elements for the algorithmic approach in measuring the average power in time are discussed. The expressions for determining the number of samples in the power measurement cycle as well as the method for determination of sampling frequency that minimizes the error of an approximate discrete calculation of power consumption are given.

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TRANSFORMING ANALYTICAL AND ANALOG DEPENDENCIES OF CRITERIA AGAINST DERAILMENT OF DIFFERENT CLASSES

Dobrinka ATMADZHOVA [1]

Abstract *– The main objective of the present study is to create a theoretical (computational) method to indirectly determine the internationally validated criteria against Y/Q derailment with transforming virtual forces according to EN 14363 and UIC Leaflet 518: with a preliminary determination (theoretical and experimental) of the so-called nominal criterion composed of real forces in their nominal forms, i.e. without supplements – YP/Q′1 (ratio between the axle force or frame force and the vertical result force at the climbing wheel-rail contact point) and its subsequent reducing to transient criterion Y1/Q1 ≈ Y/Q. The sub-goal of the paper is to create transforming functions of criteria against derailment using two models (systems). These functions have much more complete dependence on various other features. It is characteristic that transforming functions are created in two different ways: one is analytic and the other is based on analogy. The analogy established between the two models is complete and involves all defining features of models, including the especially significant feature called "security factor against derailment".*

Keywords – Railway vehicles, rolling stock, criteria against derailment, derailment.

1. INTRODUCTION

Transforming dependencies and transformation between various derailment-related features and conditions is an obvious necessity to freely operate with them, firstly – for theoretical determination of the value of virtual criterion against derailment according to EN 14363 [1] and UIC 518 [2] indirectly by transformation from a real criterion.

The conditions assumed preliminarily are:

1. As an output (assigned) real criterion to be aligned with internationally validated *Y/Q* according to EN 14363 and UIC 518, the so-called "nominal" criterion Y_p/Q'_1 is intropduced with horizontal nominal force Y_p called "frame" or "axle" force, transmitted between the axle and frame [3]; and vertical force Q'_1 representing the resultant force at the contact point of attacking wheel:

$$\frac{Y_p}{Q'_1}=\frac{1-\dfrac{\mu_1}{\sin\gamma_1(\cos\gamma_1+\mu_1\sin\gamma_1)}-\dfrac{Q'_2}{Q'_1}.\dfrac{\mu_2}{tg\gamma_1}}{\cot g\gamma_1-\dfrac{h}{c}+\dfrac{\mu_1.h/c}{\sin\gamma_1(\cos\gamma_1+\mu_1\sin\gamma_1)}-\dfrac{\mu_2.h/c}{tg\gamma_1}} \tag{1}$$

where: γ_1 and μ_1 – the flange angle and the coefficient of friction in the contact point "flange-rail" point of the attacking wheel respectively; μ_2 – coefficient of friction in the "flange-rail" contact point of the non-attacking wheel; Q'_2 and Q'_1 – vertical loads of the two wheels of wheel-axle and *h/c* – parameter considering the geometric position of nominal force Y_p (Fig.1).

2. The internationally validated criterion of Nadal *Y/Q* [4, 5, 6, 7, 8] (and the system respectively) according to EN 14363 and UIC 518:

$$\frac{Y}{Q}=\frac{Y_1}{Q_1}=\frac{tg\gamma_1-\mu_1}{1+\mu_1.tg\gamma_1} \tag{2}$$

and with the correction of Marie G.:

$$\frac{Y}{Q}=\frac{Y_1}{Q_1}=\frac{tg\gamma_1-\mu_1}{1+\mu_1.tg\gamma_1}-\frac{Q'_2}{Q'_1}.\mu_2 \tag{3}$$

is temporarily replaced with the so-called "conditional transformation" Y_1/Q_1, which is closer to reality, characterized by factually acting (reduced) forces Y_1 and Q_1 at the contact point of attacking wheel, helps to achieve methodological compatibility with the basic criterion temporarily assuming it with practically permissible deviation $Y_1/Q_1 \approx Y/Q$. Other important features of the conditional transforming criterion and the corresponding system (model) are:

2.1. The conditional transformation system is with 2 wheels (attacking and non-attacking) as the forces and bandage profile parameters have indexes "*1*" and "*2*" for the attacking and non-attacking wheels respectively.

2.2. The forces are actually active and contain the "additives" due to the effect of force Y_p.

2.4. The Q_2/Q_1 parameter reports on the impact of wheel load irregularities and is an indirect measure of security against derailment and an important identifying factor.

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2.3. Here the formula for limit value of criterion against derailment has an additional member – $tg(\gamma_2 + \rho_2).Q_2/Q_1 \approx -\mu_2.Q_2/Q_1$, through which (excluding $Q_2/Q_1 = 0$), the criterion limit value always decreases, worsens (by *20 - 25%* with $Q_2/Q_1 = 1$ and by *40 - 50%* with $Q_2/Q_1 = 2$).

2.4. Parameter Q_2/Q_1 takes into account the impact of wheel load irregularities being an indirect measure of safety against derailment and an important identifying factor.

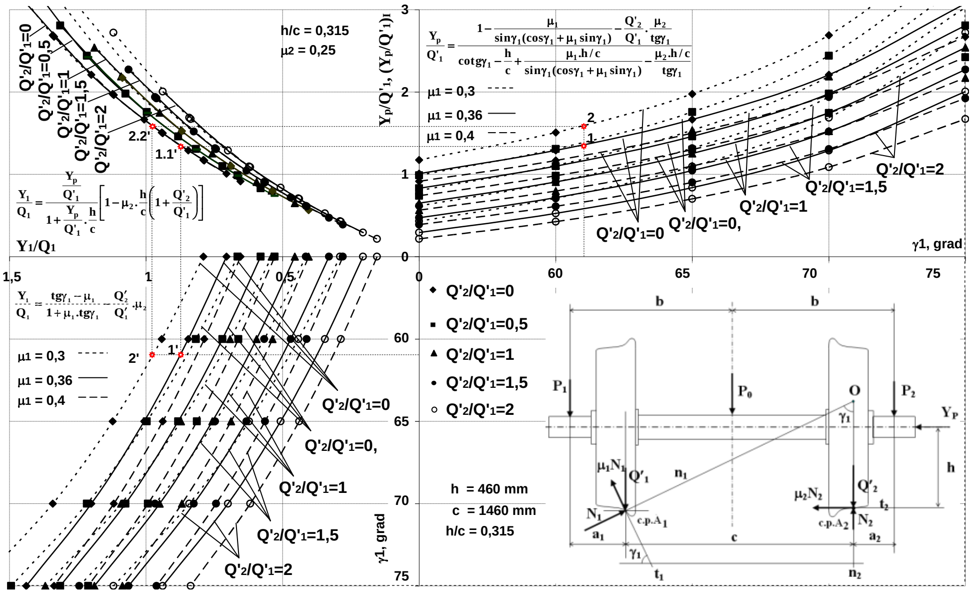

Fig.1. Nomogram with methodical reconciliation of criteria against derailment Y_p/Q'_1 and Y_1/Q_1 for standard wagon wheel axles $\phi 920$ mm, $h = \phi/2 = 460$ mm, $c = 1460$ mm.

2. ANALOGY BETWEEN CRITERIA. BASIC TRANSFORMING FUNCTION

The accepted and introduced prerequisites and criteria help in various ways to increase their methodical compatibility – starting from their initial level and reaching the state of complete analogy, which is visible from the nomogram (Fig.1). The graphs of criteria against derailment Y_p/Q'_1 and Y_1/Q_1 in abscisses γ_1 (the angle of flange) and parameters Q'_2/Q'_1 (Q_2/Q_1) and μ_1 (the coefficient of the "flange-rail friction") are given in quadrants I and III, and the transforming function of these criteria is graphically presented in quadrant II.

On the other hand, based on the primary force dependencies of transformation systems, it can be written

$$\frac{Y_1}{Q_1} = \frac{Y_p / Q'_1 \pm \mu_2.Q'_2 / Q'_1 - \mu_2.(h/c).Y_p / Q'_1}{1 + (h/c).Y_p / Q'_1} \qquad (4)$$

where signs „$\pm$" reflect the presence of "ineffective" solutions (solutions, which do not conform to reality), and for the other markings – see Fig.1.

Dependency (4) with parameter value $Q_2/Q_1 = 0$ becomes a basic dependency:

$$\frac{Y_1}{Q_1} = \frac{Y_p / Q'_1}{1 + (h/c).Y_p / Q'_1}\left(1 - \mu_2 \frac{h}{c}\right), \qquad (5)$$

whose graph is represented on a scale in Fig. 1 (nomogram , quadrant II).

In addition to the above-mentioned analogy between the diagrams of transforming criteria, it exists also between separate zones (sections) of these diagrams as well as between individual points or states; for example, points-analogs are point *1* of the quadrant I and point *1′* of the quadrant III, point *2* and point *2′*, etc. – Fig. 1. Thus, the condition of existence of points-analogs is the parameters μ_1, γ_1 *and* Q'_2/Q'_1 (Q_2/Q_1) to have the same values**.**

An important property of points-analogs is: through them, using analogy, the dependency between transforming criteria can be outlined. For example, the ordinates of points-analogs *1* and *1′* with parameter Q'_2/Q'_1 $(= Q_2/Q_1) = 0$, located in quadrants I and III respectively and representing criteria Y_p/Q'_1 and Y_1/Q_1 respectively, are "transferred" to quadrant II by rays parallel to the respective abscissas. With their intersections, e.g. point *1.1′* in quadrant II, the rays outline the dependency between the same criteria.

The dependency thus outlined on the basis of analogy coincides completely with dependency (5), which has been analytically derived [9].

Dependency (5) is determined singly and only by parameter $Q'_2/Q'_1 = Q_2/Q_1 = 0$, with all possible values of parameters μ_1 and γ_1. For example, if besides points-analogs *1* and *1′* with $\mu_1 = 0{,}36$ other points-analogs, e.g. *2* and *2′* with another value $\mu_1 = 0{,}3$ (the uppermost thin line) are taken at the same value of parameter $Q'_2/Q'_1 = Q_2/Q_1 = 0$, then intersection point *2.2′* between the rays also falls on the curve according to formula (5) – the basic transforming function; the same fall will also occur with $\mu_1 = 0{,}4$ as well as with any other value of μ_1 that is not marked in the nomogram if $Q'_2/Q'_1 = Q_2/Q_1 = 0$.

3. UNIVERSAL TRANSFORMING FUNCTION

Compared to the basic function, the universal transforming function refers to a considerably wider area with a larger number of parameters and at all possible values of theirs, which is why the task of determining this function is considerably more complex. Because of the analogy between transforming criteria, thanks to its use with a procedure similar to that in the previous case, a successful solution is obtained because the points-analogs “transferred” to the quadrant II outline curves (namely, a family of curves) there. Within the "experiment" of a given structure, these curves are separated only by the value of parameter $Q'_2/Q'_1 = Q_2/Q_1$ without any influence of the other parameters for the attacking wheel – μ_1 and γ_1.

The influence of structure on the transforming function sought is adequately expressed by inserting parameters h/c and μ_2 into it, in the same way as in the previous case with the basic transforming function.

Concerning the analytical justification of the function sought, mainly due to the strong influence of ineffective solutions, the results obtained here can be accepted unreservedly not in their entirety, but partly by selection, i.e. they can serve only as landmarks.

Also, with using the so-received "landmarks", entirely relying on the above-discovered links and applying Gaus’s method of “the least squares” (in compliance with the software), the so-called "universal" transforming function has been derived derived:

$$\frac{Y_1}{Q_1} = \frac{Y_p / Q'_1}{1 + (h/c).Y_p / Q'_1}\left[1 - \mu_2 \frac{h}{c}\left(1 + \frac{Q'_2}{Q'_1}\right)\right], \qquad (6)$$

which includes and substitutes formula (4).

The reversal formula, i.e. from criterion Y_1/Q_1 to criterion Y_p/Q'_1, is derived from formula (6).

The parameters required for practical use of the above mentioned formulas are $\mu_2 = 0{,}25$), $h/c = 0{,}315$ for standard wagon axles, and parameter $Q'_2/Q'_1 = Q_2/Q_1$ is determined by formulas arising from (4) and (5).

The exact values set for current variables (parameters) $\boldsymbol{\gamma_1}$ and $\boldsymbol{\mu_1}$ correspond to the normalized, specified, etc. values of criteria or possibly other indicators.

Consequently, three basic methods have been developed for transforming the values of so-called "nominal criterion against derailment Y_p/Q'_1 to the conditional transforming criterion $Y_1/Q_1 \approx Y/Q$ as follows:

- graphical, with nomogram (Fig.1);
- analytical, with a classical procedure;
- analytical, with software.

The analytical methods are unconditionally outlined as main methods recommended for use in practice, and the graphical one is given rather for the purpose of illustration, more convincing justification of the methodology and even including deducing basic analytical dependencies through it.

4. JUSTIFICATION OF DERAILMENT SAFETY COEFFICIENT

With fulfilling the conditions of methodological compatibility and analogy, the requirement for equivalence between the values of safety coefficients against derailment – η_{nom} (nominal) and η_{cond} (conditional) for the two criteria is necessarily satisfied, i.e. that:

$$\eta_{nom} \equiv \eta_{cond} \qquad (7)$$

or because the derailment safety factor is the ratio of its **maximum** limit value (with $Q'_2/Q'_1 = Q_2/Q_1 = 0$) to the **submaximal** limit value (with $Q'_2/Q'_1 = Q_2/Q_1 > 0$) it can be written

$$\frac{\left(Y_p / Q'_1\right)^I_{Q'_2/Q'_1=0}}{\left(Y_p / Q'_1\right)^I_{Q'_2/Q'>0}} \equiv \frac{\left(Y_1 / Q_1\right)^I_{Q_2/Q_1=0}}{\left(Y_1 / Q_1\right)^I_{Q_2/Q_1>0}} \qquad (8)$$

and substituting the corresponding expressions of (7) and (4) in (6), after conversion the identity obtains the following kind:

$$\frac{1-(Q'_2/Q'_1).(\mu_2/tg\gamma_1)}{1-\dfrac{\mu_1}{sin\gamma_1(cos\gamma_1+\mu_1 sin\gamma_1)}} \equiv \frac{1-\mu_2.Q_2/Q_1}{\dfrac{tg\gamma_1-\mu_1}{1+\mu_1 tg\gamma_1}} \qquad (9)$$

where the left part of (9) is $1/\eta_{nom}$ and the right one is $1/\eta_{cond}$.

$$\frac{1-(Q'_2/Q'_1).(\mu_2/tg\gamma_1)}{1-\mu_1/[sin\gamma_1(cos\gamma_1+\mu_1 sin\gamma_1)]} = \frac{1}{\eta_{nom}} \qquad (10)$$

$$\frac{1-\mu_2.Q_2/Q_1}{(tg\gamma_1-\mu_1)/(1+\mu_1 tg\gamma_1)} = \frac{1}{\eta_{nom}} \qquad (11)$$

Fig. 2 shows the graph of η_{nom} and η_{cond} depending on $Q'_2/Q'_1 = Q_2/Q_1$ with varied values of γ_1 and μ_1 and a fixed value of $\mu_2 = 0{,}25$.

Further, after transformations of (9), it is reached to obvious identity, which is the end of proving.

5. SOLUTIONS, WHICH DO NOT CONFORM TO REALITY

For example, when changing the sign before the 2nd member in the numerator of (1), the sign before the member with ratio Q'_2/Q'_1 in formula (3) also changes:

$$\frac{Y_1}{Q_1} = \frac{tg\gamma_1 - \mu_1}{1+\mu_1.tg\gamma_1} + \frac{Q'_2}{Q'_1}.\mu_2 \qquad (12)$$

As a result of this, the nomogram in Fig. 1 is changed as: the family of transforming function curves as well as criteria Y_p/Q'_1 and Y_1/Q_1, are located above the curves with zero values of Q'_2/Q'_1 and Q_2/Q_1 symmetrically (like a mirror) towards these curves (see Fig. 3).

For example, if besides points-analogs 1 and 1′ with $\mu_1 = 0{,}36$ other points-analogs, e.g. *2* and *2′* with another value $\mu_1 = 0{,}3$ (the uppermost thin line) are taken at the same value of parameter $Q'_2/Q'_1=Q_2/Q_1=0$, then intersection point *2.2′* between the rays also falls on the curve according to formula (5) – the basic transforming function.

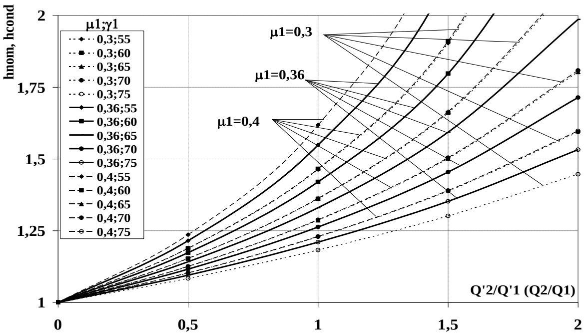

Fig.2. Graph of η_{nom} and η_{cond} depending on $Q'_2/Q'_1 = Q_2/Q_1$.

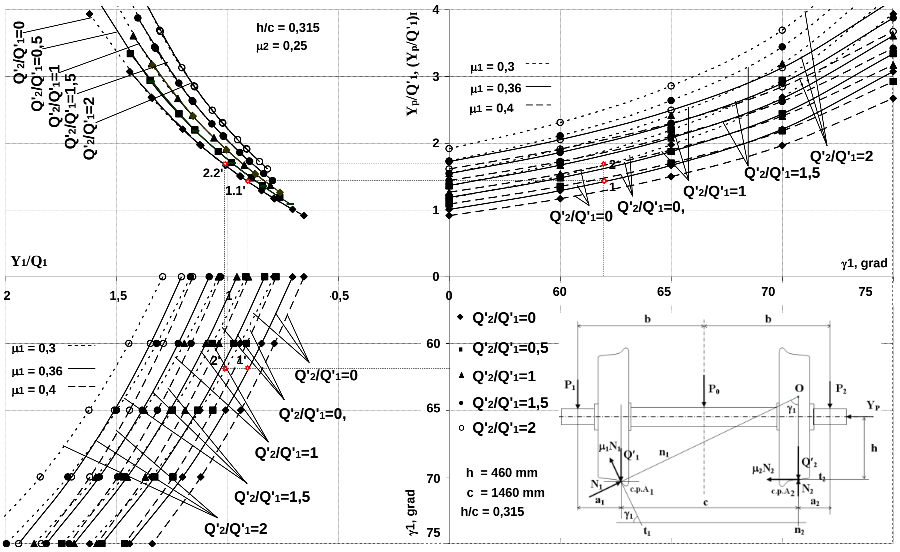

Fig.3. Nomogram with methodical reconciliation of criteria against derailment Y_p/Q'_1 and Y_1/Q_1 for ineffective solution of the problem treated for standard wagon wheel axles ϕ920 mm, $h = \phi/2 = 460$ mm, $c = 1460$ mm.

6. CONCLUSION

1. To solve the problem, a conditional transforming system with respective conditional criteria against derailment Y_1/Q_1 has been introduced.

2. Based on the fundamental dependencies of mechanics on the action of derailment forces, a basic formula has been derived, which fully coincides with the dependency obtained in a graphical method by the nomogram (Fig. 1).

3. Based on the methodological compatibility and the analogy of transforming criteria, a universal transforming function has been derived ineffective in an analytical form.

4. It has been proved that a very important requirement for **equal values of the coefficient of safety against derailment** has been met for transforming criteria.

5. An example of ineffective solution of the problem treated above has been briefly presented.

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INVESTIGATION OF THE INTERACTION BETWEEN TRAM WHEELS AND THE ROAD WHEN PASSING THROUGH A CROSSING AT A RIGHT ANGLE

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Abstract *– The paper examines the mutual influence of the tram wheels and the road when the vehicle passes through a crossing at a right angle. Special consideration is given to the impact when the crossing grooves are deeper than the given norms. Then the wheels pass through the crossings and suffer strokes from the four gaps of the grooves of the transverse tracks. Theoretical computations of the impact load and acceleration measurements in the axle box unit were made. The results show great impact loads and high peak acceleration values when the wheels pass through crossings.*

Keywords – tram, track, crossing, accelerations, wheel.

1. INTRODUCTION

The tram rail track differs from the railroad road for the conventional rail line on a number of elements. One of these elements is the crossing - the place where the tramlines cross. The intersections of the head of the rail are interrupted, the interruption being the width of the rail channel on the transverse road. When the tramway carriage (TM) passes through a crossing, its wheels bear high impact loads.

As a measure against the negative effect of some crossings, it is envisaged that the groove of the crossing is less than the height of the wheel flange. Then, when passing over crossing, the wheels roll with their flanges on the bottom of the groove. In the case of extended operation of crossings, the bottom of the grooves are worn and the wheels roll on their conical part.

2. RESULTS OF THE MEASUREMENT OF ACCELERATIONS WHEN PASSING THROUGH CROSSINGS

At the beginning of 2014, were made measurements of the accelerations in the bogies of the T6A2-BG tram type with inventory № 2016 and the working beside her tram with inventory № 2015 [1]. During the overhaul of the tram № 2016 in 2013, the original "Tatra" wheels of the first bogie were experimentally replaced with "Bochum 54" wheels. The purpose of the measurement was to compare the damping capabilities of the elastic elements on both types of wheels for this type of bogie. The route was chosen to include sections of different road conditions and all types of road construction. The measurement was performed in parallel with two simultaneously working accelerometers. The accelerometers were mounted on the bogie frame at the first right wheel jack (Fig. 1).

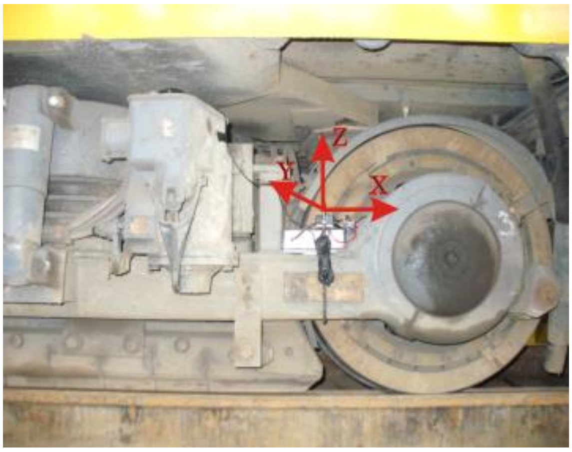

Fig.1. Place where the accelerometers were mounted

The speed of movement was the one with which the movement in normal operation took place. For

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recording the accelerations, the methodology described in [2] is used.

From the quoted study, here are the results obtained from passing over the crossings at two intersections: on "Vazkresenie" Blvd. and "Vardar" Blvd. (Fig. 2) and on "Hr. Botev "and Pirotska Str. (Fig. 3).

Fig.2. The case - Vaskresenie Blvd. and Vardar Blvd.

Fig.3. The case - Histo Botev Blvd. and Pirotska Street

The reported peak acceleration values of passing over these crossings are shown in the diagrams: for the intersection of "Vazkresenie" Blvd and "Vardar" Blvd. and for the crossing on "Hr. Botev" Street and "Pirotska" Str (Fig. 4).

The measurements show high peak acceleration values. At the intersection of "Vazkresenie" Blvd. and "Vardar" Blvd, the values reach 24 ms^{-2}, and at the crossing on "Hr. Botev" and "Pirotska" str. are over 13 ms^{-2}.

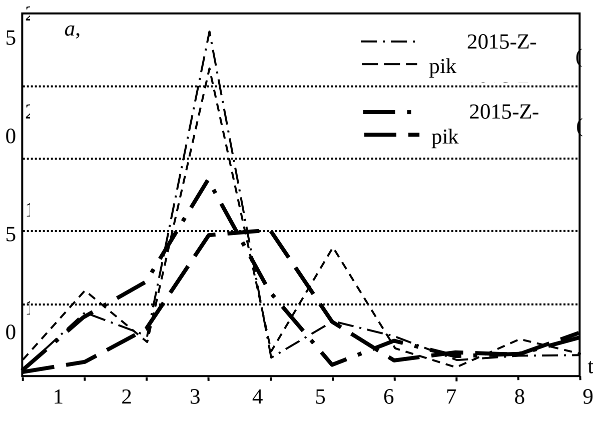


Fig.4. Peak values on Z axis at the crossing of (a)- Vaskresenie Blvd. and Vardar Blvd; (b)- Hristo Botev Blvd. and Pirotska Street

3. SCHEME FOR PASSING OF THE WHEEL THROUGH THE FLANGES OF THE CROSSING

Passing through a crossing is similar to crossing a rail. There are two distinctive features. The first is that the rail head is interrupted at a distance $\Delta = 35^{+10}_{-1}$ *mm* [3], which is the width of the flange on the transverse track. The second is that the interruption is repeated for a short time two or four times. As a track gauge of 1009 mm and a distance between the axis of the two tracks of 3000 mm, the four strikes on the band are two diametrically opposed zones.

In Figure 5, is shown a diagram when the wheel passes through the flange of the crossing [4, 5]. In the figure point A is the contact point of the wheel and the crossing before the groove of the transverse track and point *B* - the contact point after the groove. Δ is the width of the track of the transverse track. θ - angle defined by the contact points. r - radius of the wheel in the rolling circle. *V* – speed of the vehicle. V_1 – speed of the center of gravity of the wheelset before impact in point B. V_2 – speed of the center of gravity of the wheelset after impact in point *B*. V_B – vertical velocity of the center of gravity of the wheelset before impact in point B. *P* – Load on the vehicle mass distributed over one wheel.

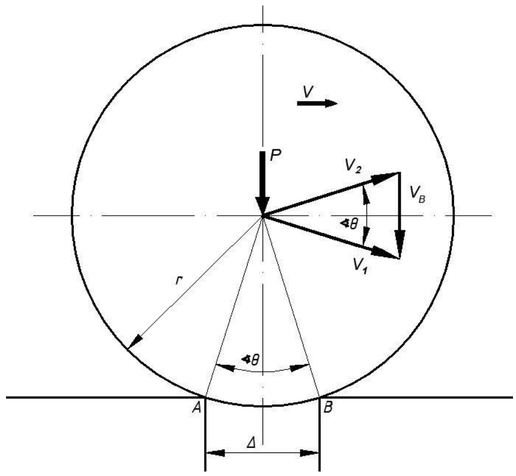


Fig.5. Scheme of the passage of the wheel through the groove of the crossing.

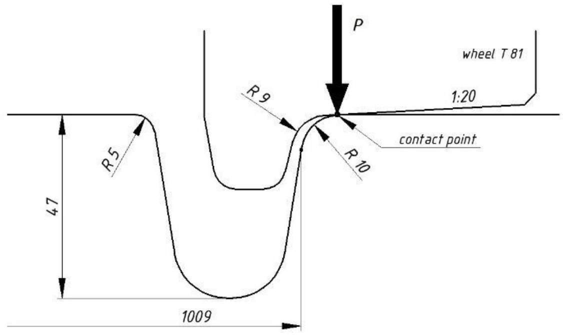


Fig.6. Contact between wheel and rail at the crossing, crosswise to the road.

From Fig. 5, the following dependencies can be written:

$$\theta = \frac{AB}{r} = \frac{\Delta}{r} \tag{1}$$

$$V_B = V_2 - V_1 = V.\theta \tag{2}$$

Figure 6 shows the position of the wheel passing over the crossing as seen crosswise to the road.

Figure 7 shows the exact position of the wheel with the specific geometric parameters of the contact when passing over the crossing.

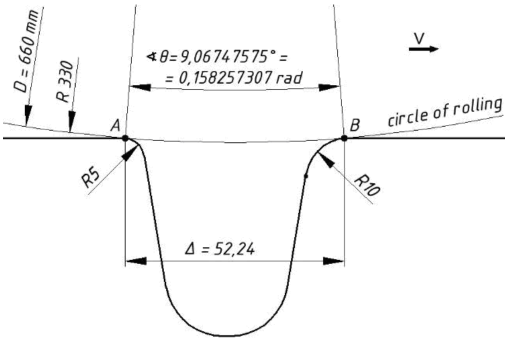


Fig.7. Contact between wheel and rail when passing through the groove of the crossing.

4. IMPACT LOAD ON THE WHEEL TYRES

The magnitude of the impulse S is determined by:

$$S = m.V.\theta\,[N.s] \tag{3}$$

In (3) *m* is the mass of the under spring elements of the bogie, i.g. wheelset with gear.

For the impact force F_{st}, operating in item *B* after timing *t*, for which the wheel passes through the groove of the transverse rail, is obtained the following [5]:

$$F_{st} = \frac{S}{t}\,[N] \tag{4}$$

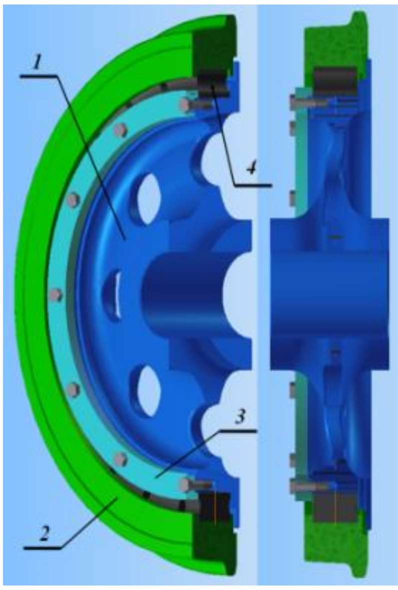
The values of the parameters shown in Figure 8 are used to calculate the impact force. The calculations are made for speeds of movement 1, 3 and 5 *m/s*.

The obtained values of the impacting force F_{st} for the three speeds of movement considered in (4) are:

- For $V = 1\,m/s \rightarrow F_{st} = 1\,590,45\ N$;
- For $V = 3\,m/s \rightarrow F_{st} = 14\,316,79\ N$;
- For $V = 5\,m/s \rightarrow F_{st} = 39\,753,63\ N$.

For the calculation of the strain, tram wheel with elastic elements "Bochum 54" (Fig. 8) has been used. Material for elements 1, 2 and 3 - steel, and for 4 - rubber.

The calculation has been performed using the FEA with Autodesk Inventor Pro 2015.



1. disc; 2. rim; 3. carrier ring; 4. elastic elements.

Fig.8. Cross-section of elastic tramway wheel

At point *A*, the gravity response of under spring masses is applied (Fig. 9.). At point *B*, the values obtained for F_{st} are applied in succession.

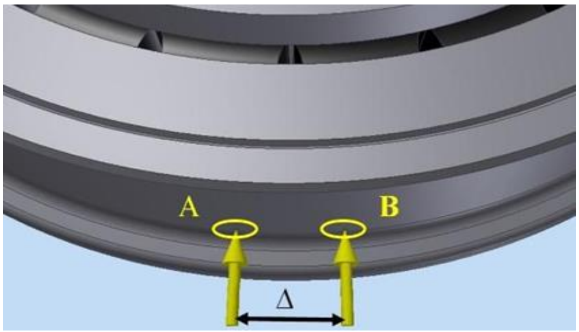


Fig.9. Forces acting on the rim at the points of contact

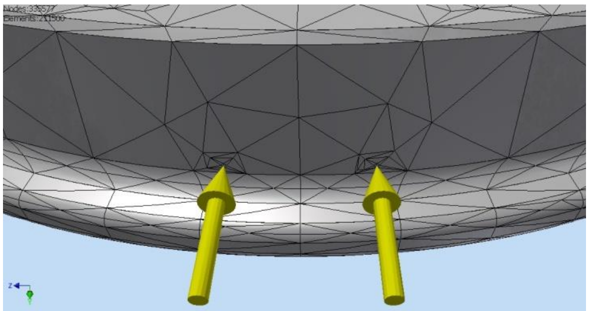


Fig.10. Mesh with Finite elements

Mesh Information (Fig. 10) - Type: Solid Mesh; Jacobian Check: 4 Points; Number of elements: 211364 and Number of nodes: 335410.

The results obtained show high stress values in a small volume of material at the point of contact with the receiving rail. It can be assumed that plastic deformations occur at the moment of impact at the point of contact.

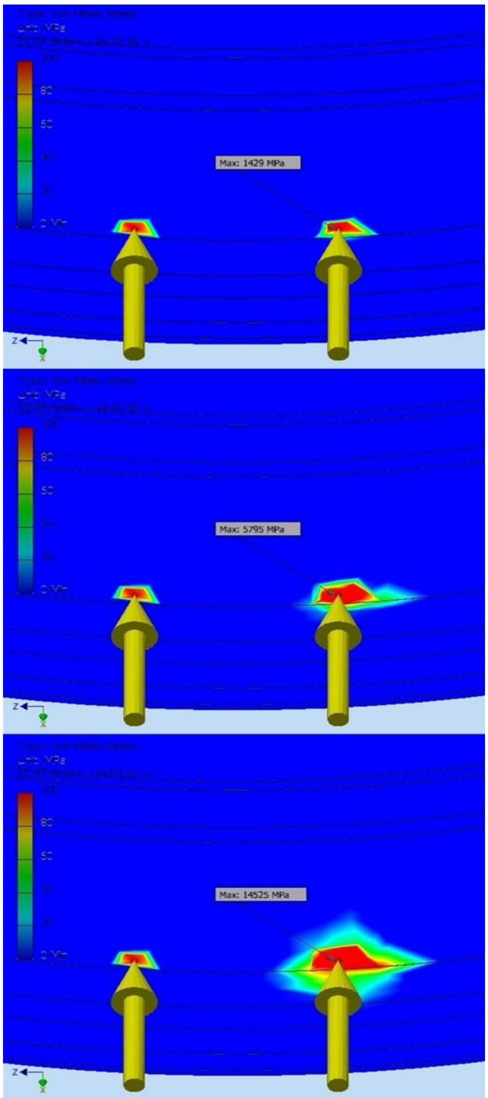


Fig.11. The results of the calculation of the stresses on the rim in the contact points

Figure 11. shows the results of the calculation of the stresses in the rim at the contact points at a maximum value of the scale of *100 MPa*. The maximum stress values are:

- For $V = 1 m/s \rightarrow \sigma_{\max} = 1\,429\ MPa$;
- For $V = 3 m/s \rightarrow \sigma_{\max} = 5\,795\ MPa$;
- For $V = 5 m/s \rightarrow \sigma_{\max} = 14\,525\ MPa$.

Since the cut of the rail head is repeated twice or four times, and the strikes on the band are on two diametrically opposed zones, and the presence of elastic elements makes it possible for the rim to be elastically deformed.

As a result of the acceleration measurements of the respective streets for the maximum force in p. B, for V = 5 m/s, are obtained - 12 600 N (for a = 24 ms^{-2} in Figure 4). The results of the simulation are given in Table 1.

The resulting maximum stresses given in Table 1 are about 3 times lower than the force loads obtained under Equation (4). The FEA calculus models were confirmed by experimental measurements performed in site.

Tab. 1.

Name	Type	Max
Stress 1	VON: von Mises Stress	4322 MPa
Displacement 1	URES: Resultant Displacement	0,02753 mm
Strain 1	RSTRN: Equivalent Strain	0,02016 ul

The calculations and simulations confirm the results of the acceleration measurement. The high values of stresses in the material, albeit in limited volumes, explain the appearance and development of cracks, as well as other defects in the rims.

4. CONCLUSION

The paper examines the mutual influence of the tram wheels and the road when the vehicle passes through a crossing at a right angle. Special consideration is given to the impact when the crossing grooves are deeper than the given norms. Theoretical computations of the impact load and acceleration measurements in the axle box unit are made. The results show great impact loads and high peak acceleration values when the wheels pass through crossings.

The calculation has been performed using the FEA with Autodesk Inventor Pro 2015.

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Traffic and Transport

LOCATION OF STATION CAN INFLUENCE THE SUSTAINABILITY OF HIGH SPEED RAIL

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Abstract *– The location of stations is one of the influencing factors concerning the sustainability of High Speed Railways (HSR) and has considerable impact on the regional development. This is important in terms of performance, competition and interconnectivity of HSR and for the future of cities where HSR stations are located. Construction of HSR stations can be the catalyst for the redevelopment of deprived areas within the neighborhoods. HSR stations can improve the image of a city and bring prosperity and economic growth. The secondary data methodology has been used in this research supported by information on some empirical evidences. Cases from countries with sufficient experiences of operating HSR were selected. Most of the data was gathered from on-line sources, reported research on HSR in selected countries and International Union of Railway's websites in addition to considering railway statistics and European and Institutional publications. The expected outcome of this research may contribute to the identification of the relationship between the choice of location of HSR stations and the performance of HSR in addition to highlighting the factors that influence the choice of location for HSR stations.*

Keywords – stations, sustainability, hub, factors, transportation.

1. INTRODUCTION

According to the UIC [1], there was a total length of 40,378 km of HSR network in 16 countries that operate HSR. It is obvious that in the future, train-travel demand will increase and there is a need for new railway stations. An HSR station is different from a convenient railway station; it is a much larger multi-modal hub which serves different trip purposes. A new multi-modal HSR station is a combination of travel facilities mixed and integrated with social and commercial activities that can improve the urban environment, offer better services for the community and boost local economy. HSR is not only about speed, it is about an experience that commuters can enjoy using the railway stations and travelling by train. The chosen location of HSR stations can significantly affect the performance of the HSR network and related local development.

In order to encourage commuters to travel by trains, the stations must be of high architectural quality and offering high-quality services. A significant part of HSR commuters come from the business sector and related service sectors such as public administration, commerce, leisure and tourism and therefore HSR stations need to be located within easy access to them. The nineteenth century railway station was called "The Cathedrals of the Industrial Revolution" [2]. Modern railway stations represent the image of speed and sustainability and in the architecture expression they can compete with airports.

2. NEW APPROACH: INTERMODAL CONCEPT

The image created by HSR stations should be unique and attractive. They need to compliment the urban space and the economic environment that they provide. Stations need to improve the quality of life in urban areas by providing convenient, affordable, reliable and environmentally acceptable solution for transportation. The most important purpose of the HSR station is that it satisfies demand for travel. The

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recently developed station should be able to anticipate demands of the passenger during at least the first 25 years with a condition for future expansion. There is a need to integrate different transportation modes such as buses, cars, trains, underground, airports, cycles and pedestrians, and to offer a good connection between the railway and other transportation modes. The station should be designed to provide journeys as seamless as possible. Interchange between transport modes should be efficient and with minimum conflicts between different means of transport.

There is a new approach in the transportation sector, which is called the intermodal concept. The core of this concept is to satisfy the increasing demand for mobility of a growing population. Intermobility will improve the connectivity and make travel more convenient for commuters. This concept presumes the seamless connection of railways with other transportation modes. One of the examples of intermodal concept is the Kyoto station in Japan. Kyoto station is one of the largest stations in the world. This transportation hub has access to railways, subway, city buses and long distance/overnight buses [3]. Intermobility influences the design of new railway stations in such a way that in addition to the obvious function of transporting people and goods, it provides commercial development and integration with other transportation modes and places for socializing.

Developing an intermodal station can sufficiently influence the growth of the local economy. Railway stations can be in the centre of regeneration projects for all areas and it can connect communities, new businesses, commercial, leisure and residential zones. One of the examples of success is the HSR station in Lyon. Lyon and Lille in France have had a large benefit from developing the HSR systems [4]. The choice of an HSR station location can sufficiently affect the future prosperity of a city.

Intermodal interchange stations can be divided into international and airport stations. The number of international stations increased with the development of HSR. Some of the facilities at international railway stations are similar to airports such as passport control, security checkpoints and separation of departure and arrival passenger streams. Apart from serving passengers, HSR stations can be terminals for freight express delivery on HSR. Modern HSR stations employ many of the characteristics and functions of airports. Stations will need to allocate large number of intermodal connections to the local transportation network. Examples of such type of stations are St. Pancras in London and Gare du Nord in Paris.

These days, some major airports have HSR services which connect airports with big cities. This type of station gives the commuters an opportunity to access the airport by public transport. This means that a station can be located near an airport or connected to the terminals. The station can be constructed as an additional part of the airport or under the airport. A good connection of an airport with HSR can reinforce the role of airports as a mass transportation mode [5]. An example of these types of station can be the station underneath Terminal 2 at Charles de Gaulle Airport and a new HS2 station at Manchester Airport. Other examples of this can be the transportation hub of Frankfurt Airport and ICE railway station or Inchon International Airport Station in South Korea [2]. The railway station is in the heart of transportation hubs that link together, urban transport network, railways and airports. The cooperation of HSR stations with airports generated more users, reduced travel cost, reduced environmental impact and contributed to the economic development in the related area. The hub network can effectively connect major cities in the region.

The HSR station must be designed to increase the value for businesses in surrounding areas, open them for new economic potential and contribute to the diversity of economic activities. The area surrounding the station and the station itself can be a new destination offering new services and new experiences. A good example of this is St Pancras Station in London. Opening shops, offices, hotels and building a residential area, all of this can create a new face of the city centre. Time spent in stations sometimes can be up to 30% of a passenger journey [6]. Many modern railway stations around the world are not just places where a train stops but begin to look like shopping districts with expensive designer shops and attractions for tourists.

3. LOCATION OF HSR STATIONS

HSR stations can be a new construction in the suburbs or as a redevelopment of a convenient central railway station. The central railway station gives the benefit of high accessibility for passengers. Because of the location in the heart of the city it can be seen as the gateway to the city. This is more common in Europe where land cost is high and HSR uses the conventional network to access the central railway stations such as the cases of Paris, London and Frankfurt. The stations located in the centre of the city have a good connection to local and regional public transport. This location will encourage walking and cycling users. One of the huge advances of HSR station located in the heart of the city is the opportunity for commuters to travel with ease from the city centre to the centre of another city. Stations such as St. Pancras in London and Gare du Nord in Paris give the opportunity for commuters to arrive within a short time before departure.

Another approach is to develop a new HSR station in a suburban area which will help the regeneration of surrounding areas and will create a new intersection of activities. The development of a new HSR station in a suburban area has the advantage of availability of land, but there will be a problem concerning the connection with the local transport system and the centre of the city. Developing an HSR station can be a catalyst for the regeneration of surrounding areas and can influence the gradual shifting of the centre of the city towards the HSR station or the creation of totally new urban districts. Constructing new HSR stations or redeveloping conventional railway stations may need suitable economic, environmental and social impact assessment. The profitability of HSR stations highly depends on the success of integration in local communities and how the location of the station fits within the general vision for the city. The performance of stations will have a huge influence on the performance of railway networks and will also have a high impact on costs and returns of the HSR corridor and sustainable whole life approach.

4. THE FACTORS THAT AFFECT A CHOICE OF RAILWAY STATION LOCATION

When choosing the location of railway stations along the rail corridor, there is a need to consider the land use, value of land, size of the development site and the environmental and social impact on the local community in addition to maximising the economic benefit for the railway and local communities, impact on local transport network, topography of site, parking opportunities, etc. Nagoya Station in Japan is the largest by floor area which is 4,800,000ft^2, but it does not take too much land as the station represents a 20-story podium station with platforms located underground [3]. The development site preferably must have a level area with good drainage. If possible, it should be located on a straight alignment that will have a good visibility of signals. The HSR station must be in the centre of the city or near towns with good accessibility. Stations must be connected by approach roads or located near major motorways. There must be an adequate water supply for passenger and operational needs. The HSR station will be more successful if it is surrounded with offices, hotels, sport and entertainment facilities, museums, retails parks and open spaces and high-density housing.

Environmental and social impacts from the new station on a local community are; using the land that can be allocated to other purposes, land and water contamination issues, noise and vibration, increased traffic to construction site, possible private property acquisition, and effect on property values in the surrounding area. Depending on minimizing the environmental impact on the local community, there will be a potential for increased revenue in local communities, increased property values and the creation of new jobs. Appropriate station location can contribute to expanding the regional and national development along the corridor by respecting the environment and promoting social equity. Railway stations in the centre of the city have higher density of population, have better accessibility for commuters and can attract more people. There will be public transportation before operating the HSR. In some cases, such as Hong Kong rail system and Shinkansen in Japan, the revenue from the land in and around the station contributed greatly to the profitability of the railway system. The profitability of a project can substantially affect the building of deep tunnels under very tall buildings.

5. CONCLUSIONS

The location and design of stations play a significant role in the performance and efficiency of HSR systems. Opening new railway stations can improve the performance of the transportation system in the corresponding region by shifting travel from roads to railways and thus reducing the environmental impact of transportation and improving access to jobs, services and trade centres. It should be a desirable place for residents and visitors complementing work with landscape and well integrated with the surroundings. Successful HSR stations will contribute to the sustainable aspects of the local community and the HSR system as a whole. HSR systems link major metropolitan areas together, support business connectivity and improve accessibility for users to reach a variety of transit systems and services. HSR stations should serve not only as local destinations or centres of retail activity but also as connection centres for local transport systems which serve HSR and local commuters. Developing HSR stations may improve the accessibility for the local community and create new jobs.

For the HSR stations to be successful it is important to have a suitable density of population, good mixture of users incorporating residential and commercial uses in the surrounding area in addition to sufficient presence of retail and trade offices coupled with good accessibility to HSR services. To maximise the benefit for the HSR system and the local communities, the new HSR stations need to be designed in such a way that they have the means to welcome the public and to have good connectivity with the surrounding areas.

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KRONECKER ALGEBRA FOR OPTIMIZATION OF RAIL TRAFFIC FLOW ON ZAGREB – RIJEKA LINE

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Abstract – *Within the Shift2Rail-Project "GoSafeRail" so called Kronecker Algebra is applied on the railway line from Zagreb to Rijeka for traffic flow optimization. Kronecker Algebra consists out of Kronecker Product and Kronecker Sum to describe concurrency of tasks as well as their inter-leavings. The railway line from Zagreb to Rijeka has been already modeled by software tool called OpenTrack. In this project data from OpenTrack model is automatically converted into input files for a 3rd party tool based on Kronecker Algebra. To model the infrastructure so called "IVT" format is used to export an itinerary covering the main track. The entire line consists out of 250 edges while station areas with more than one station track are handled by counting semaphores. The timetable is exported in OpenTrack text format and used to create train run files. On a normal working day around 115 trains are running on this line but of course not all trains use the entire line. Additionally, train characteristics are considered to calculate realistic running times.*

Keywords* – *Railway operation, rail traffic flow, optimization.

1. INTRODUCTION

One of the objectives of the Shift2Rail project Global SAFEty Management Framework for RAIL Operations is the development of an evolutionary Decision Support Tool that self-learns (evolves) based on machine learning algorithms and artificial intelligence with the main goal of offering safer, reliable and efficient rail infrastructure. Due to a low number in failures on the infrastructure network, this leads to a lack of data crucial for machine learning. This will be solved by implementation of Near-Miss Concept; in other words, low-consequence events will be also included in the model and enable use of statistically significant data for model training. Furthermore, a new train mounted multiple sensor system for Object Detection will be developed.

Moreover, with OpenTrack [4] micro-simulation modelling tool, traffic model will be developed that will use multi-criteria optimization algorithms to address complex requirements, for both passenger and freight transport. Using Kronecker algebra, which showed good results in dealing with optimization scenarios in railway traffic flow, especially avoidance of deadlocks, simulation of the line between Zagreb and Rijeka in Croatia has been performed as well as a optimisation based on Kronecker Algebra.

2. KRONECKER ALGEBRA FOR RAILWAY OPERATION

One of the constantly present problems in railway systems is the problem with deadlocks especially on single track lines or during rehabilitation work [5] on a double track line and around dead end hubs. Since there were no applicable solutions in the middle of 20th century, computer scientists tried to solve this problem by implementing Kronecker algebra in the analysis [3].

Before going into solving deadlock issue, a proper definition is needed. Stallings [6] defines Deadlock as 'an impasse that occurs when multiple processes are waiting for the availability of a resource that will not become available because it is being held by another process that is in a similar wait state'. There are four preconditions for a deadlock to occur according to Coffman [1]; in other words, if one of these conditions is not met, there will not be a deadlock. There is a mutual exclusion, where a resource can only be used by one process at a time. Second, hold and wait includes processes already holding resources and

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requiring additional resources held by other processes. Third, the so called no preemetion, no other than the process itself can release the resource. Finally, the circular wait that requires at least two processes to form a circular chain in which each process waits for a resource that is being held by the previous process in the chain. Clearly, these four conditions can be applied to railway systems.

After defining conditions for deadlock occurrence, possible ways to deal with deadlocks can be identified. These are deadlock prevention, or removing one of the above mentioned conditions in order to prevent deadlock from even occurring; deadlock avoidance, or decision about resource allocation in advance; and finally, after deadlock detection, termination and restart of the process. For the railway systems, only deadlock avoidance is applicable [3].

Kronecker algebra is a mathematical model that consists of Kronecker Sum and Kronecker Product. For the explanation of these two operations, set of matrices (1) is defined

$$M=\{M=(m_{i,j})m_{i,j} \in L\} \quad (1)$$

where L denotes a set of labels with $\langle L,+,0\rangle$ being a commutative monoid and $\langle L,*,0\rangle$ a monoid (Mittermayr and al., 2012). For this case, only matrices $M \in M$ with o (M) referring to the order of matrix. Additionally, n-by-n (2) matrices will be used.

$$Z_n = (z_{i,j}) \text{ where } \forall i,j: z_{i,j} = 0 \quad (2)$$

Kronecker product is denoted by A ⊗ B and results in mp-by-nq block matrix, as it can be seen in (3). Matrix A in this case being m-by-n and matrix B p-by-q matrix. As already mentioned above, Kronecker product is used for modelling synchronisation.

$$A \otimes B = \begin{pmatrix} a_{1,1}B & \cdots & a_{1,n}B \\ \vdots & \ddots & \vdots \\ a_{m,1}B & \cdots & a_{m,n}B \end{pmatrix} \quad (3)$$

Kronecker sum of matrices A of order m and matrix B of order n, denoted by A ⊕ B (4), is a matrix of order mn defined by

$$A \oplus B = A \otimes I_n + I_m \otimes B \quad (4)$$

where Im and In (n-by-n matrix with ones on the main diagonal and zeros elsewhere) denote identity matrices of order m and r, respectively.

Application of Kronecker algebra in optimization of railway traffic flow lies in its functionality to detect and avoid any deadlocks within the whole analysed railway system, not just on one section. To put it differently, it can is represented as a matrix that includes all possible train movements in a system. In other words, deadlock-free solutions are overall best calculated solutions that take schedules, delays and different types of restriction on the tracks into account [7]. Whereas Kronecker Sum calculates all possible interleavings of all trains not using the same track section, Kronecker Product ensures that those using common track sections can sequentially enter only free sections, namely, sections previously released by another train. Kronecker Algebra delivers results as a matrix. However, these can be represented as a graph, especially time-speed diagram.

3. USE CASE OF ZAGREB – RIJEKA LINE

Within GoSafeRail project [2] the railway line from Zagreb to Rijeka has been selected. As a first approach, the edges for the Kronecker algorithm were created between signals, speed changes and gradient changes. With this ruleset, the resulting number of edges was 1067 for the Zagreb Rijeka line, which was a fairly high amount for the Kronecker algorithm. In order to reduce execution time of the Kronecker algorithm, the infrastructure was partitioned in a macroscopic view (tracks.csv) and a microscopic view (tracks-micro.csv). For the macroscopic view, edges where only created from signal to signal. With this measure, the number of edges for the Zagreb Rijeka line was cut down to 250. Figure 1 depicts the result of this reduction, reimported into OpenTrack via IVT input.

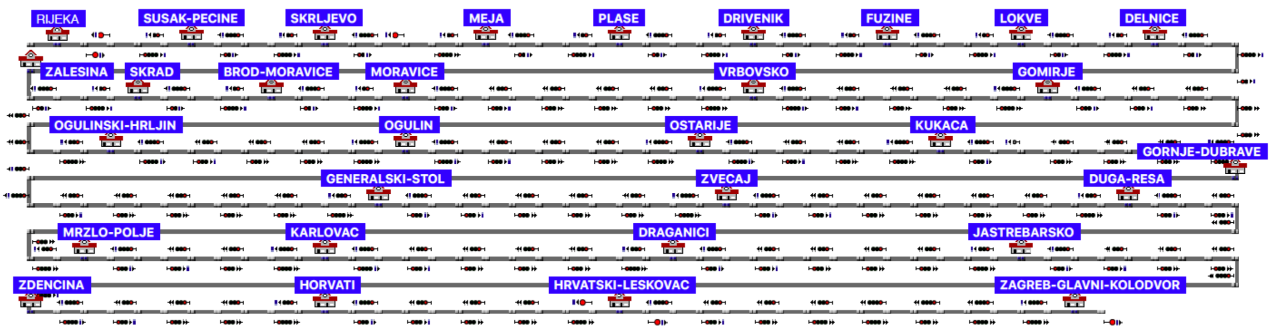

Fig.1. Reimported grapgh of Zagreb-Rijeka line

Another major aim in building the infrastructure for Kronecker was the simplest possible

```
# iteration 163

# station: DUGA-RESA ; stopAtStation: true virtual_stop: false
# at_semaphore: flush needed:
169 170 2 00  00  0000  00  00  00  00  00  0000  00  00  00  0 123 0 v167
170 171 2 00  00  0000  00  00  00  00  00  0000  00  00  00  0 123 0 v166
171 172 2 00  00  0000  00  00  00  00  00  0000  00  00  00  0 123 0 v165
# at_semaphore: flush done.

# main output for iteration 163:
172 173 20  29  11  2017  01  23  00  29  11  2017  01  27  00  165308  123
0 p163

# iteration 163: doing v final for 164
173 174 2 00  00  0000  00  00  00  00  00  0000  00  00  00  0 123 0 v164
```

Fig.2. Sample snipped of a train course file with a real stop at station Duga Resa

representation of the stations. The o2k converter takes care of this by producing only one edge per station, which receives the number of available tracks at this station as the maximum value for its semaphore.

After creating the infrastructure, the second step includes the production of all train course data files required for Kronecker operation by the o2k converter. OpenTrack's timetable data gives information about the passing location of the individual train. If corresponding data is available, time passes from the timetable are used as so-called measure points for Kronecker optimization. Train course files for Kronecker must reserve and free edges in a proper sequence. Especially at stations where a train should stop, the pattern for reserving and freeing edges seems to be somewhat complicated. The screenshot shown in figure 2 of a train course file generated by the o2k converter is presented in order to clarify what the proper solution to this problem shall look like.

The lines starting with a hash mark (#) are comments and will be ignored by the input parser of the Kronecker implementation. These comments have proved to be useful for finding errors contained in the original data from OpenTrack, which has been entered by manually and thus may be erroneous.

For this explanation, lines will always be called by the number at their beginning. Line 172 shows a real stop taking place. Real stops contain the code 10 or 20 at the third field, depending on this course's direction: 10 is for the up direction, 20 is for the down direction. The direction is set by the itinerary of the original IVT file from OpenTrack.

The last column of each line contains a P or V operation for a given edge of the Kronecker infrastructure, which can be found in the tracks.csv file. Following common naming conventions, P is used for reserving an edge and V is used for freeing an edge.

At line 172 in this example, a stop takes place when reserving edge 163. Consulting the generated infrastructure file tracks.csv for the Zagreb Rijeka line, it can be seen that edge 163 is the station area of Duga-Resa with a maximum semaphore value of 3, meaning that there are three tracks in Duga-Resa which can be used for halting trains or overtaking stopped trains.

Line 173 shows the next operation which takes place after the train has stopped at Duga-Resa. This operation is of high importance for Kronecker algorithm. The train arrives via the edges 167, 166, 165, 164 until it halts at edge 163. The edges 167, 166 and 165 are freed in the lines 169 to 171 as can be seen in the sample snipped above. This always happens as a preparation prior to a stop and is called a "flush" in terms of the o2k converter. The edge 164 must not be freed before the train stops at edge 163, but must be freed immediately after. The o2k converter takes care of this.

When a train arrives at its final station, the codes 100 or 200 are used for the third column. As mentioned above, prior to a real stop, a flush is conducted for all but the last edges. Similarly, the last edge before the stop is freed immediately after the stop. The station edge, where the real stop itself is performed, will be freed five minutes after the stop has occurred.

Tab.1. Overview on earliness in seconds calculated by Kronecker and simulated in OpenTrack

	Earliness in OpenTrack	**Earliness in Kronecker**
Sum	-3143	-2779
Number of Trains	42	35
Average	-75	-79

Tab.2. Overview on delays in seconds calculated by Kronecker and simulated in OpenTrack

	Delays in OpenTrack	**Delays in Kronecker**
Sum	1407	514
Number of Trains	14	19
Average	101	27

Table 1 and 2 compare earliness and delays from simulation in OpenTrack of all 57 daily passenger trains using the entire or parts of the Zagreb-Rijeka line with calculated values by Kronecker. While trains arrive earlier in sum in OpenTrack simulation, delays are reduced by application of Kronecker in sum and in average. Further investigations will be carried out on the level of each single train run to validate the calculations of Kronecker by simulations of OpenTrack. Thereby, the recommendations from Kronecker can be used as input for the actual performance of each single train.

4. CONCLUSION

OpenTrack, being a sophisticated micro-simulation model allows the determination of impact of safety decisions on operational network performance. Thus, by incorporating both infrastructure asset (e.g. crossings, tracks, bridges, tunnels) and traffic (e.g. vehicle, freight and passenger movement), effective delivery of maintenance or new works while maximising the connectivity and adaptability of the overall surface system will be enabled. As a performance indicator for Kronecker Algebra the delays of trains at their final station are used as a benchmark criteria. Latest test runs on the railway line from Zagreb to Rijeka show a reduction of delay of more than 60 % in sum and 70 % in average.

ACKNOWLEDGEMENT

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QUALITY AND SAFETY MANAGEMENT SYSTEMS OF TIMETABLE IN RAILWAY TRAFFIC

Dražen KALJUŽAR [1]

Abstract *– Expanding the European Union to more and more countries have led to problems with the transport system. The main challenge thus has become the development of railway traffic, which is significantly lagging behind the road. Special attention was paid to the safety of traffic and the establishment of a safety management system in this development, but the quality of the timetable and the increase of work in passenger and freight rail transport significantly neglected. Thus, the expected positive impacts were left out despite the significant investments in the railway infrastructure. This was especially the case for countries with a smaller volume of rail traffic.*

Positive experiences of establishing safety management systems in railway companies with the recognition of their basic elements (policy, goals, operational programs, rules, risks, professional training, informing, irregular events and monitoring) could therefore also be applied to the establishment of systematic timetable management in railway companies. The basis for such improvement is the application of ISO standards, in particular ISO 9001. Challenges in these activities have arisen due to the lack of recognition of the requirements of ISO 9001 in the regulatory framework related to the railway system and because of the resistance of railway management in implementing changes.

The biggest challenge for the development of the railway system from the traffic aspect was the division of the unique technological process of creating transport services into separate technological processes within the infrastructure manager and railway carriers. The timetable with its transport flows and material technical resources in this technological process was the first phase, the planning phase. Activities for making timetable have been lost in importance by dividing the unique railway system instead of strengthening. For this reason, the research on railway management has been carried out for the purpose of drawing up a model of timetable in order to find the direction of exit from identified problems.

Keywords – timetable, railway traffic safety, safety management system, quality management system.

1. INTRODUCTION

At the end of the last century, the European Union (EU) was becoming more and more important. It expanded to more and more countries; a new challenge arose with regard to facing differences in the functioning among the members. Systems were not standardized and it was difficult to make comparisons among members, joint development strategies and politics. Management systems according to ISO standards started to become more important and an increasing number of joint documents were drafted in line with the requirements of these standards.

One of the major challenges for the European Commission (EC) at that time was the non-existence of a unified transport policy, which would direct the transport sector systematically. A special problem arose in the railway sector, which share decreased in the second part of the last century from 80 to 20 per cent of total land transport market. Railway systems of specific countries which were closed, outdated and non-standardized, presented an insurmountable obstacle. This condition led to a need of determining development guidelines for the railway system and adoption of the first directive in 1991[1].

This directive had the greatest influence on the technological process of creating transport services and the safety of railway transport. In the era of integrating transport systems and logistics, it was necessary to divide the traditionally closed and unified

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railway system into separate areas. On the other hand, the experience of the next few years has shown a need to introduce a safety management system (SMS) into railway companies, which was regulated by a separate directive.[2] The provisions of this directive had to be implemented into laws and subordinate legislation framework. In the area of the technological process of creating a new transport service, such a need was not recognized. Activities connected with the timetable, path allocation and track access charges remained only at an administrative level.[3] The timetable as a phase of planning the technological process of creating a transport service was given over to railway companies.

During research for the purposes of doctoral thesis drafting, entitled “Model of timetable management in the railway system”, possibilities of improving the technological process of creating a transport service were explored, based on management systems of according to ISO standards. For the purposes of testing the model, 19 managers of all three national railway companies underwent a survey. Based on survey results, guidelines were obtained for the introduction of a timetable management system, which review is in this paper.

2. QUALITY MANAGEMENT SYSTEM

Although it was not possible to directly recognize ISO standards and norms in European regulations, this is visible through basic requirements and elements of the management system. Quality management systems (QMS) are based on ISO 9001 and recognize the following requirements and elements, which had to be carried out [4]:

- Management of documents and processes,
- Decision-making of managers,
- Training, education, awareness
- Management of products (services)
- Re-examination of management and internal audit
- Continual improvement.

In the same way, ISO 9001 required a quality policy, quality goals, monitoring customer satisfaction, internal communication and supervision of non-compliant product and process.

Safety management systems according to ISO 9001 standard, started to be introduced at HŽ – Hrvatske željeznice back in 2000.[4] Employees who arrived outside the company Hrvatske željeznice were mostly the ones in charge of introducing the QMS, which made work more difficult. They did not know the basic business processes at the company. In the same way, within the company itself, there was resistance to changes which were not understood. This resulted in two parallel management systems: the existing railway one and a new one according to QMS.

Such a situation was maintained until 2011, when HŽ Infrastruktura obtained a certificate according to ISO 9001:2008. Parallel management systems existed until 2014, when the Ordinance on Quality Management System of HŽ Infrastruktura d.o.o. was adopted (drafted according to rules for writing internal company acts) and [5] Ordinance on organization of HŽ Infrastruktura d.o.o. [6]. Quality management organization unit was extended to Quality Management Affairs, which began to include the process of managing processes and risk management process.[5] During 2015, status analyses were made, strategic guidelines, internal acts for the management of processes and risks, several weeks of education for company managers were conducted.

The actual application of the requirements contained in the standards can be seen three years later, partially in organization units important for this research.[6]

The Directive on the development of the Community's railways [1] sets out requirements connected with:

- Transparency of business operations and financial consolidation
- Legal harmonization with EU acquis
- Separation of business activities of transport from infrastructure management.

The provisions of this directive were implemented into legal provisions[7] connected to railway transport.

Separation of transport from infrastructure management activities directly influenced the technological process of transport service creation. Untimely recognition of ISO 9001 requirements in this process led to an impairment of service quality, but also reduced co-operation between railway companies, which is still going on in the Croatian railway sector (Republic of Croatia).

[2] By analysis of the contents of Directive 2004/49/EC on safety of the Community's railways

[3] Review of the contents of Directive 95/19/EC on the allocation of railway infrastructure capacity and the charging of infrastructure fees

[4] The author of the paper was deputy CEO of HŽ Cargo, and a member of the Main quality team

[5] At the time, the author of the paper was the Head of Quality Management and in charge of these activities

[6] The mentioned estimates were determined on the basis of internal audits results in the mentioned organization units

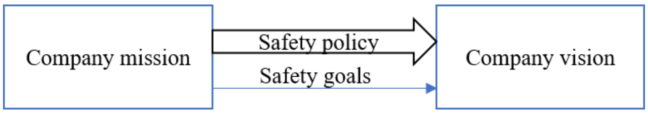
[7] Railway Act

3. SAFETY MANAGEMENT SYSTEM

The safe flow of traffic operations includes safe, ordered, regular and unhindered traffic operations. A series of complex activities of all railway traffic participant are required here. This is also recognized by the European Commission, which adopted the Railway Safety Directive.

At that time, the obligation to establish a safety management system (SMS) was prescribed in all railway companies, which is implemented into the national framework. The Railway Safety Act [7] defined the term of SMS as "a system established by an infrastructure manager or railway operator with the aim of enabling safe management of work processes and obligations for all railway companies to establish and continuously improve the safety management system". The definition shows an obligation for all railway companies to cooperate in order to ensure high traffic safety level.

The connection of SMS is especially seen in the need to draft a safety policy. In this way, safety policy represents an intention how to achieve the vision of safety from company vision in the future period, as shown in Figure 1:



Source: author's paper

Fig.1. Positioning of safety policy

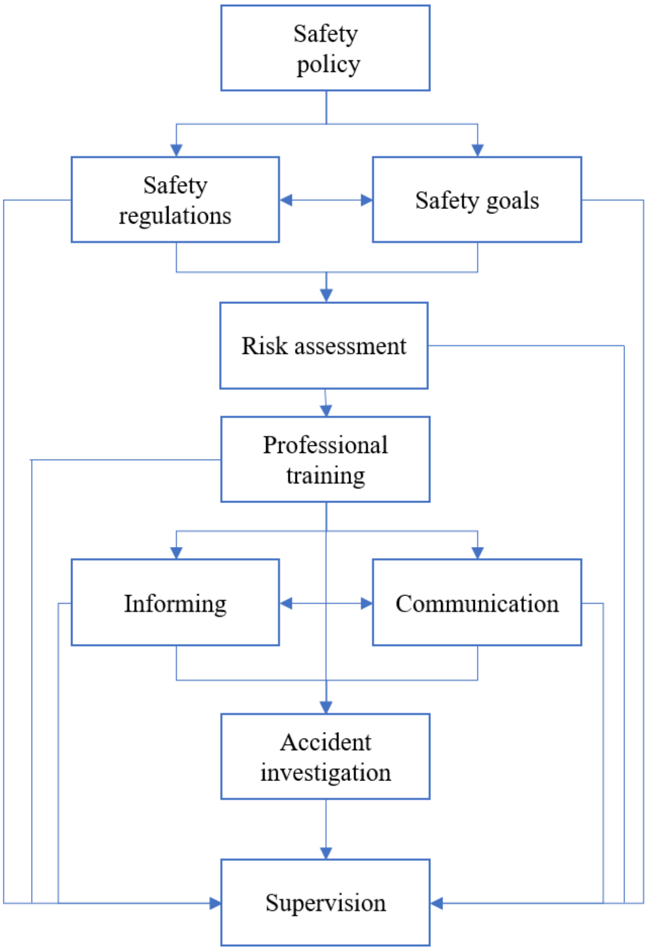
Tab.1. Comparison of QMS and SMS requirements

SMS	QMS
Responsibility of organization	Responsibility of the management
Determining competent safety person	Quality representative for the management
Continuous control and improvement	Control and improvement
Keeping system records	Document management
Professional competence	Competence, education and awareness

Source: author's paper

Years of work on the development of railway traffic safety in European countries have led to the establishment of the Railway Safety Agency at a national level and developed traffic management systems in railway companies. All of this has resulted in a series of analyses and reports, from which the current status is visible, but also proposals of traffic safety development.[8] SMS also recognizes the basic requirements and elements of safety management. Implementation of basic SMS elements has ensured positive developments.

Basic elements of the safety management system, which were made on the basis of quality management system, are shown in Figure 2.



Source: author's paper

Fig.2. Basic safety management system elements

4. TIMETABLE MANAGEMENT SYSTEM

Transport service quality primarily depends on the quality of implementation of the technological process of transport service creation, which had to be divided into activities of railway managers and railway operators. European Union directives [3] do not prescribe which activities belong to whom, but only what activities connected with path allocation and charges are.

These requirements were also implemented into national legislation, primarily into laws[9] and subordinate legislation[10]. Based on this sequence, provisions in subordinate legislation on timetabling primarily related to requests towards infrastructure managers.

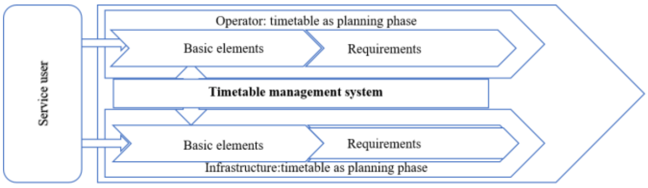
[8] In 2007, the a Supervision paper took over the organization unit management and established a safety management system at HŽ Infrastruktura

[9] Railway Act which was amended in certain ways

[10] Ordinance on timetable drafting and publishing in railway traffic, which was amended in certain ways

Activities regarding the planning of train traffic, traffic regulation, shunting, technical wagon inspection, train checking sheet and similar, are the responsibility of railway companies, which choose how to organize them.

Although European Union directives do not prescribe the obligation of creating a timetable management system (Figure 3), the survival of railway traffic required new solutions. "Timetable management system is a system established by an infrastructure manager and/or a railway operator with the aim of ensuring a unified technological process of creating a transport service under the circumstances in which the unified system is separated." [9]



Source: [9]

Fig.3. Timetable management system

During research [9], 19 managers from three national railway companies in Croatia made a matrix in order to determine a timetable management model (MUVR) (1):

- Four lines: external model elements (ai)
- Four columns: internal module elements (aj),

and guidelines for MUVR improvement were determined.

$$M_{UVR} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \quad (1)$$

Source: [9]

Questions directed at participants had to do with thinking about the necessity of changing railway systems and tradition of detailed railway regulations in the Republic of Croatia. The answers showed that railway managers still adhere to the law and subordinate legislation, rather than deciding to introduce systematic and development changes themselves.

By applying the Delphi research method, the following results of offered answers were obtained [9]:

I. Management system and Socially Responsible Management (SRM) – has to be regulated by a ministerial or another act (76%)

II. Establishment of a timetable management system- has to be regulated by a ministerial or another act (82%)

III. Documented implementation of the timetable into value systems will ensure improvement of the timetabling process (100%)

IV. Training of timetable technologists for management functions - timetabling process improvement will be ensured (88%)

V. Traditional way of timetabling by introducing excellence - timetabling process improvement will be ensured (82% of participants).

5. CONCLUSION

Technological process of creating a transport service is the basic business process towards customers, i.e. final users of railway services. As such, it has to be the main business process in all railway companies. Timetabling is a planning phase in this process, and the annual realization of railway services depends on the quality of planned transport flows, which also means the market share of land transport.

European Union directives cannot resolve all problems, nor can they define strategic guidelines of the railway system. Application of research results during the establishment of the timetable management model in the railway system presents a challenge for railway companies to turn the division of a unified system into integration activities of these entities. Whether this is a matter of relations between railway companies, relations between various means of transport, and even among several countries on the same or competitive transport routes.

In the meantime, a new ISO 9001 standard was issued, which recognizes the new elements of the management system (leadership, context and sustainable development), which also have to be implemented in timetable management.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

QUALITY OF RAILWAY PASSENGER SERVICE IN SERBIA

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Abstract – *In the process of railway passenger service planning there are two objectives that must be achieved: the service acceptable from the customers point of view and the certain profit for the railway operator. Therefore the service quality can be measured both by the customers and the operator. In this paper the quality level of railway passenger service in Sebia is observed through internal operator statistical data performed as quantitative and qualitative parameters and limited pilot survey on passengers satisfaction with various features of the railway services that are available before, during and after the journey. The survey results were compared with the results of such surveys in EU.*

Keywords - quality, railway, passenger service, passenger demands, passenger satisfaction.

1. INTRODUCTION

Railway passenger service planning is a complex multidisciplinary process where the railway operators must achieve the highest level of compliance between customers demand and their own organizational, technical and operational capabilities. The main goal to be achieved is the level of the service quality that brings satisfaction to customers and profit to an operator. Many factors influence on goal achievement. The main factors are national and international transport policies. Since 1991, the European Commission (EC) has made efforts toward rail liberalisation and Europe-wide, integrated and interoperable transport system. So the important documents are adopted such as Directive 91/440/EEC [1] and Railway Reform Packages. The Directive makes important distinction between the provision of transport services and the operation of infrastructure, identifying the need for these two areas to be managed separately in order to facilitate the future development and efficiency of the railways within EU. The First Railway Package consists of three Directives:

- Directive 2001/12/EU [2] clarify the formal relationship between the state, the infrastructure manager and the railway operators;
- Directive 2001/13/EU [3] sets out the conditions for freight operators to be granted a licence to operate services on the European rail network; and
- Directive 2001/14/EU [4] introduces a defined policy for capacity allocation and infrastructure charging.

Reform efforts in EU were continued in the Second, Third and Fourth Railway Packages, where the Directives were subsequently revised to make the European rail freight and passenger sector fit to meet the needs of operators and customers [5]. In 2001 the EC published White Paper "European transport policy for 2010: time to decide" [6], where some of the scopes were: meeting the customer's needs; accessibility to public transport; minimizing traffic negative impacts on health of the people and safety in general by an effective shift towards the use of more sustainable modes; and establishment of special principles to ensure the sustainable management of traffic flows. In 2011 the EC published White Paper "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" [7]. The goals set for the rail passenger services can be summarised as: by 2050, a European high-speed rail network should be completed; the length of the existing high-speed rail network should triple by 2030 and maintain a dense railway network in all Member States; and by 2050, the majority of medium-distance passenger transport should be by rail.

Legal framework for railway passenger transport market liberalization in Serbia is provided within the Serbian Railway Low (adopted in 2005), accordingly accepted EC Directives and other international

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documents that concern rail transport. In 2018 the new Railway Law was adopted.

2. PASSENGER TRANSPORT OPERATOR

On August 2nd, 2015 the first, and untill now the only one, railway undertaking for railway passenger transport was established (Joint Stock Company for Passenger Railway Transport "Srbija Voz", Belgrade) as a company acquirer of a part of the assets of Serbian Railways JSC. Main activities of this company are Public passenger transport performance by rail in domestic and international service, Train Traction and Rolling Stock Maintenance.

At the end of 2017, "Srbija voz" JSC had 2185 employees within 5 levels of management in hierarchical organization. By the 2017 rule book on internal organization and systematization of work positions there are 311 manager positions (14.2%), ie., there is one manager per 7 employees. For most areas and small and mid-sized companies, approximately 10 workers per manager is common. In an administrative area and big sized companies 20-to-1 is ideal ratio of managers to staff. The educational structure of employees needed for the job position has shifted from specialized to general qualifications. This opens the door for employees without proper or any railway education, in spite of the fact that mid and high railway education systems exist.

2.1. State of rolling stock

"Srbija Voz" JSC active rolling stock consists of 35 locomotives (25 electrical and 10 diesel); 35 EMU; 40 DMU; 43 passenger cars with seats; 12 couchette and sleeping cars; 1 dinning car; 16 wagons for automobiles. Out of date rolling stock is unfavorable. Existing diesel locomotives have been in use for about 22 years, electric locomotives about 43 years, EMU about 16 years and DMU about 13 years.

2.2. State of service planning and marketing activities

Passenger transport service is planned as a set of services for passengers, such as: services before the start of the trip (before arriving at the terminal and at the terminal); services during transportation; and services after the transport is completed.

At "Srbija voz" JSC the Department of Traffic and Commercial Affairs and the Sector for the Information and Communication Technologies are mainly in charge for the services planning (timetable, tariffs, services at railway stations etc.) and marketing activities. Planning system is based on old analitical and grafical methods, without use of modern optimization and simulation methods. Marketing function is still limited on small number of promotional activities and "user friendly" web services, which primarily relate to information about train schedules, tariffs and reservation services. No transport market researches were recorded.

3. NETWORK CHARACTERISTICS AND ACCESS CHARGES

Total lenght of Serbian railway network is 3764 km (3441 km single track, ei. 91.4%, and 323 km double track, ie. 8.6%). Around 42.12% of railway tracks are electrified with the AC traction power supply system of 25kV 50Hz. Average permitted speed is very low, around 42.68 km/h. Maximum permitted speed is shown in table 1.

Tab.1. Maximum permited speed on track

Speed (km/h)	not known	- 20	21-40	41-60	61-80	81-100	101-120
km	605	306	933	886	521	479	34
%	16,1	8,1	24,8	23,5	13,9	12,7	0,9

Temporary speed reductions caused by low infrastructure quality affects running time and delays for both passenger and freight trains. Functioning of a signaling and traffic management system is often disrupted by frequent cable and other equipment theft. This, also, causes a great deal of train delays. Delays have a negative effect on demand for passenger trains services. From a total of 686 establishment on the railway network, 569 (292 stations and 277 stops) are equipped with some kind of infrastructure facilities for passengers. Platform height vary from the height of: the top of rail (TR) 29.2%; above the top of rail (ATR) 300 mm < H < 350 mm 20.2%; 350 mm < H < 550 mm 0.9% and 900 mm 0.7%; for 283 stations platform height data have not been recorded. Accesibility to most railway stations is not adequate, station bildings are with poor maintenance, station information system and other inventory are in bad condition or out of work, connections with public transportation are rare, and there are no connections with airports and river ports. Only 59 stations are equipped with e-bookings and ticket sales system.

Railway infrastructure access charges in Serbia for the minimum access package are based on train-km and distinguished by category of line. It is simply regime of charges equal for passenger and freight trains, where running and reservation charge is equal.

There are many access regimes in European railway network. Some networks have time-of-day based charging system; some make distinction by type of service – the charges are not the same for passenger services (and within passenger services) as for freight services; many systems charge passenger trains per station stop; some distinguish between levels of station; most systems use train-km to charge for the use of the electric traction system and have a surcharge for diesel traction for pollution; with few charges are adjusted for particular rolling stock that is either quieter or more track-friendly; some give a discount to combined freight traffic etc. [8].

4. QUANTITATIVE AND QUALITATIVE PARAMETERS

Since transport represents a special type of service the quality of the transport is a value that defines the transport itself. The quality of transport service can be measured both by the customers and the operator.

4.1. Operator statistical data and modal split analysis

The quality level of railway passenger service in Sebia is measured through the operator statistical data. The basic parameters of passenger transport service observed are: number of trains and their capacity (number of seats); number of routes and train flows; number of passingers and passenger kilometers; average distance of travel.

According to the timetable 2017, the daily rail passenger service in Serbia was organized as: regular passenger rail transport service with total 442 trains (221 pairs of trains), as follows: 28 international trains (18 fast trains; 2 IC trains; and 8 crossborder trains) and 414 national trains (42 distant trains; 269 local trains; and 103 trains of Belgrade commuter city rail service "Bg:voz"). Total capacity of national trains is 85,453 seets. There are museum trains that operate by the calendar and facultatively within the commercial names: "Romance", "Nostalgy" and "Blue train".

There are no contracts for trains for public service obligation. International trains operate on 12 routes, and the destination terminals are located in 8 countries (mostly neighbouring). Table 2 shows comparison on travel time and price by railway (2nd class), bus and plane on international relations.

Tab.2. Travel time and price by different mode of transport on the selected international routes

Line/route (pair of trains)	L_{rail} (km)	Travel time (H)			Price (EUR)		
		T	B	P	T	B	P
Bg-Thesal. (1)	640	15.5	-	1.1	37	-	117
Bg-Budap.K. (2)	350	7.5	7	0.7	15	25	110
Bg-WienHbf (1)	600	12	9	1.4	40	35	83
Bg-Ljubljana (1)	560	10	7.5	1.4	29	37	90
Bg-Bar (2)	480	12	11	-	24	25	-
Sub-Bar (1)	660	17.5	13.5	-	27	35	-
Bg-Sofia (1)	400	10	5.5	1.2	-	23	116

Legend: T-train, B-bus, P-plane

Data from table 2 show that on selected routes travel time by train is from 9% to 88% longer than travel time by bus, and from 7 to 14 times longer than by plane. Railway ticket price is from 4% to 66% lower than bus ticket [9], and from 2 to 7 times lower than plane ticket [10].

National trains operate on 71 routes and the start and destination terminals are mostly the capital city and regional centres. Table 3 shows comparison on travel time and price by railway, bus and car on selected national relations.

Tab.3. Travel time and price by different mode of transport on the selected national routes

Line/route	L_{rail} (km)	Travel time (H)			Price (EUR)		
		T	B	C	T	B	C
Bg-Novi Sad	77	1.5	1.5	1.2	2.9	5.5	8.9
Bg-Subotica	176	4.5	3	2.1	5.2	11	19
Bg-Vršac	84	1.7	1.8	1.5	3.1	5.4	8
Bg-Zrenjanin	90	2.5	1.4	1.3	2.9	5	7.3
Bg-Niš	242	5.5	3	2.3	7.1	9.2	24
Bg-Valjevo	91	2	1.8	1.6	3.7	6.1	8.3
Bg-Užice	178	3.5	3.5	3.2	5.6	9.3	18
Bg-Kraljevo	221	4.4	3.6	2.6	6.2	6.8	19.5
Bg-Šid	114	2	1.5	1.4	3.7	6.8	12

Legend: T-train, B-bus, C-car

On some national relations travel time by train and by bus is equal, and on some is even up to 80% longer. Railway ticket price is far more cheaper than by bus and car.

Passenger trains flow (in pair of trains) on Serbian railway network is presented in Figure 1. It can be concluded that, on most lines, minimum service of 8 pair of trains per day is not acomplished. The number of canceled trains is extremely high, around 17.5% in international traffic (mostly in cross-border traffic) and around 16.3% in national traffic.

In 2017 total number of passengers carried was around 16 million. Around 10 million passengers (33,000 passengers daily) are carried in "Bg:voz" city commuter system, and 6 million passengers (20,000 passengers daily) are carried with distant and local trains with total 4.4 billion pkm. In past three years the growth rate is negative. EU statistics show that average growth rate in European passenger transport in past three years is around 4%. In comparison to 1990 a number of rail passengers in Serbia is 4 times less. Utilisation of seats is around 62%.

In Serbia 62.5% of rail journeys were for commuting (around 50% is in Europe). Only 5.3% of total are international journeys. Monthly variation index is 1.12. Average journey distance is 71.96 km (212 km in international traffic and 64.2 km in national traffic).

The modal share of railway passenger transport in Serbia compared to other modes of transport (excluding city public transportation) is less than 1%.

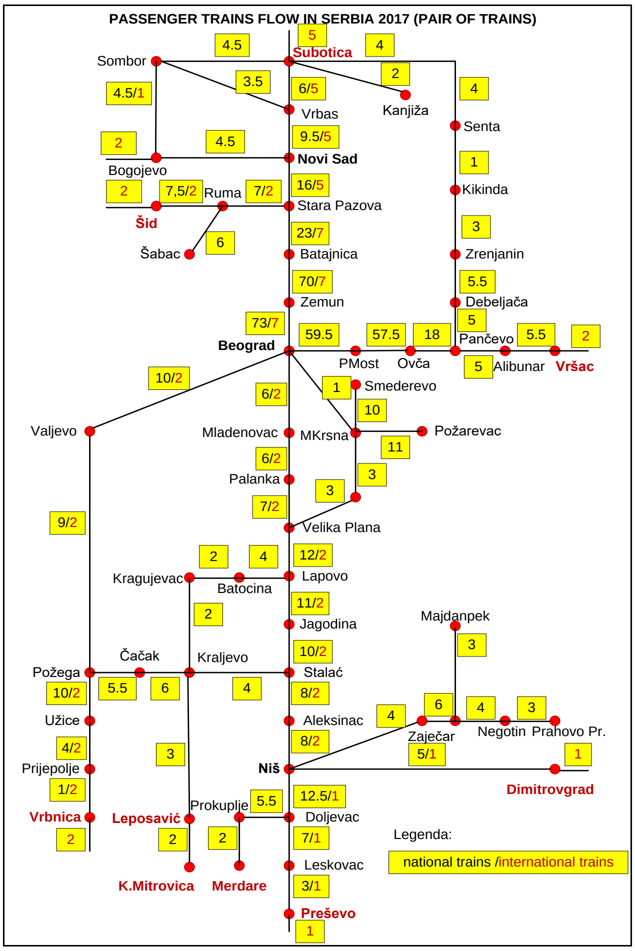

Fig.1. Passenger trains flow (in pair of trains) 2017

The highest modal share in EU is in Switzerland (19.1%), Austria (12%) and Netherlands (10%), and the lowest modal share of less than 2% is in Greece, Turkey, Estonia and Lithvania [11].

5. SURVEY OF THE SERVICE QUALITY

The service quality level is estimated by limited pilot survey conducted on a certain number of passengers on board and on stations. The results show that passengers were *dissatisfied* (85%) with a timetable, punctuality, cleanliness of trains and stations, (70%) with a travel time and accesibility.

The result of latest surveys in EU show that passengers were *very satisfied* (77%) with the ease of buying tickets; provision of information about train schedules; personal security in stations; travel time; comfort; seating capacity; connections with other modes of public transport. Passengers were *rather satisfied* (37%) with car parking facilities; services in train stations (e.g. toilets, shops and cafes); and trains' punctuality and reliability. Passengers *were dissatisfied* (36%) with the cleanliness and maintenance of station facilities. Passengers in Europe find railway fare and prize system complicated. In 2018, in UK, public consultation is being launched to find ways of simplifying the rail ticketing system that currently means 55 million different fares exist on European railway network. The study aims to identify ways to make the system fairer and easier to use. It follows a survey which found that only 34% of passengers in UK were "very confident" bypurchasing the best value ticket for their last journey [12].

6. CONCLUSION

The overall conclusion is that the railways provide limited quality in passenger transport even though the railway transportation is sustainable, efficient and less expensive than the other transport modes [13].

For the railway passenger service in Serbia that is compliant with passenger travel demand, a number of measures must be taken, such as: reconstruction of infrastructure capacities (at list to the projected level of speed); better maintenance of signaling and train management and control system; differentiation of track access charges; improvement of timetable planning; reduction of planning and operating costs; better maintenance and utilisation of passenger cars and MU; simplifying fare system; introduction of new on board and station services (mostly free WiFi).

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DETERMINATION OF SUBURBAN TRAIN TURNAROUND LOCATION IN PANCEVO RAILWAY JUNCTION USING OPENTRACK

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Dušan VUJOVIĆ[2]

Abstract *– Train services require most careful scheduling in order to fit existing infrastructure capacities, while avoiding conflicts between large numbers of trains of different types, speeds and directions and satisfying other constraints and objectives. One of the most difficult part of scheduling is solving a problem of how to achieve as many trains as possible with as little train sets as possible. Solving a scheduling problem is connected with solving a turnaround problem. What is presented in this paper is the determination of suburban train turnaround location in Pancevo railway junction, which consists of one station on double track line and one station and two stops on single track line. The main problem is how to achieve regular - 20 minutes interval (cyclic) timetable according to passenger demands. For this purpose the OpenTrack was used for modeling the railway junction and performing the simulation of the traffic scenario. The results of the simulation are presented on a train graph.*

Keywords - timetable, turnaround, simulation, OpenTrack.

1. INTRODUCTION

For densely serviced urban and suburban railway lines with high frequency passenger trains it is appropriate to schedule trains in regular time intervals. Running operations on a line according to a regular-interval (cyclic) timetable increases the infrastructure capacity and, thus, the network productivity. This provides the consistent time coverage of the services through the day, and ensures passenger transfers between the two or more lines which extends geographical coverage of origin-to-destination links (O/D) over the suburban territory.

As a consequence, coordinated, regular-interval timetables offer advantages for both:

- the customers, thanks to enhanced level of service in terms of time and spatial coverage, and
- the train operators, thanks to standardized operational procedures and better productivity of their resources (rolling stock and personnel) [1].

According current timetable, suburban (commuter) trains on (Belgrade) - Ovca - Pancevo route are running according to an irregular time intervals. The problem discussed in this paper is how to ensure cyclic timetable for suburban trains, and to determine turnaround location for these trains within a complex Pancevo railway junction (use PRJ below) with appreciation of infrastructure constraints. Turnaround means the running of a physical train composition during its operation with all its course numbers and over all its tracks. Turnaround location is a track in a station/stop where train changes the course number and direction of operation, but not the train composition. For this purpose the OpenTrack was used for modeling the railway junction and performing the simulation of the traffic scenario.

2. MODELING PANCEVO RAILWAY JUNCTION IN OPENTRACK

Modeling and simulation were performed according to simulation methodology phases [2] as follows:

- Phase 1. Definition of the problem;
- Phase 2. Designing the study;
- Phase 3. Designing the conceptual model;
- Phase 4. Formulating inputs, assumptions, and process definition;
- Phase 5. Data collecting, separating, selecting and preparing;
- Phase 6. Choosing the simulation tool, simulation language or simulation software;
- Phase 7. Building and verifying the simulation

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model;

- Phase 8. Calibrating and validating the simulation model;
- Phase 9. Simulation experiments planning (scenarios planning);
- Phase 10. Exploiting the simulation model (experiment with the model), performing the simulation by defined scenarios;
- Phase 11. Analyzing the simulation results;
- Phase 12. Presenting the simulation results and
- Phase 13. Defining the model life cycle.

2.1. Pancevo railway junction topology

In PRJ, commuter trains dwell on one station (Pancevo Main st.) on a double track line and one station (Pancevo Varos) and two stops (Pancevo Streliste and Pancevo Vojlovica) on a single track line. Both stations are junction stations. Pancevo Main st. has three public, and Pancevo Varos has three public and one industrial incoming line as shown in Figure 1. All public lines are for both passenger and freight trains. Railway tracks between stations and stops in PRJ are electrified with the AC traction power supply system of 25kV 50Hz.

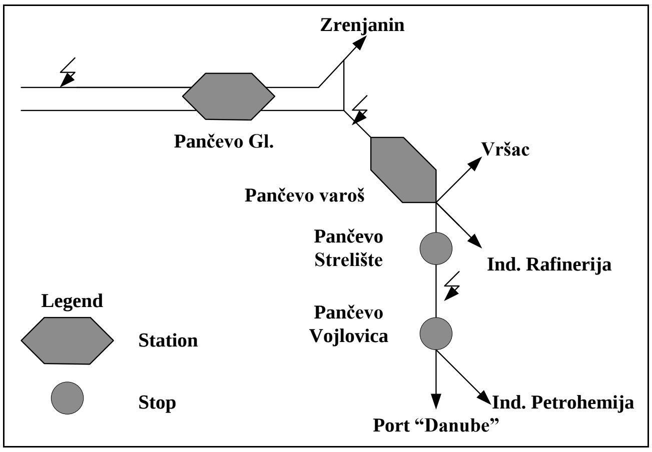

Fig.1. Pancevo railway junction scheme

Stations are equipped with electro-mechanical signal boxes. Distance between stations, permited speed and travel time (2017) are shown in Table 1.

Tab.1. Distance, permitted speed and travel time

Distance between stations	Lenght (m)	Perm. speed (km/h)	Fastest scheduled run (min)	Travel Time (min)
P. M.st - P. Varos	2,141	50	4	5
P. Varos - P. Strel.	1,300	50	3	4
P. Strel. - P. Vojlov.	1,450	50	3	3
Total	4,891		10	12

2.2. Definition of a problem

According timetable 2017, destination, i.e. turnaround location (point) for suburban trains is the stop Pancevo Vojlovica that lies on a single track line. By the railway regulation that concerns train traction, the minimum dwell time at the turnaround location is 20 min. That means that minimum interval between train departure from this stop can be 34 min. Within this time, acceleration time to full speed is calculated to be 1 min, breaking time from full to zero speed is calculated to be 1 min, dwelling time in station and stops is 1 min.

This time interval corresponds with travel demands for trains departure from railway stops (Pancevo Vojlovica and Pancevo Streliste), but does not correspond with travel demands for trains departure from rail stations (Pancevo Varos and Pancevo Main st.) during rush hours, and represents constraint for high frequency commuter trains.

The main goal of the study is to explore possibilities for 20 min regular time interval on (Belgrade) - Ovca - Pancevo route. Presumption is that it should be two turnaround locations, the Pancevo Varos station and the stop Pancevo Vojlovica. This paper deals with rescheduling as well as train set utilization problem by taking the infrastructure, running time and running distances constraints into consideration. For this purpose, the simulation method is applied. The simulation software OpenTrack has been used for modeling and simulation.

2.3. OpenTrack structure

OpenTrack is a simulation program for simulation of railway networks. OpenTrack uses a mixed discrete/continuous simulation process that calculates both the continuous numerical solution of the differential motion equations for the vehicles (trains), and the discrete processes of signal box states and delay distributions [2].

The main modules of OpenTrack are illustrated on Figure 2.

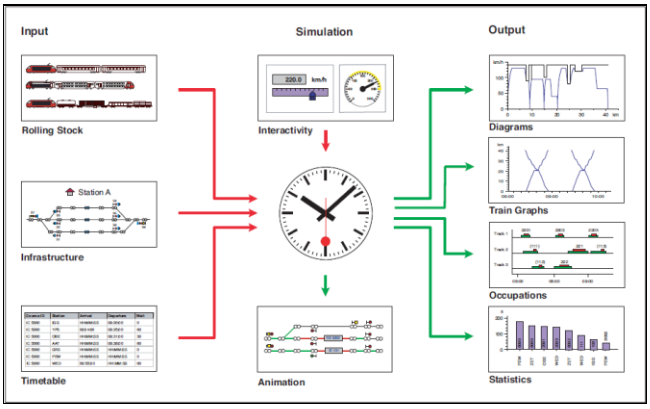

Fig.2. OpenTrack processes: Input-Simulation-Output

OpenTrack administers input data in three modules: rolling stock, infrastructure, and timetable. Users define and enter input data and informations into these modules following the rules, and then run the simulation. Within the simulation process, program develops a wide variety of output data that can be presented in different formats such as tables, graphs diagrams etc.

2.4. Modeling infrastructure

The track layout of the PRJ has been described in OpenTrack as a graphical layout in terms of double vertex graphs. The physical infrastructure has been modeled by using actual infrastructure data sorted and put on a layout in a form of verteces and track segments (edges). Vertices are joined with edges. Each vertex is a point on the infrastructure where parameters are changing. Thus, vertices are used for assigning attributes such as: name, kilometer reference point, switch, signal, station building information etc.. Information such as length, gradient, and maximum speed, have been assigned to a particular edge.

The boundaries of the model are home signals: in Pancevo Main st. (km 19+000); in Jabuka st. (km 22+753); in Pancevo Varos (km 19+242) and in Pancevo Vojlovica (km 2+857).

On the graphical layout, there are 461 vertices, 439 edges. Hereto, the 88 signals, 79 switches, 6 cross levels, 9 platforms were placed on the layout with their attributes. A part of PRJ infrastructure layout modeled in OpenTrack is illustrated in Figure 3.

In OpenTrack, train movements are governed by signals controlling the track layout. Therefore, physical elements of the infrastructure modeled were logically grouped together in three levels of safety elements (Routes, Paths and Itineraries) where higher levels consist of lower level sets.

2.5. Modeling locomotives, motor units and composition of trains

Database depot. was used for modeling tractive units such as locomotives and motor units. Tractive units were modeled in terms of technical specifications such as tractive effort/speed diagram, weight, length, adhesive value, resistance factor, rotation mass factor, power supply system, max. speed, etc. Five types of tractive units have been modeled as: electric locomotive 441, diesel locomotive 661, EMU 412/416, DMU 711 and DMU 812/814.

Composition of freight trains and international passenger trains have been created by selecting one locomotive from the locomotive database and combining it with length and weight data of freight/passenger wagons. Suburban passenger trains have been created by selecting EMU. Other national passenger trains (local trains) have been created by selecting one of DMU. For train's motion, proper formulas with their values were assigned to each train. Furthermore, the acceleration and breaking values were assigned to each train as well.

2.6. Modeling courses and timetable

Modeling an operation of a train is defined by combinations of schedule data with the physical infrastructure (itinerary) used by a train. Total number of trains modeled is 166 (108 suburban trains, 22 local trains, 2 international passenger trains and 34 freight trains).

Timetable data consists of information on the movement of trains. This information includes desired arrival and departure times, connection information, minimum stop times, and turnaround locations. It is determined by the traffic scenario that suburban trains ends their journey alternately (when one train ends its journey in Pancevo Varos station, the following train ends its journey at the stop Pancevo Vojlovica). Timetable scenario for the suburban trains was determined according to direction of travel and turnaround location. All other trains operate through PRJ according to actual timetable.

By the Pancevo Varos station technology book it is determined that each station track serves different purposes. The part of the 1st station track is used for loading and unloading freight wagons, the 2nd station track is used for trains that run from the beggining to the end of railway line, the 3rd station track is used for trains that run in oposite direction, and the 4th station track is used as passing track and trains crossing. So, another presumtion has been made that the part of the 1st station track could be used for turnaround location.

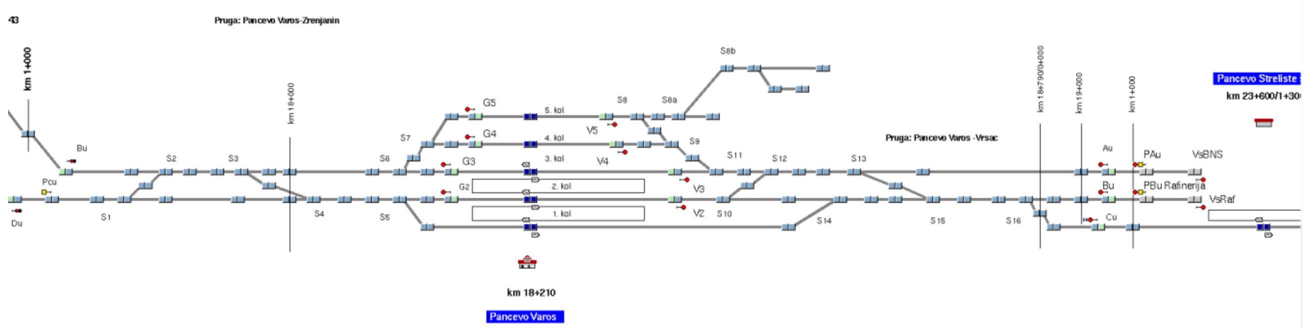

Fig.3. Pancevo Varos station and tracks layout in OpenTrack

Continuation of a train unit at its end station/stop under a new course number has been modeled by creating a train split at the end station/stop to the new course number, Figure 4, and a connection for the new course to the original course at its starting station/stop.

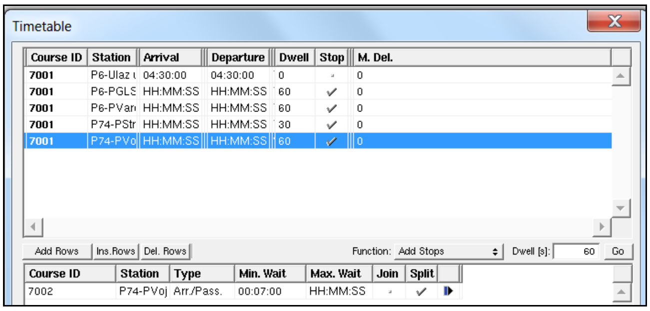

Fig.4. Modeling turnaround of a train

3. SIMULATION AND SIMULATION RESULTS

For a validation of a model, a simulation has been performed. The results showed that actual timetable data and simulation data of train movement through the model are highly correspondent. The model was verified for exploatation. Simulation was performed for one day (24 hours time).

The simulation results are presented on a train graph devided into 4 graphs of 6 hours time intervals. Three of them are illustrated in Figures 5, 6, and 7.

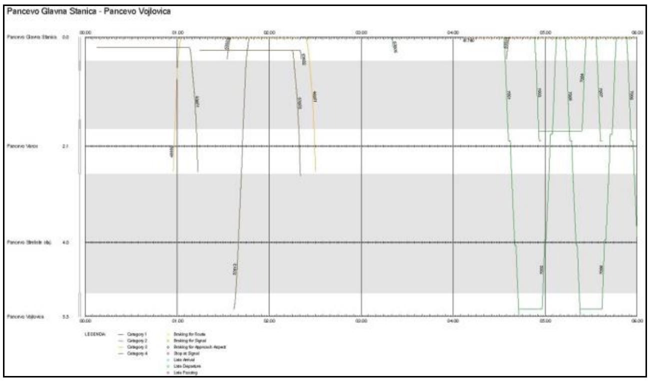

Fig.5. Train graph from 00:00 to 06:00

From the train graph it can be seen that the first train (7001) arrives at Pancevo Varos station at 4:37, dwells 1 min, departs at 4:38, and arrives at Pancevo Vojlovica at 4:43:21, then connects the train 7002, waits for the turnaround time and, departs Pancevo Vojlovica at 4:58, arrives at Pancevo Varos at 5:04, dwells 1 min, and departs at 5:05.

The next train (7003) arrives in Pancevo Varos station at 4:57, then connects the train 2004, waits for the turnaround time and, departs at 5:25.

Simulaton results shows that 20 min interval can be achieved only if: the turnaround time in Pancevo Vojlovica is 15 min (turnaround time less than 20 min is allready applied in scheduling Belgrade city trains) and the turnaround time in Pancevo Varos is 27 min.

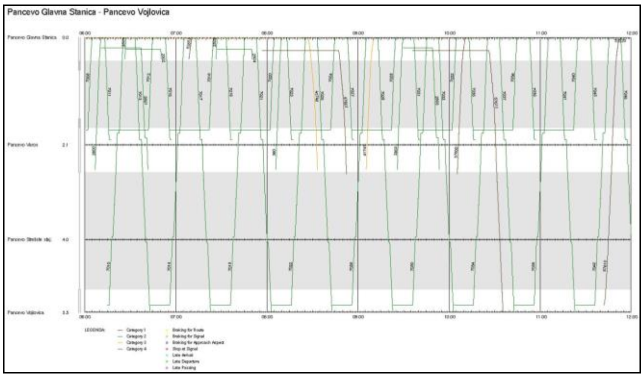

Fig.6. Train graph from 06:00 to 12:00

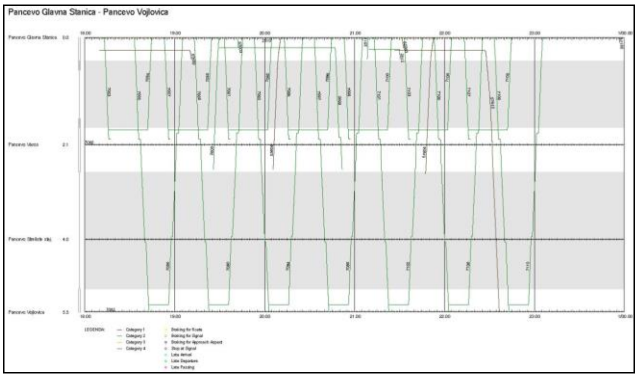

Fig.7. Train graph from 18:00 to 24:00

4. CONCLUSION

This study shows that it is possible to schedule suburban trains within PRJ in regular time interval. Some changes on infrastructure elements must be made such as: to devide the 1st station track in two parts (a purpose of the part of the track in front of the station bulding with total length of min 200 m has to be for suburban trains arrival/departure, and the purpose of the other part of the track has to be for loading/unloading freight). A home signal must be located beside the track on the place of track separation, and the part of the track for suburban trains must be electrified. As a concequence of new suburban trains introduction, a minor rescheduling for other trains in PRJ was performed.

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APPLICATION OF FUZZY TOPSIS METHOD FOR SELECTION THE ADDITIONAL PROTECTING SYSTEM ON RAILWAY CROSSING

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Dušan JEREMIĆ[3]
Goran VIL[4]

Abstract – *Railway crossings, as places of crossroads of rail and road traffic, represent the sites of potential conflicts, and as such, require continuous monitoring and implementation of adequate measures that lead to increased safety due to elimination of accidents. For that reason, railway crossings need to be properly marked and protected with appropriate protection system. The goal of this paper is to improve the railway of safety at the railway crossing with active protection, by selection additional insurance system. This paper presents the application of fuzzy TOPSIS method on railway crossing PBK-2 on railway line Belgrade - Šid - state border. This approach helps in solving problems where the vagueness and subjectivity are handled with linguistic values parameterized by triangular fuzzy numbers. To validate the results, the sensitivity analysis was performed through changing the weight coefficients of the criteria. The results of the sensitivity analysis show that the proposed method gives valid and stable results.*

Keywords – railway crossing, fuzzy, TOPSIS.

1. INTRODUCTION

Railway crossings are places of conflict where traffic accidents often occur. They are weak point in road and railway infrastructure that serioslу jeopardizing traffic safety. A lot of accidents in traffic with serious consiquences, material damage and fatalities are occur on railway crossings [1].

The main purpose of the traffic control device is to provide appropriate warning to drivers using appropriate visual and audio devices and to help them in undertaking correct activities to avoid accidents at railway crossings. Traffic control devices are divided into active and passive. The basic conventional warning devices in Serbia are the Andreas cross, the stop sign (passive) and half-barriers with light signaling (active) [1].

In the literature we can find various additional passive traffic control measures. Some of them are: marking a roadway in front of a railway crossing, enhanced warning signs, speed bumps and ramps in front of the crossing in order to reduce the speed of the road vehicle and other measures.

Active traffic control devices are devices that are activated when the train comes in. These are light signals, bumpers and half-barriers. Active traffic control devices are also supplemented with signals used in passive traffic control.

This paper combines TOPSIS method and fuzzy logic, for creation hybrid method which is used in [2], [3] and [4]. The authors of [5] presented the ANFIS model, which supports the process of selecting which railway crossings should receive an investment of safety equipment and which was tested on 88 level crossings in Serbia. In paper [6] authors presented how and to which extent certain influential parameters cause accident mechanisms on railway crossings, some of which are used in this paper.

2. FUZZY TOPSIS METHOD

The TOPSIS method is a multiple criteria decision making technique proposed by [7] to identify a solution from a finite set of options. The fuzzy TOPSIS technique was proposed by [8] and this method has nine important steps:

Step 1: Form a committee of decision-makers, then identify the evaluation criteria.

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Step 2: Choose the appropriate linguistic variables for the importance weight of the criteria and the linguistic ratings for alternatives with respect to criteria.

Step 3: Aggregate the weight of criteria to get the aggregated fuzzy weight $\tilde{w}_j$ of criterion C_j, and pool the decision makers’ opinions to get the aggregated fuzzy rating $\tilde{x}_{ij}$ of alternative A_i under criterion C_j.

$$\tilde{R}_k = (a_k, b_k, c_k), k = 1,2,3,..., K \quad (1)$$

than aggregate fuzzy ranking can be calculated using equations:

$$a = \min_k (a_k), b = \frac{1}{k}\sum_{k=1}^{K} b_k, c = \max_k (c_k) \quad (2)$$

Step 4: Construct the fuzzy decision matrix and the normalized fuzzy decision matrix.

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn}, i = 1,2,3,..., m; j = 1,2,3,..., n \quad (3)$$

where B and C are the set of benefit criteria and cost criteria, respectively, and

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), j \in B \quad (4)$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), j \in C \quad (5)$$

$$c_j^* = \max_i c_{ij}, j \in B \quad (6)$$

$$a_j^- = \min_i a_{ij}, j \in C \quad (7)$$

Step 5: Construct the weighted normalized fuzzy decision matrix. Considering the different importance of each criterion, we can construct the weighted normalized fuzzy decision matrix as:

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn}, i = 1,2,3,..., m; j = 1,2,3,..., n \quad (8)$$

$$\tilde{v}_{ij} = \tilde{r}_{ij} \times W \quad (9)$$

Step 6: Determine the fuzzy positive-ideal (FPIS) and fuzzy negative-ideal (FNIS) solutions [9].

$$\begin{aligned} A^* &= (\tilde{v}_{1^*}, \tilde{v}_{2^*}, ..., \tilde{v}_{n^*}) = \\ &(\max v_{ij} | i \in B), (\min v_{ij} | i \in C) \end{aligned} \quad (10)$$

$$\begin{aligned} A^- &= (\tilde{v}_{1^-}, \tilde{v}_{2^-}, ..., \tilde{v}_{n-}) = \\ &(\min v_{ij} | i \in B), (\max v_{ij} | i \in C) \end{aligned} \quad (11)$$

where B is associated with benefit criteria, and C is associated with cost criteria.

Step 7: Calculate the distance of each alternative from FPIS and FNIS, respectively. The separation of each alternative from the A^*, A^- is given as:

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_{j^*}), i = 1,2,..., m \quad (12)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_{j^-}), i = 1,2,..., m \quad (13)$$

where *d(.;.)* represents distance between two fuzzy numbers.

The distance measurement between two fuzzy numbers can be calculated as [1-8]:

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right]} \quad (14)$$

Step 8: Calculate the closeness coefficient of each alternative. A closeness coefficient is defined to determine the ranking order of all alternatives once the d_i^* and d_i^- of each alternative $A_i (i=1,2,…,m)$ has been calculated. The closeness coefficient of each alternative is calculated as:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, i = 1,2,...m \quad (15)$$

Step 9: According to the closeness coefficient, the ranking order of all alternatives can be determined. The best alternative has a highest value.

3. APPLICATION OF FUZZY TOPSIS METHOD

The proposed model was used to determine the additional protecting system, which should be placed on the railway crossing PBK-2. The observed crossing is located on the open track and it is equipped with an automatic device for securing traffic at railway crossings, as well as half-barriers with electrically powered devices and light path signals.

In order to increase the level of security, in addition to the existing insurance system, three experts proposed four types of additional protecting system for the road crossing [10]:

1. video surveillance (A_1) - the camera is installed at the railway crossing, and serves to detect irregular behavior in traffic and reduce accident.
2. Separators (A_2 and A_3) - Separators are physical barriers that are placed in the middle of the roadway on both sides of the railway crossing, as a supplement to the system with half-barriers, in order to prevent the going around of half-barriers. In this paper two types of separators, metal (A_2) and plastic (A_3) are observed.

3. rumble strips (A_4) - used as an additional protecting and warning device to alert drivers of road vehicle to emerging potential hazards.

Defining the criteria for evaluating alternatives is one of the most important decision-making tasks. The most important criteria are:

1. possibility of controlling the behavior of participants in road traffic,
2. technical possibility of installing the system,
3. the cost of installing the system,
4. the possibility of restricting participants in road traffic to irregular behavior,
5. the estimated lifetime of the technical devices after which there are increased defects that leads to the replacement of the existing device,
6. the influence of the technical solution on the psychological moment in the participants in road traffic.

Considering that all the criteria and their weights are descriptive (linguistic), they can be represented by fuzzy linguistic descriptors, which is presented in table 1.

Tab.1. Linguistic variables for the ratings

Lingvistic terms	Fuzzy numbers
Very low (VL)	(1,1,2)
Low (L)	(1,2,3)
Medium (M)	(2,3,4)
High (H)	(3,4,5)
Very high (VH)	(4,5,5)

Based on first three steps from fuzzy TOPSIS algorithm mentiond above, linguistic values of the importance weight of the criteria and the linguistic ratings for alternatives with respect to criteria are shown in tables 2 and 3.

Tab.2. The importance weight of the criteria

	D_1	D_2	D_3
C_1	M (2,3,4)	L (1,2,3)	L (1,2,3)
C_2	H (3,4,5)	M (2,3,4)	M (2,3,4)
C_3	H (3,4,5)	VH (4,5,5)	H (3,4,5)
C_4	VH (4,5,5)	M (2,3,4)	H (3,4,5)
C_5	H (3,4,5)	M (2,3,4)	L (1,2,3)
C_6	H (3,4,5)	VH (4,5,5)	L (1,2,3)

Tab.3. The ratings of three candidates by decision makers under all criteria

Decision makers	Alternatives/Criteria	C_1	C_2	C_3	C_4	C_5	C_6
D_1	A_1	L (1,2,3)	M (2,3,4)	VH (4,5,5)	M (2,3,4)	L (1,2,3)	H (3,4,5)
	A_2	H (3,4,5)	H (3,4,5)	M (2,3,4)	VH (4,5,5)	H (3,4,5)	M (2,3,4)
	A_3	M (2,3,4)	VH (4,5,5)	M (2,3,4)	H (3,4,5)	VH (4,5,5)	VL (1,1,2)
	A_4	L (1,2,3)	VH (4,5,5)	L (1,2,3)	VL (1,1,2)	M (2,3,4)	VL (1,1,2)
D_2	A_1	M (2,3,4)	H (3,4,5)	H (3,4,5)	L (1,2,3)	M (2,3,4)	VH (4,5,5)
	A_2	H (3,4,5)	M (2,3,4)	M (2,3,4)	VH (4,5,5)	M (2,3,4)	H (3,4,5)
	A_3	L (1,2,3)	H (3,4,5)	L (1,2,3)	VH (4,5,5)	H (3,4,5)	L (1,2,3)
	A_4	VL (1,1,2)	VH (4,5,5)	VL (1,1,2)	L (1,2,3)	L (1,2,3)	L (1,2,3)
D_3	A_1	L (1,2,3)	M (2,3,4)	VH (4,5,5)	M (2,3,4)	M (2,3,4)	VH (4,5,5)
	A_2	M (2,3,4)	M (2,3,4)	H (3,4,5)	H (3,4,5)	H (3,4,5)	M (2,3,4)
	A_3	H (3,4,5)	H (3,4,5)	M (2,3,4)	H (3,4,5)	M (2,3,4)	M (2,3,4)
	A_4	L (1,2,3)	VH (4,5,5)	L (1,2,3)	L (1,2,3)	M (2,3,4)	VL (1,1,2)

Next step is construction the weighted normalized fuzzy decision matrix and calculation the (FPIS) and (FNIS):

$$A^* = \begin{bmatrix} (0,4;1,7;4,0),(1,2;2,9;5,0), \\ (0,6;0,9;1,7),(1,2;3,7;5,0), \\ (0,4;2,4;5,0),(0,6;3,4;5,0) \end{bmatrix} \tag{16}$$

$$A^* = \begin{bmatrix} (0,4;1,7;4,0),(1,2;2,9;5,0), \\ (0,6;0,9;1,7),(1,2;3,7;5,0), \\ (0,4;2,4;5,0),(0,6;3,4;5,0) \end{bmatrix} \tag{17}$$

The distance of each alternative from D_i^* and D_i^- can be calculated by eqations (12-14). Calculations and final ranking of alternatives are shown in table 4.

Tab. 4. Results of fuzzy TOPSIS model

	D_i^*	D_i^-	CC_i	Rank
A_1	2.758	5.915	0.682008	2
A_2	1.667	6.931	0.806098	1
A_3	3.624	5.315	0.594551	3
A_4	8.218	0.128	0.015373	4

As we can see from table 4, the best alternative is A_2 metal separator, and the worst is alternative A_4.

4. SENSITIVITY ANALYSIS

Special attention in this paper is committed to sensitivity analysis, which can determine the stability of the observed solution. The sensitivity analysis was done by changing the values of the weight coefficients of the criteria. Table 5 gives the scenarios of changing the weight coefficients of the criteria.

Tab.5. Scenarios with different criteria weights

Scenarios		Criterion Weight					
		C_1	C_2	C_3	C_4	C_5	C_6
S_1	Uniform Weight Criteria	0.1667	0.1667	0.1667	0.1667	0.1667	0.1667
S_2	Priority of Criterion C_1	0.5	0.1	0.1	0.1	0.1	0.1
S_3	Priority of Criterion C_2	0.1	0.5	0.1	0.1	0.1	0.1
S_4	Priority of Criterion C_3	0.1	0.1	0.5	0.1	0.1	0.1
S_5	Priority of Criterion C_4	0.1	0.1	0.1	0.5	0.1	0.1
S_6	Priority of Criterion C_5	0.1	0.1	0.1	0.1	0.5	0.1
S_7	Priority of Criterion C_6	0.1	0.1	0.1	0.1	0.1	0.5
S_8	Combined Priority of Criterion C_2, C_3 and C_4	0.1	0.2	0.3	0.2	0.1	0.1

The ranking of the alternative for different scenarios are presented in table 6, where S_0 is the rank of alternative obtained using the actual weight of the criterion. By analyzing the obtained results, it can be concluded that there is significant stability in most cases.

Based on the table 6 we can see that alternative A_2 is the best solution in six of nine cases (67%) with values in the range of 0,66-0,86, which is an adequate verification of the proposed model. Alternative A_4 in all models are also on the same position, the last place.

Tab.6. Alternatives ranking for different weight criteria scenarios

Alternatives	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
A_1	2	2	3	3	1	3	3	1	2
A_2	1	1	1	2	2	1	1	2	1
A_3	3	3	2	1	3	2	2	3	3
A_4	4	4	4	4	4	4	4	4	4

5. CONCLUSION

The obtained results using the fuzzy TOPSIS method show that the presented method can be used to support decision makers when choosing a system of additional protecting system. Through the sensitivity analysis, it has been shown that the solution has stability, and through which the subjectivity and imprecision that are occurring every day in decision making are reduced. In addition to the example shown, the advantage of this model is its ability to solve other decision-making problems.

The future development of the model can be seen in a more detailed analysis of the input parameters and the formation of larger groups of experts that would improve the input values. In the future period, presented model will be tested using another methods of multi criteria decision making combined with fuzzy logic or rough numbers theory.

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IMPACT OF THE GLOBAL MARITIME CONTAINER TRANSPORT ON RAIL TRAFFIC IN EUROPE

Klaus Jurgen UHL[1]
Tatjana MIRKOVIC[2]

Abstract *– More than 80% of international trade is carried by maritime ships. Almost more than 2/3 of the handling services in the big ports of the world is container handling. Container ships of the last generation will carry more than 25.000 TEU. Transhipping containers from ship to rail may require more than 50 full container trains both, for incoming and outgoing containers. Container sizes will change in volume and in height. The shippers demand integrated multimodal supply chains. Therefore, it is elementary that railway infrastructure managers and railway undertakings critically evaluate whether they will be able to cope with the future volumes and technical requirements of the container shipping industry. In Asia, where the container revolution is taking place, rail infrastructure already adapts to the new requirements, for example in the dedicated freight corridors in India. There is another challenge facing rail. Still considered as the environmentally most desirable mode of transport, the rail will soon face autonomously driving lorries with non-fossil engines. The paper will give first insides about what might happen.*

Keywords – Maritime container, intermodal trade, container train, customer requirements.

1. INTRODUCTION

Overall objective of the customer's requirements is to reduce the incidence of transport cost on the total cost of the product by designing supply chains with the following major characteristics:

- Reduce dead weight.
- Stay on water as long as possible.
- Stay on land as short as possible.
- If on land, by rail or by any ecological combination of mode of transport.

As a consequence, the transport industry shall have to:

- turn multi-modal.
- get away from the ideology of rail vs. road vs. water.
- Turn towards the development of customer-oriented transport products.

2. WORLDWIDE MARITIME CONTAINER TRANSPORT

More than 80% of international trade is carried by maritime ships. Almost more than 2/3 of the handling services in the big ports of the world is container handling. Container ships of the last generation will carry more than 25.000 TEU. Fig. 1 presents MSC Zoe with 19.200 TEU which started operations in 2015. Transhipping containers from ship to rail may require more than 50 full container trains both, for incoming and outgoing containers.

Fig.1. MSC Zoe with 19.200 TEU (2015 in operation)

Samsung Heavy Industries for OOCL which is under construction will have 21.100 TEU, while China Shipping Container Lines plan 24.000 TEU vessels [1].

In order to take the load from a 20.000 TEU ship, there will be a need for 3.596 Lkw or 49 train formation, as presented in Fig. 2, and these numbers are theoretical numbers which in reality will be higher, [2].

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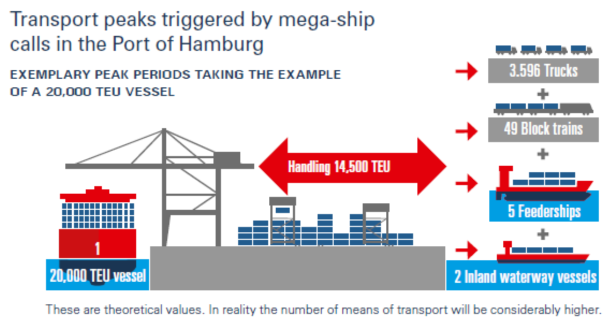

Fig.2. Transport peaks triggered by mega-ship calls in the Port of Hamburg

3. HOW DOES THE RAIL SECTOR REACT TO THE ABOVE CHALLENGES?

Fig. 3 shows the most important transport flows between Asia and Europe with time needed for each flow.

At resent 98 to 99% of the goods are transported by sea, mostly via Suez and the Cape of Good Hope.

First trials via the Behring Street and the Murmans are already under way. The "North-East Passage" would significantly reduce time and costs, rendering Euroasian exchange less vulnerable.

As part of the Silk road initiative, the rail sector has developed new products for highly valuable goods with time constrains between China and Europe.

The rail routes are at present:

- Main route Central China via Kazakhstan, Russia to Germany, mostly Hamburg and Duisburg as eurasian rail hubs, with antenna to Central Europe via Ukraine.
- "Northern" route from North-East China via Russia or Mongolia to Germany.
- "Southern" route via Kazakhstan, Georgia, Black Sea/Turkey or Iran/Turkey to South-Eastern Europe.

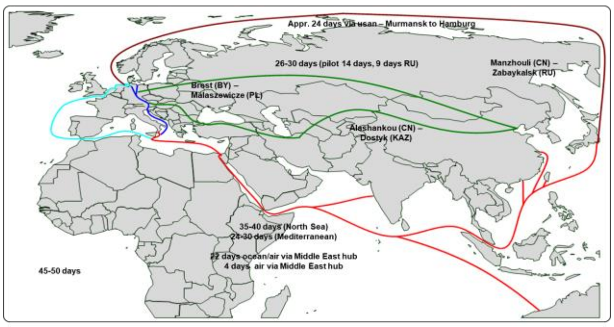

Fig.3. Transport flows between Asia and Europe

The number of operated trains significantly increased in 2017 and was 3800 in comparison with 300 trains in 2014. At the same time, transport volumes increased from 25,000 TEU to nearly 300,000 TEU in the same period. Despite this strong development, bulk of freight is transported by ship while rail transport still has a low intermodal market share of 1% to 2% in the trade between Asia and Europe, [3].

4. CONTAINER SIZES

Container sizes will change in volume and in height. The latest developments, mostly coming from the Far East are: shown in Fig. 4. The new dimensions might become a survival challenge for rail since the height might be in conflict with rail infrastructure design.

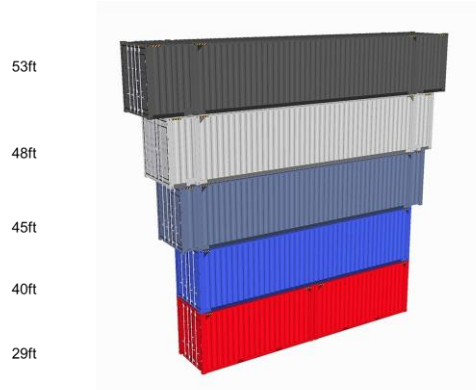

Fig.4. Container sizes

European industry is also looking for solutions to maximise the load per metre and still use the rail. A good example are the so-called STORA Boxes.

A STORA Box is presented in Fig. 5 and it looks like a standard 40-foot ISO Container but measuring 13.8×3.6×3.6 m (45×12×12 ft) carrying 80 tonnes (79 long tons; 88 short tons) of cargo. This is compared to the normal 12.2×2.7×2.4 m (40.0×8.9×7.9 ft) size and 26.5-tonne (26.1-long-ton; 29.2-short-ton) capacity of an ISO Container, [4]. But,

- A STORA Box is too big and heavy to be transported on road.
- By railway in Sweden. Special rail wagons and rail infrastructure with higher axle weight is needed.
- Transport by ship on ferries/RORO only.

The benefit is to reduce the number of containers and therefore handling cost. The drawback is that special (rail) solutions are needed.

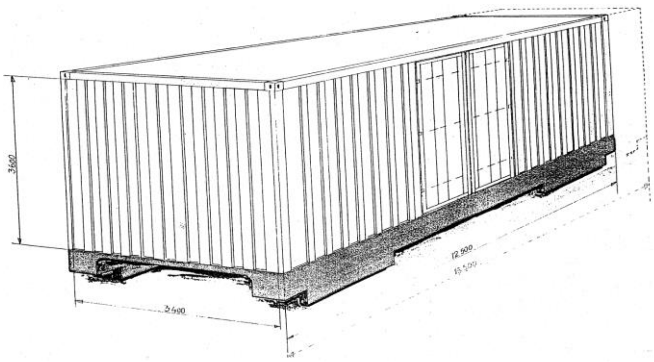

Fig.5. STORA Box

Another rail solution is "double-stacking" already used in other parts of the world, but not in Europe. Most recent examples for „double-stacked "rail infrastructure:

- Australia - double-stacked trains operate between Perth, Adelaide, Darwin and Parkes, New South Wales, 6.5 m (21 ft) clearances
- China - double-stacked container trains under 25 kV AC overhead lines.
- India - Mundra Port and Pipavav Port - double-stacked diesel trains on 1,676 mm gauge using flat wagons with double stack 9 ft 6 in (2,896 mm) tall (high cube) containers.
- Netherlands - The Betuweroute, a freight rail between Rotterdam to the German border built in 2007 is prepared for double-stacking, tunnels are designed to accommodate double stack. But not yet used. The current catenary wire is too low for double stack rail transport and the upgrade depends on the German section.
- Panama - The rebuilt Panama Canal Railway operates double-stack container trains 47.6 miles (76.6 km) across the Isthmus of Panama from Colón on the Atlantic Ocean, to Balboa on the Pacific, near Panama City.
- Saudi Arabia - Saudi Railways Organization line to Dammam.

5. MODERNISATION OF INDIAN RAILWAY

India has already take up the challenge coming from the sea by developing dedicated freight corridors with new rail dimensions as can be seen from the Fig. 6 and Fig. 7, [5].

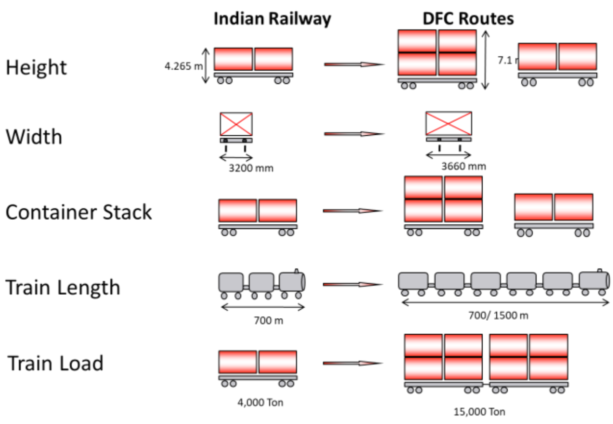

Fig.6. Modernisation of Indian Railways (1)

In fact, the new corridors fulfil almost all requirements, the export-oriented and container shipping customer wish to see. Dedivated freight rail corridors of India are presented in Fig. 8.

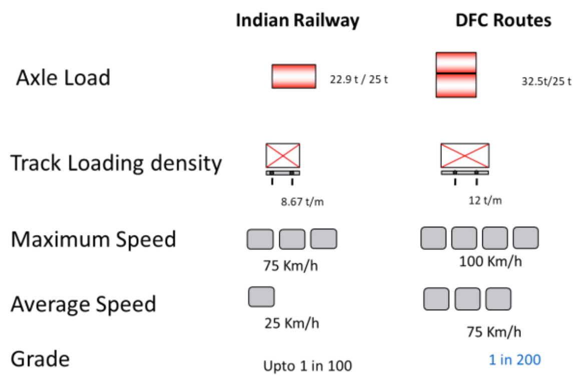

Fig.7. Modernisation of Indian Railways (2)

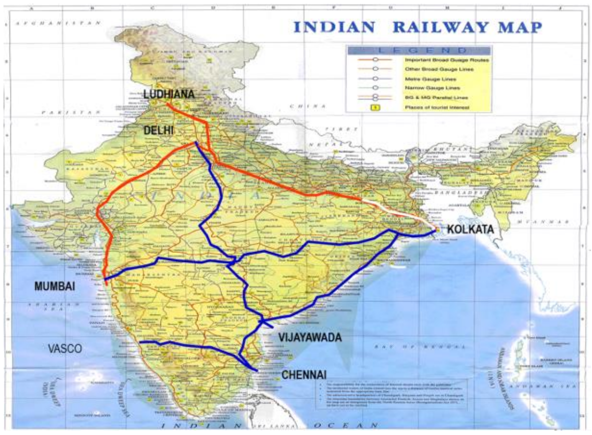

Fig.8. Dedicated freight rail corridors

6. AND WHAT HAPPENS BEYOND 2040 …

There are some challenges for the rail sector which could easily turn into the end of the rail.

Fig.9. 3D printing

3D printing will certainly reduce the transport of goods, in particular long-distance haulage for all modes of transport, [6]. One example of 3D printed is shown in Fig. 9.

Autonomous lorries with electric traction might reduce the attractiveness of the rail as environmentally-friendly mode since every transhipment will become an ecological disadvantage, [7].

The lorry with its door-to-door service will become the most ecologically-friendly mode of transport.

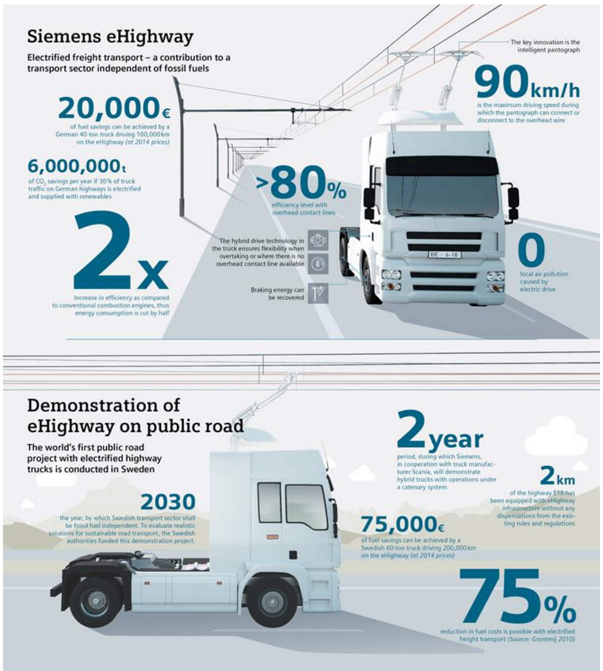

Fig.10. Electrical freight transport

The infrastructure capacity of motorways will increase due to teleguided complete “full lorry trains”. Siemens eHighway solution is presented in Fig. 10.

7. CONCLUSION

There is a high likelihood that rail shall be gradually replaced by road, at least in the freight sector, by at least two factors:

- The rail shall not have the transhipment capacity to distribute in time and capacity the cargo of the new generation of container ships.
- The rail infrastructure shall be unable to receive the new container sizes.
- The future generation of lorries shall offer environmentally-friendly transport from door-to-door at lower costs and with higher speed and efficiency.

It may be the beginning of the end of an already old means of transport that has missed to understand the signs of a digitalised, automated, and environmentally-friendly new age because, for too long time, it has been protected with subsidies and special privileges.

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A DECISION SUPPORT SYSTEM FOR INTERMODAL FREIGHT TRANSPORT CHOICE BASED ON MS EXCEL: ROAD-RAIL

Teodor BEROV [1]

Abstract – *This article deals with the problem of choosing between road transport and intermodal road-rail transport. Cost efficiency and transport quality are great importance in the decisions of the real life choices of the shippers. This Decision support system is based on the capabilities of the commonly available MS EXCEL (Visual Basic for Applications (VBA) and Google Maps™). A modeling framework is used for calculating's the costs, travel time and Emissions CO_2 for the two competitive transport types. Results for Bulgaria-Turkey destination are shown.*

Keywords – Intermodal Transport, Freight, Road, Rail, Excel, VBA.

1. INTRODUCTION

Globalisation and increasing international trade have necessitated more frequently integrating of intermodal freight transportation into the supply chain strategy. Intermodal transportation is an attractive alternative to long-haul trucking and provides organizations with flexible options in their supply chain as they move their goods from the source to the customer.

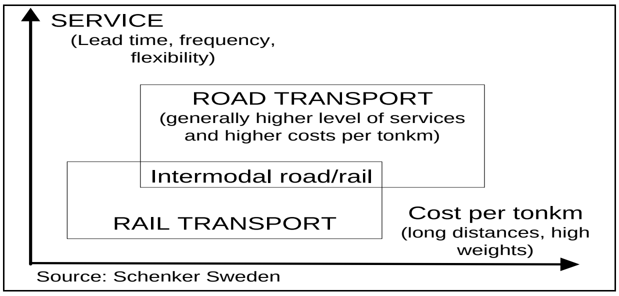

Fig.1. Intermodal road/rail flexibility [1]

Intermodal freight transport involves the transportation of freight from origin to destination using two or more transportation modes (rail, ship, and truck). This transport process is using intermodal container or vehicle, without any handling of the freight itself when changing modes.

In Bulgaria from 2018 year starts an Intermodal Trailer Trains from the Intermodal Terminal at T. Kableshkov railway station to the Cerkezkoy in Turkey. This is one of the two terminals in the European part of Turkey. The composition has 34 wagons for fully loaded semi - trailers. The train has a total length of 600 meters, weighs 1600 tons, along with the load. Such a train for Austria will be with 30 trailers as it will pass through Serbia where there are limitations on the length of the train.

Tab.1. Intermodal Terminals in Bulgaria [2]

Intermodal terminal	Ownership / Terminal Operator	Modes Served	Status
1.Plovdiv, (T. Kableshkov)	PIMK Rail	Road, Rail	Yes
2. Sofia - Yana	Ecologistics	Road, Rail	Non- opera
3.Dragoman RoLa	NRIC	Road, Rail	Non-operational
4.Varna	NRIC	Road, Rail, Sea	project
5.Ruse	NRIC	Road, Rail	project
6.Stara Zagora	Metalimpex	Road, Rail	Yes
7. Bourgas (Dolno Ezerovo)	Despred Plc	Road, Rail, Sea	Yes
8.Svilengrad RoLa	NRIC	Road, Rail	perspective

***** NRIC (the National Railway Infrastructure Company of Bulgaria)

This material proposes an implementation approach for a mode-choice tool to intermodal as an alternative to road freight transport based on MS EXCEL.

2. PROBLEM DESCRIPTION

The modern intermodal transport management not only focuses on goods transport and logistics, but also concentrates on responses from marketing and business strategy.

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Tab.2. Roles in the physical transport chain

Place	Local processes	Rail/ Road transport	Road-only transport
1*	• Loading of trailer • Collecting by truck	Road Operator	Forwarder
2*	• Positioned by truck • Internal movement • Lift on rail wagon • Local shunting by rail	Terminal Operator Railway Undertaking	LSP
3*	• Local shunting by rail • Lift from rail wagon • Internal movement • Picked up by truck	Terminal Operator	Road operator
4*	•Positioning of truck •Uploading of trailer	Road Operator	

1* Shipper, 2*, 3* Intermodal terminal, 4* Consignee

For effective distribution, the shipper and distributor can make a process of the analysis for intermodal transport. Many elements needs to be take into account in this process, such as regional transport policy, the design of transport network (nodes, route, terminals, etc.) and transport mode choice.

Following the objectives of this study, the core of the model consists of three main components: rail transport, road transport and terminal handling [3].

- Generation of direct route legs between origin and destination using a unimodal search;

- Generation of route legs between transfer points using a unimodal search;

- Construction of route tree;

- Calculation of costs for all routes and transfer points;

- comparing costs.

The ***TOTAL TRANSPORT COST*** (TTC) for a combined transport chain would take the following general form:

$$TTC_{INT} = RC_{road} + TC_{term} + RLC_{rail} + TC_{term} + RC_{road} \quad (1)$$

Where RLC_{rail} is the total cost generated by the rail operations; RC_{road} is the total cost for road haulage consisting of pre- and post-haulage to terminals; TC_{term} is total cost for terminal handling, which is derived from the cost per transferred unit associated with the type of terminal.

Mathematical calculations are similar to those that are in [4] for determining the efficiency of RO-LA transport.

The ***TOTAL TRAVEL TIME*** (TTT) for a intermodal transport chain would take the following general form:

$$TTT = \sum T_{road} + \sum T_{rail} + \sum T_{term} + \sum T_{delay} + \\ + \sum T_{bord} + \sum T_{dr.rest} \quad (2)$$

Where are respectively: travel times for the road links T_{road}, rail links T_{rail}, for terminal handling T_{term}, expected delay time for all transport chain T_{term}, for border crossing T_{bord} and driver rest $T_{dr.rest}$.

Carbon dioxide (CO2) is the predominant greenhouse gas (GHG) emitted by vehicles and is directly related to the amount of fuel that is consumed by vehicles. Vehicles also emit other GHGs, including methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs). An activity based approach for estimation of CO_2 emissions is applied by formula (3). Data for energy consumption is derived from the three modules of this model.

$$E(CO_2) = EC * EF(CO_2) \quad (3)$$

Where $E(CO_2)$ is CO_2 emissions by mode/transshipment technology; *EC* - Energy consumption by mode/transshipment technology; $EF(CO_2)$ CO_2 emission factor by energy source.

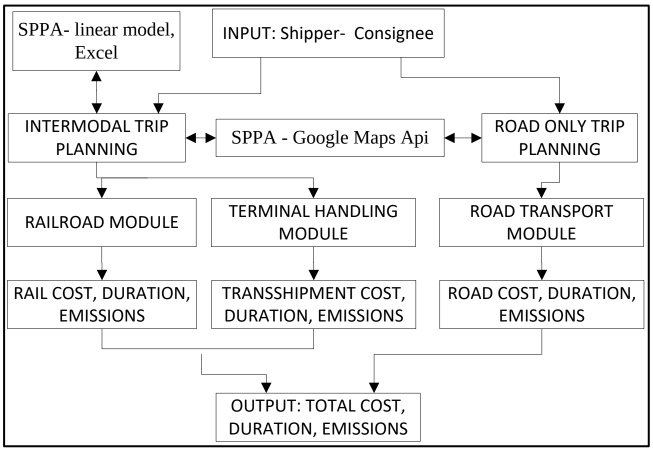

Fig.2. The conceptual framework for the proposed model

Depending on the needed depth of the calculations is the structure of the input data for the modules[1],[3],[4],[5],[6]. Needed data is stored in a different sheets: for road module, for railroad module and for terminals.

In order to evaluate the whole trip duration, cost and CO_2 emissions in a combined transport, it is important to evaluate the time, cost and emissions related to the terminals. Time is a factor that includes loading and unloading time and it can be calculated by applying formulas and delays of loading and unloading that are recorded in the individual terminal.

Moreover, the deviation of manipulation time should be taken into consideration to estimate the total value of handling duration in hubs.

3. REALIZATION IN EXCEL (VBA)

For the implementation of the proposed model, the generally available MS EXCEL (VBA) was chosen. It is manufactured by Microsoft Corporation and is part of the Visual Studio programming package. The

Visual Basic programming environment contains all the tools needed to quickly and efficiently build GUI utilities for Windows OS, providing easy access to ActiveX-based databases.

```
Public Function GetDistanceGM(ByVal start As String, ByVal dest As String) As Double()
   Dim m_exit() As Double,  firstU As String, secondU As String, lastU As String
   firstU = "http://maps.googleapis.com/maps/api/distancematrix/json?origins="
   secondU = "&destinations="
   lastU = "&mode=car&language=bg&sensor=false"
   Set objHTTP = CreateObject("MSXML2.ServerXMLHTTP")
   URL = firstU & Replace(start, " ", "+") & secondU & Replace(dest, " ", "+") & lastU
   objHTTP.Open "GET", URL, Fals
objHTTP.setRequestHeader "User-Agent", "Mozilla/4.0 (compatible;MSIE 6.0;Windows NT 5.0)"
   objHTTP.setRequestHeader "Content-type", "application/x-www-form-urlencoded"
   objHTTP.send ("")
   If InStr(objHTTP.responseText, """distance"" : {") = 0 Then GoTo ErrorHandl
      ReDim m_exit(1 To 2)
Set regex = CreateObject ("VBScript.RegExp"): regex.Pattern = """value"".*?([0-9]+)": regex.Global = False
 Set matches = regex.Execute(objHTTP.responseText)
   tmpVal = Replace(matches(0).SubMatches(0), ".", Application.International(xlListSeparator))
   m_exit(1) = CDbl(tmpVal)
 m_exit(1) = m_exit(1) / 1000
      Set regex = CreateObject("VBScript.RegExp"): regex.Pattern = "duration(?:.|\n)*?""value"".*?([0-9]+)": regex.Global = False
     Set matches = regex.Execute(objHTTP.responseText)
        tmpVal = Replace(matches(0).SubMatches(0), ".", Application.International(xlListSeparator))
        m_exit(2) = CDbl(tmpVal)
           m_exit(2) = m_exit(2) / 60
              GetDistance = m_exit
        Exit Function
     ErrorHandl:
        ReDim m_exit(1 To 2)
           m_exit(1) = -1        m_exit(2) = -1
             GetDistance = m_exit
     End Function
```

Fig.3. Pseudo code for Calculate Google Maps distance between two addresses

The formatting of input and output databases is done in the standard way for tables set in MS Excel, and all modules for input information processing and setting of parameters for the simulation as well as the implementation of the designed algorithms is in the VBA. The software interface must have parameter entries and definitions prior to trip simulations being computed.

The base using module is the Shortest Path Routing Algorithm for the two road and rail routes (links).

Routing Algorithms

Algorithm for Shortest Path Problem (SPPA) needed in order to find origin-to-destination routes along the road/rail network. The shortest path approach used for this study is:

- for road transport: implementing the Google Maps™ and Google Maps Api (GMA) for the calculation of distance between points;

- for railway: Excel based calculation of distance between points [7].

For railway problem, the task of finding the shortest path between two points (points) of the transport network based on a linear model that is solved by using the Excel Add-in Solver.

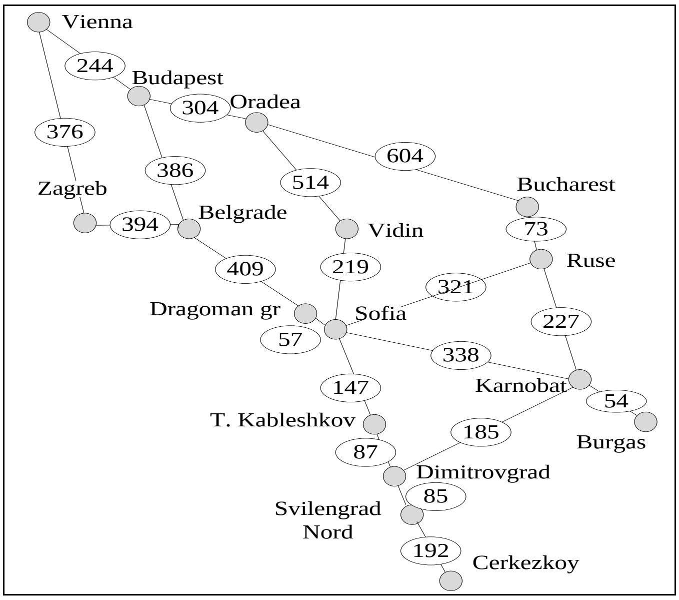

Fig.4. Network graph

Excel calculations is needed to find out if an arc is on the shortest path or not (Yes=1, No=0), between two points in an undirected network. The Net Flow (Flow Out - Flow In) of each node should be equal to Supply/Demand. Node “From Node” should only have one outgoing arc (Net Flow = 1). Node “To Node” should only have one ingoing arc (Net Flow = -1). All other nodes should have one outgoing arc and one ingoing arc if the node is on the shortest path (Net Flow = 0) or no flow (Net Flow = 0). The overall measure of performance is the total distance of the shortest path, so the objective is to minimize this quantity.

In the Undirected network (graph)(Fig.3):

- Nodes are: Intermodal terminals, border crossings, railway deviations, and others;

- Lines in a network (arcs) are Distance between nodes.

The network graph must be updated for using of new terminals (same for the Excel Sheet corresponding to the graph).

VBA program modules are required to trigger the "Solver" for each new search for "from - to" and retrieve from the result the required information - distance, including nodes and arcs. From the node descriptions is defined the border crossings through which the route runs.

When using GMA is necessary a GPS coordinates for best results.

4. CASE STUDY RESULTS

The considered approach is applied to the case of transportation of 20 ton cargo weight in semi-trailer from Sofia, Bulgaria to Istanbul, Turkey. To avoid urban traffic the Shipper (42.633577, 23.459386) and Consignee (41.057845, 28.628548) are selected in logistics parks near the entrance / exit highways.

Intermodal Terminals are: Çerkezköy Terminali (41.279356, 28.00974) and T. Kableshkov terminal (42.126772, 24.636483).

In the calculations are used cost rates, referred to [5] and costs of the local logistics operators.

Calculation of Emissions, CO2 is based of emission factors [6].

Intermodal Trip planning

Link1	Sofia - T. Kableshkov,	truck
Hub1	T. Kableshkov	
Link2	T. Kableshkov – Svilengrad Nord,	rail
Link3	Svilengrad Nord - Cerkezkoy,	rail
Hub2	Cerkezkoy	
Link4	Cerkezkoy – Istanbul,	truck

Tab.3. link information of the example

<table>
<tr><th>Link</th><th>Distance (km)</th><th>Duration (h)</th><th>Cost (EUR)</th><th>Emissions, CO_2 ($kgCO_2$)</th></tr>
<tr><td>Link1</td><td>142</td><td>2</td><td>128</td><td>144,3</td></tr>
<tr><td>Hub1</td><td></td><td rowspan="4">15,5 (+7)</td><td rowspan="4">450</td><td rowspan="4">358 (2,06+2,06)</td></tr>
<tr><td>Link2</td><td>172</td></tr>
<tr><td>Link3</td><td>192</td></tr>
<tr><td>Hub2</td><td></td></tr>
<tr><td>Link4</td><td>74</td><td>1</td><td>90</td><td>75</td></tr>
</table>

Road-only transport

Sofia - BCCP Kapitan Andreevo - Kapikule, E80, - Istanbul

Distance - *520km (289)*

Cost – *650* EUR

Duration – *36* h

Emissions, CO_2 ($kgCO_2$) 527,8 kg

For this transport variant cost and duration are from logistics operators data. In the duration is calculated rest for driver (0,75h+ 9h) and waiting time for the border crossing.

5. CONCLUSION

This study has provided a methodology for evaluating the feasibility of applying concepts and technologies within intermodal freight transport regarding cost, time and emissions.

From the results of the case study one could conclude that a regional rail based intermodal transport system is on the threshold of feasibility in the studied region.

The loading space utilization of the train and the transshipment cost are the most critical parameters. The latter restricting the competitiveness of intermodal services on short distances as it is not proportional to transported distance but rather to the utilization rate of resources.

The parameter which is critical for the results are the fuel prices, where the results shows that if diesel prices would increase so would the feasibility of the intermodal option.

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Infrastructure

XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '18

ACCESSIBLE RAILWAY PLATFORMS – CZECH AND SERBIAN DESIGN EXPERIENCE AND RECOMMENDATIONS

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Jaroslav MATUŠKA [2]
Luka LAZAREVIĆ [3]

Abstract *– Accessible railway platforms are an important part of modern railway infrastructure. Accessibility for all passenger categories, including people with reduced mobility (PRM), is one of basic and mandatory requirements for new and reconstructed European railway infrastructure. According to the results of the research conducted within the framework of the Visegrád Group (cultural and political alliance of four Central European nations – Czech Republic, Hungary, Poland and Slovakia, that are members of the European Union) in 2015, the existing railway platforms and passenger information systems represent serious barriers for PRM passengers (especially for people in wheelchair, with crutches, with baby prams, as well as for blind and visually impaired passengers). This paper deals with design requirements for railway platforms from the aspect of accessibility, tactile walking surface indicators and acoustic information for blind and visually impaired passengers. Paper analyses legal framework and shows examples of practical application of accessibility standards in Czech Republic and the Republic of Serbia. Furthermore, it provides concrete recommendations for barrier-free design of railway platforms.*

Keywords – accessibility, railway, platform, design, persons with reduced mobility.

1. INTRODUCTION

Mobility is an essential need and a legal right in modern European society. According to PRM TSI [1], the functional and technical requirements for the infrastructure subsystem related to accessibility for persons with disabilities and persons with reduced mobility are: platform width, edges of platforms, end of platforms, and boarding aids stored on platforms.

In addition, necessary conditions for a comfortable and safe access for all passenger categories to the railway platforms (Figure 1) are: parking facilities, obstacle-free routes, doors, entrances and floor surfaces, highlighting of transparent obstacles, toilet facilities, furniture and free-standing devices, ticketing, information desks and assistance points, lighting, visual (printed or dynamic) information, spoken information, and level track crossings. Railway infrastructure, which is adapted to the needs of passengers with disabilities and reduced mobility, accelerates the flow and increases the safety of all passenger categories.

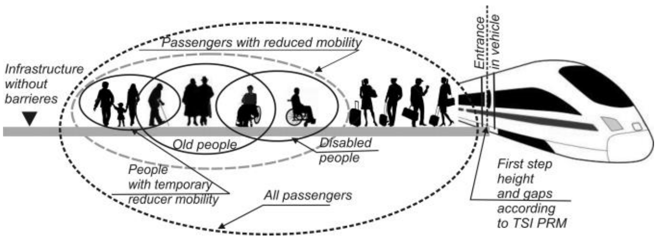

Fig.1. Structure of passenger flow on the platform

This paper deals with design requirements, which are a legal obligation, experience and recommendations for: a) accessible railway platforms, b) tactile walking surface indicators, and c) acoustic information for blind and visually impaired passengers in Czech Republic and the Republic of Serbia.

2. LEGISLATIVE FRAMEWORK

In the Czech Republic, the first Decree defining mandatory requirements for accessible environment for wheelchair users and visually impaired people entered

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into force in 1994 [2] indicating parameters for civil facilities, and also traffic structures (railway platforms, public transport stops, etc.). It was the first time the definition of a person with reduced mobility and orientation appeared. Its two amendments [3, 4] gradually specified requirements and completed necessary parameters. To design particular modifications of traffic structures, the Decree [4] refers to relevant national standards ČSN, e.g. [5, 6], or other relevant regulations.

The legal right of all passengers to unobstructed access to transportation in the Republic of Serbia is stated in the Prevention of Discrimination of People with Disabilities Act (passed by the National Parliament on April 17th 2006). Nevertheless, this Act was preceded by Regulations on conditions for planning and the design of buildings for unobstructed access of children, the elderly, the handicapped and the disabled in 1997, which defined technical conditions for planning and designing pavements, footpaths, pedestrian crossings, parking places, public transport stops and access to buildings.

The Planning and Construction Act passed in 2006 [7] introduced new standards of accessibility in the form of mandatory technical measures, standards and conditions of design, planning and construction, which ensure unobstructed movement for people with disabilities, children and the elderly.

The technical regulation [8] prescribes in more detail the standards that define the obligatory technical measures and conditions for the planning, design and construction of facilities, which ensure the smooth movement and access for persons with disabilities, children and the elderly.

2.1 Railway platforms in the Czech Republic - Regulations and design

Nowadays the requirements for accessible platforms in the Czech Republic are laid down in the following regulations:

- Decree 398/2009 which defines general requirements for railway platform accessibility for visually impaired and wheelchair users,
- ČSN 73 4959 is a technical standard specifying design parameters of platforms: height of the platform edge (preferably 550 mm above the rail head surface), tactile modification of paved surfaces and minimum safe distance for obstacles from the edge of the platform;
- Internal regulation SŽDC Ž 8.7 of the infrastructure manager (SŽDC) defines detailed modifications of platforms (using schemes), which applies especially for visually impaired people. This regulation, reflecting TSI PRM requirements, is most frequently used by designers for platform shaping;
- TSI PRM – is a legal obligation in Czech Republic as an EU member country. It adjusts parameters of railway infrastructure (platforms, departure halls and access paths), information systems and carriages. Design parameters of platforms for wheelchair users are mostly identical to those in the previously stated national regulations. Tactile ground surface indicators on platforms are rather different;
- Graphic user manual of the information system, which serves as the internal regulation of the infrastructure manager SŽDC, specifies e.g. some parameters of information systems for passengers including their modifications for visually impaired passengers [9].

On the Czech railway network, there are three types of platforms (Table 1):

- 200 - 250 mm above the rail head surface. These are so-called earth-filled embankments, which represent platforms without solid edges. They appear in small stations on regional railway lines;
- 380 mm above the rail head surface. These are platforms with solid edges, which are introduced in 2009 according to TSI PR. This height is allowed only under specified conditions, thus is rarely found on Czech railway network;
- 550 mm above the rail head surface. These are island platforms, with the access across the tracks and also side platforms. The platform height corresponds to the floor level in low-floor railway coaches (550 ± 20 mm).

Tab.1. Railway platforms on CZ railway network

Type of platform	**Edge height [mm]**	**Railway line category**	**Share [%]**
Earth filled	200-250	regional	42
Raised platform	380	regional	3
Island platform	550	national or regional	55

Tactile adjustments for visually impaired can be used only on island platforms, platforms with the access across the rails and also side platforms where it is possible to lead the visually impaired person within safe distance from the platform edge. SUDOP panels used for island platforms or side platforms are 1450 mm or 2300 mm wide. Figure 2 (left) shows position of SUDOP panels on supporting structures (U 65, U 85, U 95, height corresponds to platform edge up to 300 mm, 500 and 550 mm).

Figure 2 (right) demonstrates tactile adjustment for visually impaired people – tactile ground surface indicator (with the turn to the stairs), which is laid 800 mm from the platform edge with carved grooves and total width 400 mm, accompanied by 150 mm wide yellow signal line. The grooves, which are cut into the paved surface of the platform, enable smooth use for visually impaired people with a white stick. They do not represent an obstacle for other passengers (small children, people with walking difficulties, etc.). At the point of the turn (e.g. to the stairs) the tactile ground surface indicator is interrupted in the length of 400 mm with the link to the signal line (800 mm wide with dots). Tactile ground surface indicator leads the visually impaired people to the wall and then along the wall to the stairs.

Fig.2. SUDOP type platform (left) and tactile ground surface (right)

Recently, the SUDOP platform edge has been often replaced by the H type construction (Figure 3) consisting of prefabricated parts with standard height (550 mm), without the side lap to the rail yard (unlike SUDOP panels – Figure 1a). Its disadvantage is that it is necessary to pave all the area of the platform and put together tactile elements (tactile ground surface indicator, signal lines, etc.).

Fig.3. H type platform

2.1 Railway platforms in the Republic of Serbia - Regulations and design

According to INF TSI, designed height of the platforms is 550 mm on new and reconstructed railway stations on Corridor X through the Republic of Serbia, as well as in the Belgrade railway junction.

Unfortunately, on the existing infrastructure (including the Belgrade Railway junction), the most platforms do not comply with the prescribed accessibility requirements (Figure 4 shows gap of 40 cm). On the other hand, Figure 5 shows good compliance of the platform height and vehicle floor level in Belgrade Center station. Unfortunately, the platform surface is slippery and there is no surface guiding for blind and visually impaired passengers.

Fig.4. The unsafe gap in the Vukov Spomenik railway station in downtown Belgrade

Fig.5. Comfortable and safe access to the platform (platform height 550 mm) from the vehicle

3. ACOUSTIC INFORMATION FOR VISUALLY IMPAIRED

The Czech Republic is one of the European countries, which introduced acoustic information system. System TYFLOSET® was developed between 1993 and 1994, enabling orientation of visually impaired people on boards of transport means and public buildings (station halls of Prague underground railway, departure halls of railway stations, etc.). This system consists of a command transmitter (radio set), command receiver with antenna and voice software. These acoustic devices for visually impaired passengers are placed on railway platforms and in departure halls. They inform these people about their position or other details. The system is based on transmitted signal (requirement) from the passenger's radio. For example, the device above the entrance in the departure hall in Pardubice Main Station transmits following information: initial sound * (informs about the level entrance) followed by voice information 'Pardubice Main Station'. On the platform, the system informs about the number of platform, name of the station and the way from the platform to the departure/arrival hall: initial sound ** (informs passengers about stairs in their direction) followed by audio information 'towards the departure hall - down the stairs then to the right'. The same system is used to inform the passenger how to get to the platform from the departure hall.

For blind and visually impaired passengers, the Serbian Railways print the timetables and installs the timetable panels with Braille tactile writing system.

4. CONCLUSION AND RECOMMENDATIONS

Based on surveys conducted in member countries of Visegrád Group, accessibility of railway platforms is one of the crucial aspects when deciding whether to use railway transport [10]. Information itself and information systems proved to be of key importance for visually impaired people [11]. The authors recommend that a similar survey should be carried out in Balkan countries and based on results focus on systematic modifications of the core elements of railway infrastructure (platform halls, access paths) and information systems.

In 2012, the survey about requirements of long-distance passengers was conducted in the Republic of Serbia [12-14]. The results clearly indicate an uncompetitiveness of rail transport in this area, which is the result of lacks in infrastructure and related services for passengers with reduced mobility in Serbia (Figure 6).

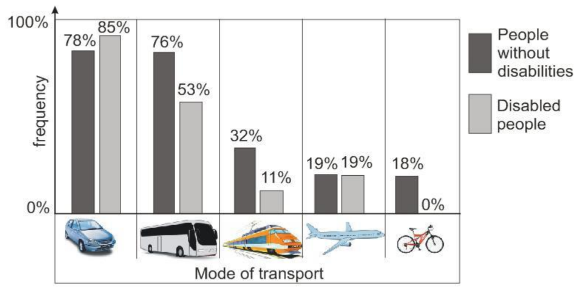

Fig.6. Frequency of travels by different modes of transport regarding the mobility of passengers

The authors also recommend improvements in accessibility of railway platforms and other parts of public transport for visually impaired passengers by installing acoustic information systems. Higher electivity of installation and utilisation of acoustic systems is necessary. Many years of Czech experience can serve and help this purpose.

ACKNOWLEDGEMENT

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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PASSENGER DISTRIBUTION ON THE PLATFORM - IMPACT ON DWELL TIME

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Abstract – *The behavior of passengers has a major influence on operational components such as passenger flows in railway stations, passenger exchange times and thus the punctuality of trains. This paper deals with the influence of passenger behavior and passenger needs on the infrastructure facilities of transport stations. Passenger distribution along the platform has a significant influence on passenger exchange time and thus on hold time and operating quality. This shows that most passengers orient themselves to the deboarding situation, which leads in part to a very pronounced unequal distribution along the platform. This in turn results in the overloading of individual doors and significantly extended passenger exchange times. The paper will give an overview about the interaction between passengers and platform infrastructure and how behavior will influence the train stop time.*

Keywords – passenger distribution, crowding, dwell time.

1. INTRODUCTION

Especially in local transport there are significant factors influencing the distribution of passengers along the platform resulting from the platform infrastructure and the platform facilities.

The unequal distribution along the platform inevitably leads to one door, the so-called "critical door", having the highest proportion of passengers boarding or deboarding the train. As a rule, the passenger exchange at this door takes longer than at other doors, which makes this "critical door" a decisive factor in the entire station stop. Regarding the distribution of passengers, there are the following influencing parameters on the infrastructure side.

2. ENTRANCES AND EXITS

The entrances and exits have the most influence on passenger distribution. In general, it can be said that local and system-knowledgeable passengers know exactly at which door along a train they will find the shortest path to the exit at their arrival station. In the sense of overall travel time optimization, a possible waiting time at the platform is therefore used to go to the area where boarding is expected to provide the shortest path to the exit after deboarding. The longer the interval times between trains, the higher the probability is of having to wait for the arriving train and therefore the more frequently passengers board at the above mentioned door.

If the train interval times are short, the likelihood increases that a majority of the passengers will not have enough time to reach the desired door after arriving on the platform. In this case, it is shown that the position of the platform entrances have an increasing influence on passenger distribution.

Entrances and exits can be divided into three categories according to their expected passenger frequency, **main** (H), **middle** (M), **secondary** exit (N).

Main exits in transfer stations usually lead to the most direct way to other (main) means of transport such as further underground trains or to several tram and bus lines. Main exits can also be exits to commercial streets or shopping centres. In any case, these are exits with a high volume of people.

Middle exits can be exits to the surface or to other means of transport, which however, have a noticeably lower volume of people compared to main exits.

Secondary exits are exits in a station that are frequented by only a few people.

Generally, the category of exits may vary throughout the day. For example, during peak time in the morning the main traffic directions may be opposite to those during evening peak time. This means that in transfer stations, main exits in the morning can become middle exits in the evening and vice versa.

Fig. 1 shows an example of a station with a secondary exit (N) and a main exit (H) with direct connection to other main means of transport. It depicts the distribution of boarding and deboarding passengers

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along the entire train. It shows that especially the deboarding passengers orient themselves to both exits. Alone at that door which is closest to the main exit, over a third (37%) of all passengers deboard. Nearly 72% of all deboarding passengers pass through those three doors that are closest to the main exit. Further along the train, the proportion of deboarding passengers is to some extent very low (under 4%) and then increases somewhat towards the secondary exit.

The behaviour of the boarding passengers is different. Certainly here also a distribution toward both entrances can be seen, this is however not as pronounced as with the deboarding passengers. However, still approx. a third of all passengers (34%) board at the three doors closest to the main entrance.

The reason for the more even distribution is to be found in the fact that the stations in the following illustrated example have different arrangements of the main exits. There are respectively two stations with the main exit at the same place, two stations with the main exit at the other end and one station with a main exit more in the middle. The green line shown in Fig. 1 depicts the average of all passengers boarding and deboarding in the station in relation to in each case one door and represents an ideal case of even distribution along the entire train. At the same time, it shows that door 18 in the stated example is more than five times as heavily frequented as the average!

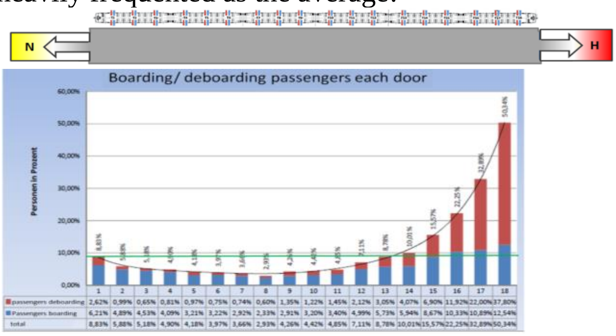

Fig.1. Boarding and deboarding passengers at a station with one-sided main exit (Eigner 2014)

Fig. 2 shows the example of a platform with two main exits arranged approximately at the quarter points. Here too it shows a distribution towards the exits with both peaks exactly at the doors closest to the respective exit.

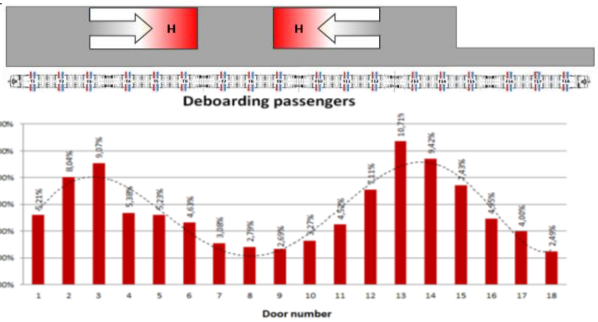

Fig.2. Deboarding passengers at a station with two main exits inserted on the platform (Eigner 2014)

Fig. 3 shows an example of a special case. Here on both platforms there are two equivalent middle exits. The "main exit" in this case is the platform itself because a same platform transfer between two underground lines takes place. It shows the following flow: there is in each case an increase in the number of deboarding passengers toward the two middle exits. Nevertheless, the flow along the entire platform is relatively balanced. The ratio is less than 2:1 between the most and the least frequented doors. The increase towards the two exits is encouraged as well by the fact that the exits at the adjacent stations of each subway line into which it is possible to transfer, are also located at the respective platforms. Thus, when changing trains on the same platform, already in boarding the first train, knowledge about the nearest exit to the connecting train also influences deboarding behaviour.

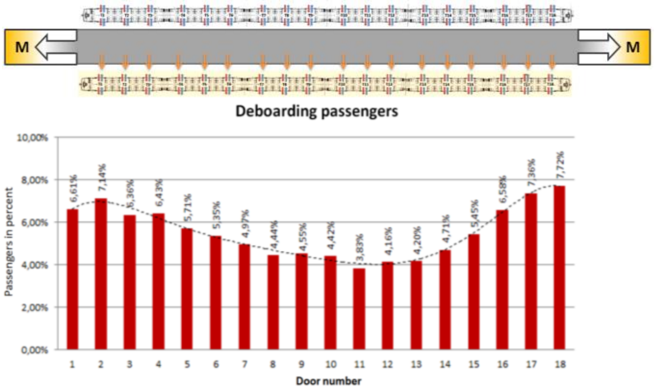

Fig.3. Distribution of deboarding passengers with same platform change of trains between two underground lines (Eigner 2014)

If there is only one main exit and if this is placed in the middle of the platform and not at the end of the platform, there is already a much better passenger distribution (see Fig. 4).

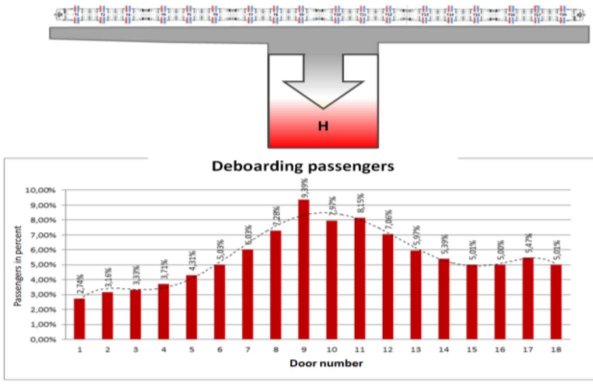

Fig.4. Distribution of the deboarding passengers with a centrally arranged main exit (Eigner 2014)

Fig. 5 shows a comparison of different types of platforms with regard to the exits and their effect on the degree of overcrowding in terms of deboarding passengers at the most frequented door, the so-called "critical door". The factor 1 means the ideal condition when all doors are evenly used to capacity.

The lower the "overcrowding factor", the more uniformly the doors are occupied and the lower the negative influence on hold time due to uneven passenger distributions. The case with a same platform transfer to another underground line with an additional two exits with moderately heavy use shows the lowest level of overcrowding. Good values are further achieved when the main exits are centrally arranged on the platform or if they are divided into two exits but also not at the platform end. The worst distribution values and thus the highest values for overcrowding at the critical door are obtained if the main exit is at the end of the platform or there is only one exit at all at the end of the platform.

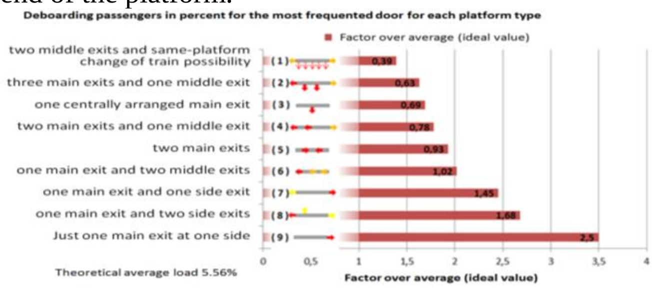

Fig.5. Comparison of the most frequented door per platform type (Eigner 2014)

3. PASSENGER DISTRIBUTION OF BOARDING PASSENGERS

If passengers have sufficient time before the arrival of the train and if they are local and system-knowledgeable as well, they usually go to the area where they expect the nearest exit at the destination station.

In the following cases, passengers do not however use the boarding door depending on the nearest exit at the arrival station. Passengers who are location or system-knowledgeable are most likely to choose those doors which are close to the platform entrance that they have used.

In the event of overloading at a door, passengers in part switch to nearby doors. Whereby, as a rule only the two adjacent doors to the left or right are chosen. This also only happens when passengers are boarding or deboarding at those doors and it is thereby ensured that by switching to the nearby doors they do not in the end miss the train. Otherwise, they wait at the overloaded door until boarding is possible.

In the end, there are still those people who reach the platform only when the passenger exchange is already in process. In the case of railway long-distance transport, the stopover can take several minutes, in which case travellers often go to the desired door. The fact that the train is already at the platform causes many passengers have an uneasy feeling that the train is about to depart. These passengers board the train early and move on through train.

In local transport, especially in urban local transport, hold times are limited to a possible minimum. Here, the fact that a train is already at the platform means that after reaching the platform, the train is boarded according to the shortest way to the train. This usually happens at each door which can best be reached from the platform entrance. In particular, those people who reach the platform after an already completed passenger exchange and still want to reach the train quickly, select that door which can most quickly be reached from the entrance without any further changes of direction.

The above mentioned circumstances mean that in addition to a noticeable correlation between deboarding passengers and the proximity to the exit in the destination station, there is also an accumulation of boarding passengers near the entrances. Because of those people who enter the train at the last moment before or during the servicing of the train, there are also load peaks from boarding passengers especially at the doors which can best be reached from the platform entrance.

Fig. 6 illustrates in this regard the distribution of passengers along a platform depending on platform entrances. In the specific case, an example is visualized in which there is a main entrance (H) and two middle entrances (M).

Likewise, from the same figure the influence of the architectural infrastructure on passenger distribution is shown. To the right of the main entrance there are regularly spaced columns on the platform. It can be seen that in this area despite a platform width similar to the area to the left of the main entrance, on average 50% to 80% fewer passengers are waiting per door than in the area to the left. Furthermore, it can be seen that as the platform width increases in an otherwise comparable situation (regularly spaced columns), the number of passengers per door increases again.

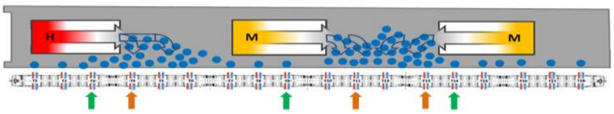

Fig.6. Passenger flow depending on the access situation (Eigner 2014)

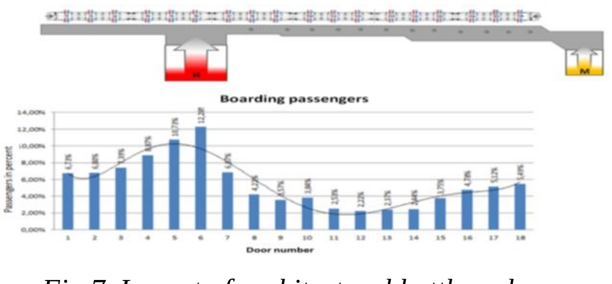

Fig.7. Impact of architectural bottlenecks on passenger distribution on the platform (Eigner 2014)

Fig. 7 illustrates the peaks at the most reachable door from the main entrance (H), (door 4 from the left).

4. FURTHER CONTRIBUTING FACTORS TO THE PASSENGER DISTRIBUTION

In addition to the entrances and exits as well as different platform widths or fixtures such as columns (see above), there are other contributing factors that influence passenger distribution along a platform.

An accumulation of waiting passengers can be found in information areas on the platform such as information monitors but also news and advertising screens behind the platforms. There is also a general accumulation by seating areas. It can be observed here, however, that the age distribution of seated passengers depends on the distance to the main entrance. It should be noted that seating areas closer to a main entrance tend to be used by older passengers and in comparison seating areas that are farther away are more often used by younger passengers (see Fig. 8). This suggests that elderly people on the platform are more likely to remain close to the entrance because of the shorter distance.

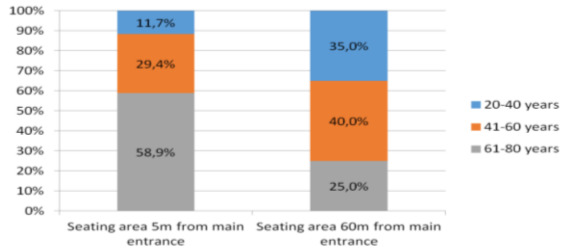

Fig.8. Age distribution of seated passengers - distance to the main entrance (Delac 2015)

Furthermore, the investigation shows that the seating areas along a platform are evenly occupied even if the passenger occupancy along the platform is in part highly varied. This means that passengers will also go to less occupied areas of the platform if free seats can still be found there. These observations, however, are based on inner-city suburban railways, where slightly longer waiting times are expected compared to the underground.

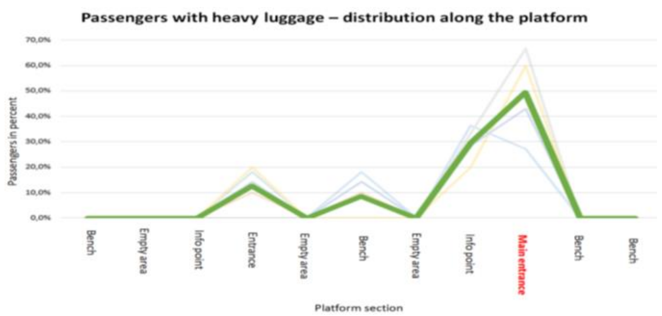

Fig.9. Distribution of passengers with heavy luggage along the platform (Delac 2015)

Passengers with heavy luggage, who are often not local or system-knowledgeable (e.g. tourists), are often located with above average frequency in the immediate vicinity of the platform entrance, which leads to the conclusion that because of the luggage they would like to cover the shortest distance possible (See Fig. 9).

5. CONCLUSION

Significant influences on operating procedures can ultimately be passengers who are waiting on the platform and unevenly distributed along the entire platform. Particularly with urban transport networks such as undergrounds, it is shown that the overwhelming majority of passengers are local and system-knowledgeable and already when boarding use that door by which when deboarding they expect to find the shortest path. This behaviour is only suspended if the time until the departure of the train is no longer sufficient to go to the desired door or if people are not local or system-knowledgeable. Likewise, there are influences from infrastructure facilities such as information areas and seating areas which tend to lead to an accumulation of waiting passengers. However, the most pronounced influencing factor is the deboarding behaviour of passengers.

Along transport lines, in planning concerning this matter, it should be considered that on each platform there are at least two exits which do not lie exactly at the respective ends. Exits with the widest possible design approximately at quarter points on the platform or at third points with additional exits on the platforms lead to a relatively even distribution of passengers.

Along a line, it should as well be ensured that the exits do not lie precisely at the same places at all stations, above all those with a high passenger volume. A slight variation in the position of the exits along a line in the progressing stations inevitably results in a significantly more balanced passenger distribution along the platform with significantly shorter hold times. This is an advantage not only for punctual and smooth operation but also with regard to energy consumption, because avoiding regular delays must not be achieved through reducing the respective possible maximum speeds.

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TRACK ALIGNMENT PARAMETERS ON MODERN RAILWAY LINES FOR MIXED TRAFFIC

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Milica VILOTIJEVIĆ[3]
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Abstract *– One of the most important parameters of the horizontal railway alignment is horizontal curve radius including the shape of transition curve and superelevation ramp. In case of mixed traffic railway lines, the choice of radius has to ensure a comfortable ride of passenger vehicles, safe freight transport and acceptable maintenance costs of vehicle wheels and railway infrastructure. Paper presents the experience in design of horizontal railway alignment for modern railway lines. Furthermore, paper presents theoretical analysis of cant deficiency and provides recommendations for design of track alignment according to European standard EN 13803:2017 and current practices. The main goal of this paper is to provide basis for harmonisation and advancement of national technical regulations for design of modern railway lines for mixed traffic.*

Keywords – railway infrastructure, design, horizontal curve radius, cant deficiency, cant excess.

1. INTRODUCTION

European standard EN 13803 [1] defines alignment parameters for new and reconstructed railway lines according to maximum train speed. This standard applies to nominal track gauge of 1435 mm and wider and speeds up to 360 km/h. Therefore, it covers both the speed range of conventional and high-speed railway lines.

The designer of railway line has to apply adequate values for track alignment parameters, considering the traffic safety and local conditions, as well as national technical regulations in accordance with the Infrastructure Manager preferences.

Standard EN 13803 defines six track alignment parameters, which are closely related to traffic safety: minimum radius of horizontal curve (R), cant (D), cant deficiency (I), uncompensated lateral acceleration (a_q), cant gradient (superelevation ramp - D/L) and speed (V). These parameters completely define railway curve alignment for the chosen design speed.

This paper presents theoretical analysis of cant deficiency and its impact to other parameters of track alignment. Furthermore, it provides recommendations for design of track alignment according to EN 13803, as well as the design experience from twelve high-speed railway line projects in Germany, France, Italy, Japan and Korea.

2. THEORETICAL ANALYSIS OF CANT DEFICIENCY

Railway vehicle is subjected to centrifugal and gravitational acceleration during curve negotiation with speed V (Figure 1). Difference between components of these accelerations that are parallel to the vehicle floor determine uncompensated lateral acceleration in accordance to equation (1).

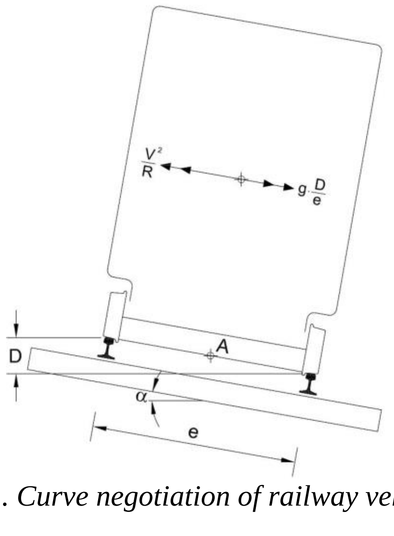

Fig.1. Curve negotiation of railway vehicle

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$$a_q = \frac{V^2}{R} - g \cdot \frac{D}{e} \tag{1}$$

Cant value for which a_q=0 is equilibrium cant and it is defined with equation (2).

$$D_{eq} = 11.8 \cdot \frac{V^2}{R} [mm] \ , V \rightarrow \left[\frac{km}{h}\right], R \rightarrow [m] \tag{2}$$

In the case of mixed traffic railway, changing the speed of passenger trains in equation (2) gives cant value, which is larger than equilibrium cant for freight trains. On the other hand, changing the speed of freight trains in equation (2) gives cant value, which is lower than equilibrium cant for passenger trains. Therefore, designer has to consider relation between maximum speed of passenger trains and permissible minimum speed of freight trains.

Considering equation (2) and the previous statement, it follows:

$$D + I_{lim} = 11.8 \cdot \frac{V_{max}^2}{R} \tag{3}$$

where D is designed cant, I_{lim} is the limit value of cant deficiency and V_{max} is the maximum speed of passenger trains. Furthermore, equation (4) defines minimum radius of horizontal curve for a given maximum speed:

$$R_{min} = 11.8 \cdot \frac{V_{max}^2}{D_{max} + I_{lim}} \tag{4}$$

where D_{max} is prescribed maximum cant value, which equals 160 mm according to [1]. In addition, standard EN 13803 defines exceptional cant value, which equals 180 mm. However, values larger than 160 mm can cause freight load displacement and passenger discomfort when the train stops in such track or runs with low speed [1]. Infrastructure Manager (IM) has to consider maintenance strategy and rolling stock requirements when prescribing of the maximum cant.

Furthermore, standard [1] defines 153 mm as a limit value of cant deficiency for speeds up to 300 km/h. It should be noted that in previous version of this standard limit value was 130 mm [2]. This value was increased in new version of this standard according to the experience on the European railway network. For speeds above 300 km/h, standard defines 100 mm as a limit value of cant deficiency [1].

Common practice on European railway network is to apply different cant deficiency limits to different categories of trains. For example, maximum cant deficiency in France could be 80 mm (for speeds above 300 km/h), 130 mm (for mixed traffic and conventional speed) and 160 mm (for most passenger trains). Additionally, each railway vehicle should be tested and approved in conditions covering its own range of operating cant deficiency according to the procedures defined in EN 14363 [3]. Therefore, IM has to consider train categories (speeds), track type (conventional or slab track) and local conditions (crosswind) when prescribing the maximum cant deficiency. It should be noted that high values of cant deficiency are related to the passenger discomfort.

Prescribed value of cant deficiency directly influences minimum radius of horizontal curve for a given speed, as defined by equation (4). Figure 2 shows the relation between minimum radius of horizontal curve and maximum speed for different values of cant deficiency (assuming D_{max}=150 mm as prescribed for Serbian railway network).

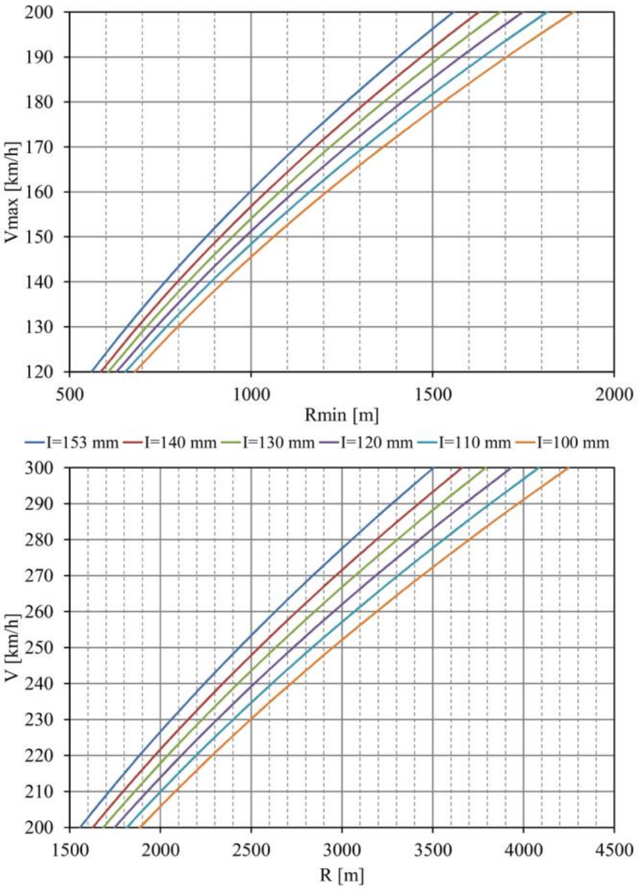

Fig.2. Relation between minimum radius of horizontal curve and maximum speed

As it is shown in Figure 2, increasing the maximum cant deficiency leads to decrease in the minimum radius of horizontal curve. This relation is more noticeable in the speed range between 200 km/h and 300 km/h. For example, depending on the applied cant deficiency, minimum radius could vary between:

- 1000 m and 1200 m for V_{max}=160 km/h,
- 1550 m and 1900 m for V_{max}=200 km/h, and
- 3500 m and 4250 m for V_{max}=300 km/h.

3. RELATION BETWEEN CANT DEFICIENCY AND PASSENGER COMFORT

Methods for measurement and evaluation of ride comfort for passengers are defined in standard EN 12299 [4]. These methods imply determination of lateral acceleration inside the vehicle, which is experienced by the passengers. This acceleration is larger than the one defined with equation (1) and it can expresed with equation (5):

$$a_i = (1 + s_r) \cdot a_q \tag{5}$$

where a_i is uncompensated lateral acceleration inside the vehicle (parallel to the vehicle floor) and s_r is coefficient of roll flexibility that depends on the vehicle characteristics (usually between 0.2 and 0.4). Permissible value of a_i depends on the train type and could be up to 1.0 m/s^2 or more according to the current practice [5].

According to equation (1), a_q strictly depends on the *V/R* ratio. On the other hand, equation (4) and Figure 2 shows that the increase of cant deficiency leads to the decrease of minimum curve radius for a given speed, thus increasing *V/R* ratio and uncompensated lateral acceleration. Figure 3 shows the influence of cant deficiency to uncompensated lateral acceleration in minimum radius curve.

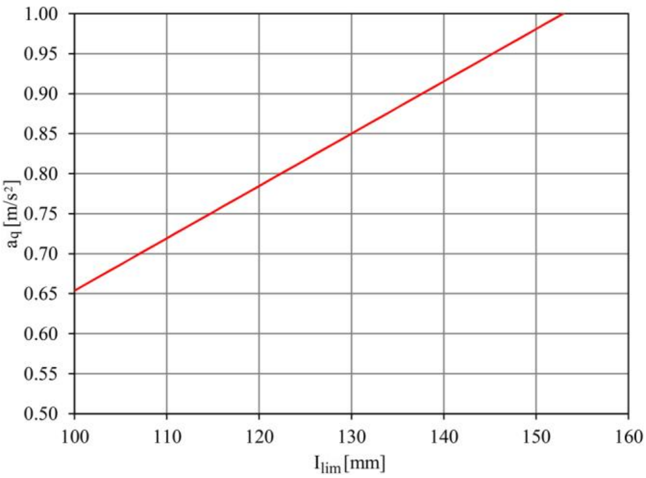

Fig.3. Relation between cant deficiency and uncompensated lateral acceleration based on eq. (1)

Correlation between cant deficiency and uncompensated lateral acceleration (Figure 3) is independent of the speed and it could be approximated with simple linear regression. Calculated values of uncompensated lateral acceleration in minimum radius curve, which are presented in Figure 3, correspond to the limit values that are commonly applied on the European railway network.

4. RELATION BETWEEN CANT DEFICIENCY AND CANT EXCESS

Considerations presented in Chapter 2 and 3 relate to the maximum vehicle speed. In the case of mixed traffic railway lines, this speed reffers to the maximum speed of passenger trains. Therefore, cant designed according to equation (3) would be larger than equilibrium cant for freight trains. Speed of freight trains mainly depends on maximum railway gradient and vehicle characteristics. The difference between these two cant values is referred to as cant excess and is defined with equation (6):

$$D - E = 11.8 \cdot \frac{V_{min}^2}{R} \tag{6}$$

where E is the value of cant deficiency and V_{min} is the minimum operating speed of freight trains.

Large values of cant excess directly increase track maintenance costs and could lead to the vehicle derailment and overturning. Limit value of cant excess is 110 mm according to [1].

Figure 4 shows the relation between cant excess in minimum radius curve (assumed freight train speed equals 80 km/h) and design speed (maximum speed of passenger train).

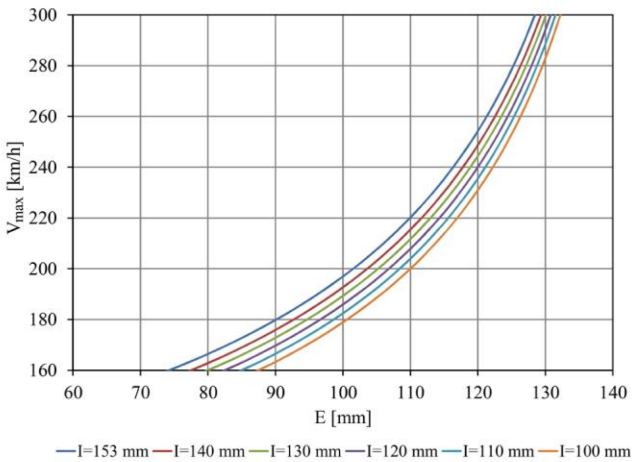

Fig.4. Relation between cant excess in minimum radius curve and design speed

Figure 4 shows that cant excess limit value (110 mm) is exceeded for design speed above 200 km/h. Therefore, design of mixed traffic railway lines for speed between 200 km/h and 300 km/h demands increase of minimum curve radius and minimum speed, which could be performed by reducing maximum cant value and limit value of cant deficiency.

5. TRACK ALIGNMENT PARAMETERS – EXPERIENCE FROM HIGH-SPEED RAILWAY PROJECTS

According to [6], Table 1 presents applied track alignment parameters on 12 railway lines (column 1) with design speed larger than 220 km/h (columns 3-6), as well as the assessment of other parameters (columns 7-9). In addition, column 2 shows traffic type on these railway lines.

Tab.1. Applied track alignment parameters on 12 high-speed railway lines [6]

Railway line	Traffic type	V_{max} [km/h]	D_{max} [mm]	I_{lim} [mm]	R_{min} [m]	$R_{min,calc}$ [m]	$a_{q,calc}$ [m/s^2]	E_{calc} [mm]
Manheim - Stuttgart	P+F	250	90	55	5100	5087	0.36	78
Hanover - Würzburg	P+F	250	90	55	5100	5087	0.36	78
Cologne - Frankfurt	P	300	170	150	3350	3319	0.96	-
Paris - Lyon	P (+F)	270	190	35	4000	3824	0.16	173
Paris - Le Mans	P (+F)	300	150	27	6000	6000	0.18	136
Rome - Florence	P+F	250	125	120	3000	3011	0.79	106
Tokyo - Osaka	P	220	180	60	2500	2380	0.32	-
Osaka - Okayama	P	260	180	30	4000	3799	0.13	-
Okayama - Hakata	P	260	180	30	4000	3799	0.13	-
Omiya - Niigata	P	260	155	45	4000	3989	0.29	-
Omiya - Morioka	P	260	155	45	4000	3989	0.29	-
Seoul - Busan	P	300	130	65	7000	5447	0.14	-

As it could be observed in Table 1, five projects were designed with maximum cant above 160 mm. However, these projects implied railway lines for passenger traffic only. Furthermore, railway line Cologne - Frankfurt has significanlty larger uncompensated lateral acceleration in mimimum radius curve comparing to other projects. It should be noted that IM in France considers the possibility of freight trains running on presented railway lines [6], but calculated cant excess shows that this would not be recommended.

Although three projects of mixed-traffic railway lines (grey rows in Table 1) were designed for the same speed, there is a significant difference between applied maximum cant value and limit value of cant deficiency. This shows that there are differences between decisions made by different IMs in Europe.

6. CONCLUSION

Design of mixed traffic railway lines is a very complex task from the aspect of horizontal and vertical alignment determination. Chosen parameters have to ensure safety for all vehicle types. In addition, it is necessary to ensure ride comfort for passenger trains. Meeting these requirements implies restriction of minimum and maximum speeds for passenger and freight trains.

European standard EN 13803 [1] prescribe limit values for parameters of horizontal and vertical alignment. However, Infrastructure Manager has to define limit values for above-mentioned parameters in national regulations according to the adopted railway maintenance strategy.

ACKNOWLEDGEMENT

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THE TECHNICAL METHODS FOR BUILDING OF SOFIA METROPOLITAN

Stoyna KOSTOVA [1]

***Abstract** – The construction of tunnels is responsible and challenging engineering task. The specialists have to overcome various obstacles associated with geological characteristics of the terrain,water level, under rivers, available buildings, structures, roads and comunication on the surface, with the available equipment. And all this can be done within the prescribed period, and of course, a guarantee for safe and reliable operation. Article consider methods used for building of metro in Sofia. During the building of metro in Sofia are implemented and applied four methods of construction: classical open pit – method, Milanese method, shield method and new Austrian Tunneling Method. The main features of these difrent methods is shown. The used geothechnical structures are presented. The consruction pecularities of tunneling is given. The technological order of building diferent tunnels is shown. The advantages or disadvantages of used methods depending on existing conditions are highlighted. Analise of diferent methods and teir implementation according to the geotechnical conditions are given.*

Keywords – metropolitan, city railway, tunnel, Milanese, open pit, top down, shield methods.

1. INTRODUCTION

Seventy percent of the European population lives in cities and urban areas. Cities are economic, social and cultural centers of European countries.

Europe has only a small number of very large metropolitan regions, such as London, Paris, Prague, Moscow. Most of the urban areas contain between 500,000 and 4 million people.

The construction of tunnels is responsible and difficult engineering task. The experts have to overcome different obstacles connected with geological conditions of the terrain, water level, buildings and transport infrastructure on the surface. They used modern methods and machines. And metropolitan can be done within the prescribed period, and of course, a guarantee for safe operation.

The first decision for building of some underground transport in Bulgaria was occurred in 1968, when the Sofia had 600,000 habitants. The researches have begun and after that in 1972, has been accepted a technical-economic report on metropolitan construction. The municipality aproves the metro scheme (Fig. 1).

The building of first metro diameter started in 1979, according to government decision and documents.

The first metro stations were built between 1979-1991. They are "Liulin" and "Vardar" stations.

The Republic of Bulgaria became a member of the European Union on 01.01.2007. Since then, the construction of metro has begun to develop with fast steps.

Fig.1. One of the first schemes of the Sofia metro, 1981

As it seen in (Fig.1) and (Fig.2) the current metro lines are nearly the same directions as in the first scheme.

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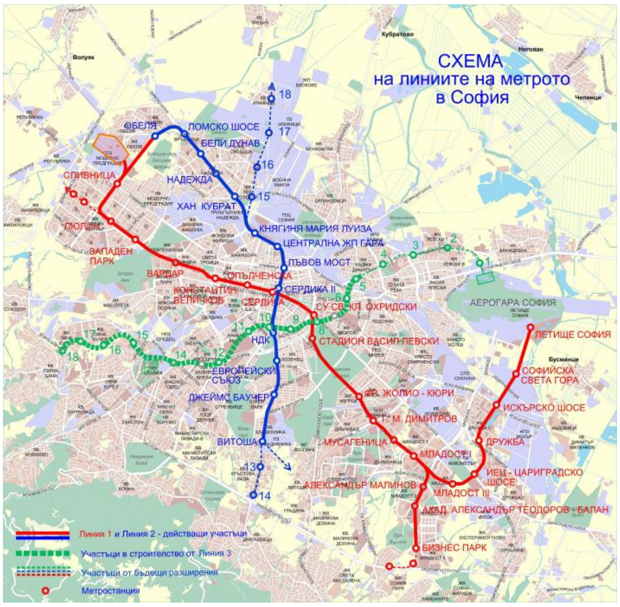

Fig.2. Current scheme of the Sofia metro in 2018 (Metro Line 1 is in red color, Metro Line 2 is in blue color, dashed line in blue shows a section under construction)

In (Fig. 2) are shown metro diameters which are built till now. Metro diameter 1 is in the direction Southeast - Northwest. The construction started in the 1979. It has a total 23 stations and a length of 28 km in 2015.

Metro diameter 2 is in the direction South – Northwest. The construction starts in 1980. The first stations and a part of tunnels were constructed during the building of the National Palace of culture.

Metro Line 3 will be from the Northeast to Southwest - in green color. The construction of the line started in 2015. Until now, metro in Sofia has two lines, length of 39 km and 34 stations [1].

2. MERTHODS FOR BUILDING OF SOFIA METROPOLITAN

The construction of metropolitan is responsible and complex task.

During the building of the metro in Sofia were implemented and applied four methods of construction as follows.

2.1. Classical open pit - method

This method can be performed in two variants - with or without reinforcements of the lateral sides.

a) Opened trenches /pits/ with slopes without reinforcements

When there are no buildings near the metro route, or there are open spaces, it is possible to excavate open trenches with sloping sides.

The stages of excavation is shown in (Fig. 3 a). After digging the trench or pit, the building of structure for the metro tunnels and stations start. The foundations and structures were made general from reinforced concrete. They build most stations from the first metro diameter with sloped trench /pit/. The inclinations of slopes are according the soil type. That slopes are not fortified. After making, the surrounding structure and upper plate, begins the backfilling (Fig. 3 c). This method is very simple.

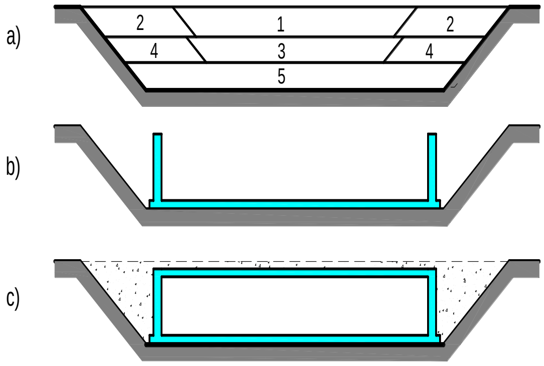

Fig.3. Technological sequence of construction - classical method:

a) stages of excavation, b) building of structure, and c) backfilling

b) Opened trenches /pits/ with reinforcement

Structure of tunnels is built in the fortified trenches. In some cases, the side supporting structure is a part of the strtructure of station.In some cases were built separate internal supporting structure.

Fig.4. “Berlin wall” – Metal column whit wooden wall used to fortify the trenches.

The supporting structure can be metal sheet wall (Fig.5) wooden wall, reinforced concrete diaphragm wall, or pile wall. The distance between piles varies depends on soil characteristic. The wooden walls are strengthened whit metal columns and beams so-called “Berlin wall” (Fig. 4). From the beginning, they imbedded metal columns - 2T. After that, excavate the first level and put the wooden boards to prevent the soil fall. Then going down and digging the second level and put the wooden boards and the next level and so on.

To prevent from higher water level in the excavated pit, were used metal sheet walls or diaphragms. In some cases water level can be decreased by water pumps.

The arm packet has to be in the hole before concreting. In Figure 5 is shown concreting of the tunnel plate. To fortify the sheet metal walls are used metal beams between two sides of metal walls. Instead of metal beams, in bigger distances, between metal sheets, to fortify them are applied anchors behind them. Metal sheet walls support lateral soil.

Fig.5. Tunnel in "Youth" complexe

Using opened trenches with reinforcement were built from the first metro area Sq. St. "Nedelya" to residential complex "Lyulin" and some stations from Sq. St. "Nedelya" to residential complex "Youth". This method is applied in the part of the stations of the second metro diameter – "Central Railway Station ", in front of the National Palace of Culture and others.

Diaphragm walls are mainly applied for strengthening, the stations. Pile walls are used for a few stations.

2.2. Milanese method

This method applies when you need faster recovery the surface over the metro. The technological sequence of construction is as follows: at the direction of the walls of the structure of stations and tunnels build diaphragm walls, without developped a pit.

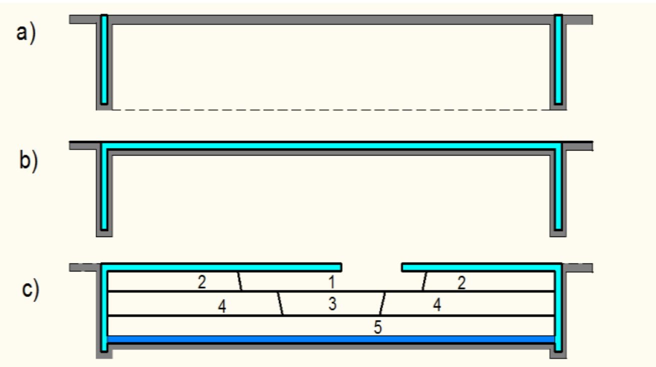

Fig.6.Technological sequence of construction - Milanese method:
a) diaphragm walls; b) building construction;
c) stages of excavation.

The diaphragm walls are built in soil before any excavations (Fig 6a). At first made holes in soil by special digging machines for diaphragm walls. Bentonite clayey-soil solution is used to protect the soil sides of diaphragm walls from destroying. The bentonite suspension is calculated in advance and produced on place. In the holes are descended previously prepared arm-packet and start to concrete the wall. These diaphragm walls are used for the external walls of the structure of the station or tunnels. The upper plate of the tunnels or metro stations is built on the diaphragm walls. (Fig. 6b).

After compleating the top plate the zone is filled and the transport trafic is restored. The next step is to carry out excavation work under the protection of top plate and other bearing elements of the structures (Fig 6c). In Figure 7, the anchors reinforcement of 22 m height four row anchored diaphragm wall providing 10 m of free space for work is shown.

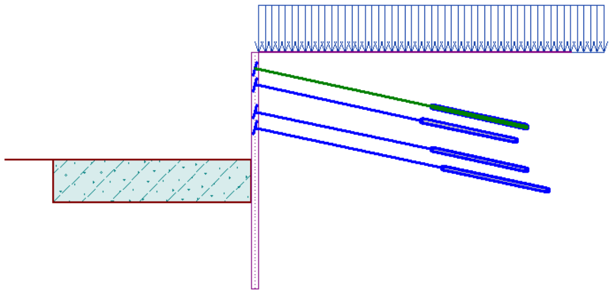

Fig.7. Scheme of diaphragm wall

This method was used in the construction of the "Joliot Curie" and "GM Dimitrov" stations and part of the tunnels nearly of these stations in Sofia. On the second metro diameter in order to minimize the time for stopping or restricting traffic on major streets, this method is applied to the stations: "Maria Louisa", "Central Railway Station" and "James Boucher" under the bulevard Bleack peak".

2.3. Shield method

Mechanized shield method is applied for building of tunnels in dificult geological conditions and in cental part of the city.

Because of archaeological finds in Sofia and considerable length of the tunnels, TBM (Tunnel-Boring Machine) were used. This method is based on a mechanized excavation of soil by a steel cylinder called shield. The tunnel parts are installed under the protection of this cylinder. Tunnels are made from prefabricated arch parts. Al this parts make a cilindrical form of the tunnel (Fig.8). The machine moves by system hydraulic jacks. The jacks are stepped on the ready tunnel arches.

Shape of the cross section of the shield corresponds to the lining of the tunnel and may be circular, rectangular, arched or elliptical. Circular shield was used in Sofia - metro.

Fig.8. Tunnel made form tunnel boring machine

a)Tunnel-boring machine (TBM)

In Bulgaria, Tunnel-boring machines (TBM) were used for digging the tunnel of the second metro line in Sofia (Fig.9). The tunnel has two lines with internal diameter of 8.43 m. Archaeological layer is located at a depth of 7 m, and this method allows the metro-tunnel lays under it. The project was completed on time, despite aggressive high groundwater and complex geology, all in combination with intensive traffic in central Sofia boulevards.

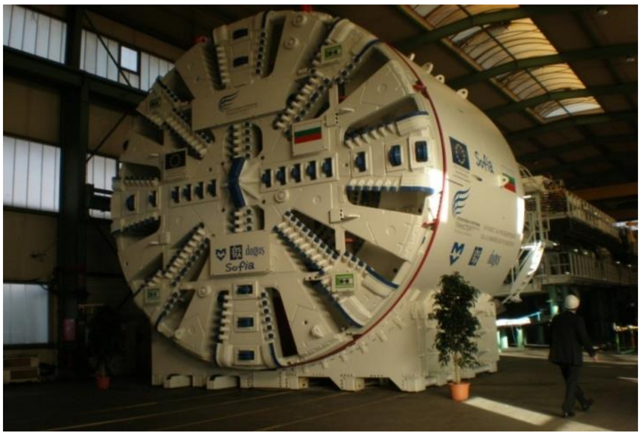

Fig.9. One of Tunnel-boring machine (TBM)

Due to the significant depth of the tunnels, this method was applied to the section between "Sq. St. Nedelya" and the "Vasil Levski" Stadium as well as the "Road junction Nadezhda - street Han Asparuh" section before Patriarch Evtimii Blvd. Due to the location of tunnels below the groundwater, shields with hydraulic camera are provided. The hidraulic pressure from the shield is bigger than the existing surrounding pressure. This allows to prevent the ground above tunnels and lying over their buildings from collisions. The last TBM for the third line are working by now. The diameter of this machine is 9.40 m for two - way in the tunnel. At the end of July is finished about 77% of tunnels. The middle speed of digging is about 25 m/day.

2.4. New Austrian Tunneling Method

This method is effectively implemented in areas with significant dept and limited water flow. The tunnel is excavated in section (Fig.10). Tunnel can be fully excavated or partially excavated, depends on conditions and then reinforced it. The excavated part of tunnel is stabilised whith preliminary tunnel lining(shell) [2]. Lining can be efectued by reinforced shortcrete, with or whitout anchors. It can be done by special movable formwork. In the next stage the structure of the tunnel are made inside of the preliminary lining.

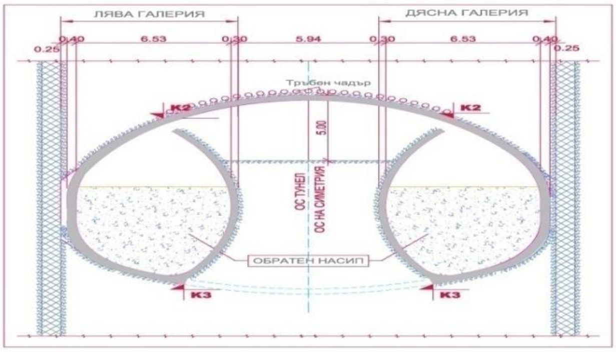

Fig.10. New Austrian Tunneling Method scheme

All railway tracks were designet with two - block reinforced concrete sleepers in rubber boots for reduction of vibrations [3].

The engineering and geological conditions in Sofia were very difficult, because of the higher water level, but the specialists are going thru all difficulties.

CONCLUSION

In the Metropolitan in Sofia, contemporary methods for building and contemporary machines and facilities were used. This article showed the peculiarities of the methods and existing conditions.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '18

ELECTRONIC INTERLOCKING

Dejan LUTOVAC [1]
Tatjana LUTOVAC[2]

Abstract – *This paper describes the* ***Electronic Interlocking - EI*** *system produced by Signalling & Control d.o.o., Belgrade. The system is developed, realized and tested in Serbia. It is verified and approved for use on Serbian Railways by the Directorate for Railways of the Republic of Serbia. EI is a computer system based on the PLC family - HiMax, produced by the German company HIMA Paul Hildebrandt GmbH, which has the highest safety integrity level - SIL4 in accordance with European railway standards - CENELEC. EI is a standardized, modular and scalable system practically independent from the track layout and the country of the application. The operational, functional and traffic requirements and safety principles of an interlocking system are converted to general interlocking software of EI. The track layout dependent data and particular interlocking requirements, which are usually presented in a form of a conventional control table are standardized and converted into a new form of the computer control table. This table is suitable for the application of formal proving methods and can be used as a simple data file for further computer processing. An advanced method of representing the layout of a railway station for HMI purposes in accordance to the standardized Catalogue of symbols of Serbian Railways is also described. The described approach allows a fast and efficient realisation of a railway station interlocking system and contribuites to the significant cost reduction of the complete interlocking system.*

Keywords - Railway interlocking system, railway signalling, safety integrity level 4, safety critical software, safety analysis, control table, availability and maintainability.

1. INTRODUCTION

A railway interlocking system controls the traffic in a railway station, and between adjacent stations. The control includes train routes, shunting moves and the movements of all other railway vehicles in accordance with railway rules, regulations and technological processes required for the operation of the railway station [1]. It gives the authority for moves through the station areas and defines the route and the speed of the move in every particular situation. Hence, it is of paramount importance for the safety and security of the railway traffic for every railway administration [2].

EI is developed and realized on the bases of world wide experience and know how of Serbian engineers [3]. EI system is produced by Signalling & Control d.o.o., Belgrade and approved for use in Serbia.

EI system is a HIMA, HiMax and HiMatrix PLC, based controlling system of the highest safety integrity level - SIL4 in accordance with CENELEC European railway standards.

It is dedicated to cover all types of the railway stations and lines between the stations (automatic blocks or permissive inter-station dependency).

EI represents an economical system, which is very competitive to other Computer-based Interlocking - CBI systems, as well as, to the conventional Relay Interlocking – RI systems.

2. HARDWARE ARCHITECTURE

EI is realized as a modular and scalable system, which can cover all types of various stations track configurations and signalling arrangements, from simple (small) to very complex (large), for various country practices and various railway authorities [4]. Architecture of the system consists from five levels:

- **Level 1**: HMI - Operator console (single or duplicated for availability, typically SIL0.
- **Level 2**: Central safety controlling system (SIL4) realized with HIMA PLC family HiMax or HiMatrix (for small and simple interlocking systems, like simple crossing loops or mobile interlocking systems).
- **Level 3**: Safety controlling sub-systems (SIL4)

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realized with HIMA PLC family HiMatrix.

- **Level 4**: Interfaces for the control of signalling elements are realized as standardized modules (SM - signal module, PM - points module, DIM – digital input module, DOM – digital output module).
- **Level 5**: Signallling elements: signals, point machines, track circuits, axle counters, etc.

An example of EI for is presented in Figure 1.

Fig.1. EI - Prototype for Serbian Railways

2.1. HMI

HMI (Human Machine Interface) is an electronic system that allows the interactive communication between the operator and the central EI system.

Fig.2. HMI - Serbian Railways layout

The software package WinCC (Siemens) on the PC is used as a base for the realization of the HMI.

Communication with HiMax PLC is realized over the Ethernet using the HIMA XOPC server.

HMI is typically realized as a single SIL0 system and can be duplicated for the availability.

It can also be connected to other computer-based interlocking systems via appropriate communication protocols.

An advanced method of representing the layout of a railway station for HMI purposes is realized for EI. An exapmle is HMI layout presented in the previous picture that is realized in accordance to the standardized Catalogue of symbols of Serbian Railways.

2.2. Interface to the relay interlocking system

This subsystem is realized as an independent system that can be used with relay interlocking system or an other computer-based interlocking.

The same HMI operating console, with the appropriate communication protocol, uses for this purpose.

The HMI interface for relay interlocking system SpDrS64-JZ (Siemens), with Simatic S7 communication protocol and Simatic S7 PLC family (Siemens) is shown on the picture.

Fig.3.HMI Interface for RI for Serbian Railways

Directorate for Railways of the Republic of Serbia issued the permanent approval for use of the EMMI - Electronic Man Machine Interface on the Serbian Railways, I-01-1 No. 6/08, from 19.01.2009.y.

2.3. Central safety controlling system (SIL4)

Central computer controlling system is realized by use of the safety HIMA PLC family HiMax (SIL4), which is also highly reliable and highly available system.

Each safety module individually is realized in the safety architecture - "2 out of 2".

HiMax PLC for EI application is typically realized in the architecture - "2 times 2 out of 2" with hot swap-ability feature for the failed modules (worm replacement of the failed module).

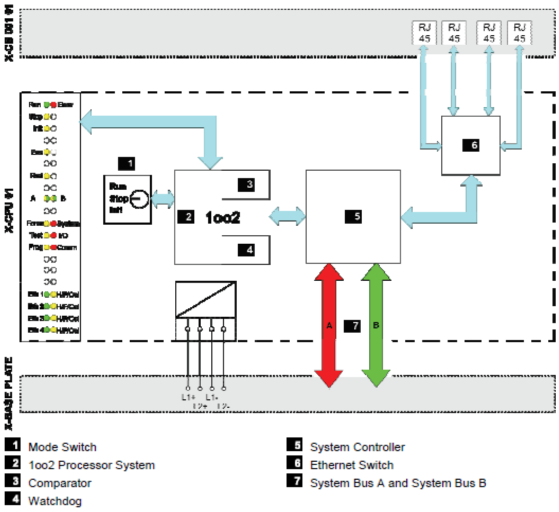

Fig.4.Safety structure of EI safety processors

2.4. Safety controlling sub-systems (SIL4)

Safety sub-systems of the EI are individual safety computer controlled systems, which are realized by use of the safety HIMA PLC family HiMatrix (SIL4):

- ELC – Electronic Level Crossing System
- EAC – Electronic Axle Counter System
- Electronic Interfaces

The sub-systems are typically connected to EI via Safe-Ethernet, but they can, also, be connected to the EI (or the other relay or computer-based interlockings) via DIO (hardware connection)

Fig.5. An Electronic Interface module for EI

2.5. Interfaces for control of signalling elements

Interface modules are realized as standardized functional modules such as basic functional modules:

- SM - signal module,
- PM - points module,
- DIM - digital input module,
- DOM - digital output module

and additional functional modules:

- EFL – Electronic Flasher,
- ECD – Electronic Current Detector,
- RM – Relay Interface,
- IP – Indication panel,
- GSM – SMS diagnostic,
- LPM – Lighting Protection,
- TERM – Electronic Thermostat,
- ETIM – Electronic Timer,
- EODT – Electronic Off-Delay Timer.

Fig.6. Electronic flashing module for EI

3. SOFTWARE

EI software is realized on the bases of the PhD dissertation of Dr. Dejan Lutovac: "Universal Computer-Based System for Railway Interlocking Control" [5].

Software is realized as an integrated package that contains all necessary data and functional modules.

It covers complete safety principles and functionality of the railway authority, independently of the station track layout.

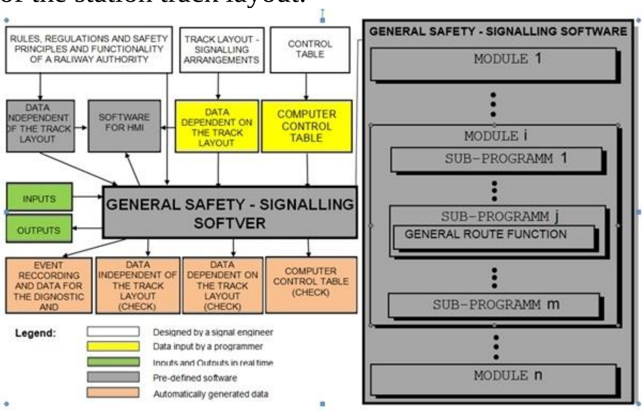

Fig.7. Structure of EI software

EI is a standardized, modular and scalable system practically independent from the track layout and the country of the application. The operational, functional and traffic requirements and safety principles of an interlocking system are converted to general interlocking software of EI. The track layout dependent data and particular interlocking requirements, which are usually presented in a form of a conventional control table are standardized and converted into a new form of the computer control table. This table is suitable for the application of formal proving methods and can be used as a simple data file for further computer processing.

4. MODULARITY AND SCALABILITY

EI is realized as a modular and scalable system and covers whole range of interlockings, from simple (small) to very complex (large).

Minimum configuration is: 10 modules inside a single housing (rack).

Maximum configuration is: 16 housings (racks) with total 288 modules.

Mixture of HiMax (SIL4) and HiMatrix (SIL4) depending on the requirements and complexity is possible.

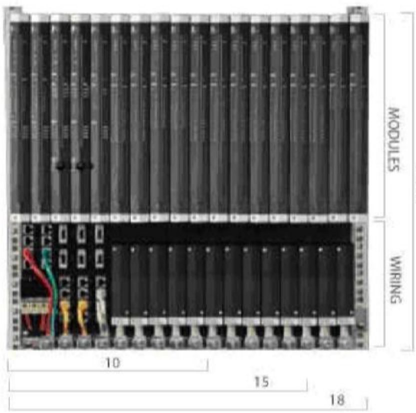

Fig.8. HiMax rack arrangement

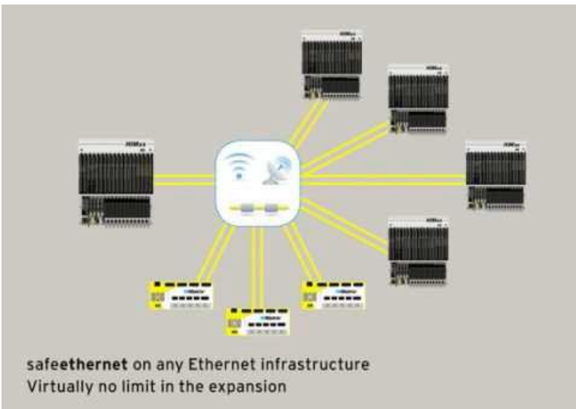

Fig.9. An example of EI mixed architecture

5. COMMUNICATION

EI communication is duplicated for the availability. Depending on the safety requirements, each communication channel is realized as:

- Ethernet (non-vital): HMI (SIL0) with HiMax (SIL4) or HiMatrix (SIL4), or
- Safe-Ethernet (vital): HiMax (SIL4) with HiMatrix (SIL4).

6. MSEI

MSEI - Mobile Simple Electronic Interlocking represents simplified Electronic Interlocking with dependencies between stations entrance signals and applicable principle of one entrance route at the time. Announcement of a train and replacement of the entrance signal after passage of the train is achieved via ERC - Electronic Rail Contacts (short track circuits).

MSEI is realized by HiMatrix HIMA PLC Family and other stated standard functional modules that are produced by the company Signalling & Control Ltd.

It is used instead of the station interlocking system during the reconstruction to provide safe entrances of the trains to the station. It is connected to the existing outside equipment via the existing cables from the equipment room, or uses new outside equipment with temporary cables.

7. CONCLUSION

The described way of realization of EI system allows a fast and efficient realisation of a railway station interlocking system and contribuites to the significant cost reduction of the complete interlocking system. Directorate for Railways of the Republic of Serbia issued the permanent approval for use of the EI on the Serbian Railways, I-01-1 No.: 340-142-3/2016, from 09.03.2016.y.

ACKNOWLEDGEMENT

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

ELECTRONIC HMI COMMAND TABLE FOR MEASURING POINT MACHINE FORCES

Dejan LUTOVAC[1]
Tatjana LUTOVAC[2]

***Abstract** – This paper describes **electronic** - computer based HMI equipment for the **measuring** and recording of the railway **point machine forces** - EPMFM (the retention force and the trailing resistance force) produced by Signalling & Control d.o.o,. Belgrade. The equipment is developed, realized, tested and implemented in Serbia and it is accepted for use by the expert commission of the Infrastructure of Serbian Railways a.d. (IZS). EPMFM is meant for measuring point machines' forces after reparations and before reinstallations on sight for IZS. Various types of point machines from different producers: Siemens AG - Germany, AZD - Praha and Sigma - Serbia, are analyzed and their features, in the view of detection and movement for the force mesuring purposes, are standardized and implemented in the functionality of the EPMFM. Force mesurements are based on the use of the certified and quality approved force sensor. The automatic calibration of the sensor, at the beginning phase of the each measurement process, is implemented in the application software of the EPMFM with the aim to reduce human activity and improve the accuracy of measuring. A modular design with standard industrial components of high quality is applied in the realization of the equipment in order to allow a higher reliability and easier maintenance.*

Keywords - Railway point machine, signaling interlocking system, force measurements and recording, test list, retention force, trailing force, reliability and maintainability.

1. INTRODUCTION

EPMFM is developed, realized, tested and implemented by the company "Signalling & Control" d.o.o,. Belgrade. The equipment ir ordered by the Infrastructure of Serbian Railways a.d. (IZS).

EPMFM is meant for measuring point machines' forces after reparations and before reinstallations on sight for IZS.

It represents an inovated solution for handling measuring and recording of the point machines forces, that is based on modern PLC based HMI system in communication with a standard personal computer - PC and useing PC operating system and application software (Microsoft Excel).

The basic requirements from the customer are fully implemented and extended in accordance with the ability of the new technology used. Also, user frendly interface with realtime graffics commands and indications are available to the operaters.

Real time grafics and final measuring lists, ready for printing and signing and verifying are available on the PC in the sprervisors room.

2. THE PURPOSE AND THE APPROACH

EPMFM is realized for the various types of point machines from different producers: Siemens AG - Germany (two types: S-400 and S-700 [1]), AZD - Praha [2] and Sigma, Subotica, Serbia (option) [3]. The relevant feature of the points machines are analyzed, in the view of detection and movement for the force mesuring purposes, are standardized and implemented in the functionality of the EPMFM.

In accordance with the applied approach, it is possible and easier to include additional point machines from different producers and extend functionality of the realized equipment.

Both hardware and software are realized using modularity and commercially available equipment. For the realization of the modules and their functionality, the knowledge in controlling and detecting points machines inside other railway signalling systems, like interlockings, are used. Hence, the hardware and software modules are simplified and standardized and main logic is placed at the HMI PLC.

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Communication between HMI PLC and PC works over the commercial Ethernet. The same real-time graphics are available to both, the operater at the measuring room and the supervisor at the PC room.

The measuring lists are generated and saved at the PC automatically. The supervisor can at the real-time monitor the measuring process and values and take appropriate actions. The saved lists are in the form that is ready for printing. Correctness of the measuring is also implemented automatically, i.e. the incorrect measuring lists are clearly marked with red and bold label "INCORRECT MEASURING".

3. ARCHITECTURE OF THE EPMFM

EPMFM cosists of three, functionally independent, main parts:

1. HMI command cabinet,
2. Electro-mechanical measuring equipment and
3. PC with a 27 inch monitor and a laser printer.

First two components are placed in the measuring room (working area) that has enough space in the aim to allow handling of balky and havy point machines. Layout of stated equipment at measuring room is presented on Figure 1.

PC, monitor and printer are situated at the other room in the same building - supervisors office (office area).

HMI is connected to the three fase isolated power supply with standard flexible power supply five wires cable. With the PC is connected via standard LAN cable and with Electro-mechanical part is connected with three aditional flexible cables (two standard power supply 5 wires cables and one separate cable for force sensor).

3.1. HMI command cabinet

HMI control cabinet represent the main part of the EPMFM equipment. IT contains HMI PLC with all necessary IO and communication module, module for measuring values related to three phase power supply with appropriate LED indications, safety protection switch and all other necessary interface equipment. Layout of the front panel of the cabinet is shown on Figure 2.

Complete controlling and monitoring equipment that is placed at the HMI command cabinet is high quality and commercially available. The cabinet has four whiles and it is connected with other parts with flexible cables in the aim to allow easy movement and positioning as required by the operator.

The HMI cabinet has two doors equipped with key locks, as a protection from the unauthorized access. The layout and arrangement of the equipment inside the HMI cabinet is presented on Figure 3.

Fig.1. Layout of the EPMFM in the measuring room

Fig.2. Layout of the front panel of EPMFM

Fig.3. Arrangement of EPMFM equipment

3.2. Electro-mechanical measuring equipment

Electromechanical measuring equipment is reused and refurbished the existing equipment that is used for an earlier designed force measuring table. It is designed as a mechanically enforced table, which contains the following:

- holder for placement of the point machine,
- three phase motor with a moving leaver and the brake for force simulation purposes (the trailing resistance force and the retention force) and
- moving leaver with the holder for the placement of the force measuring sensor.

This part originally had the interface group with the interface relays, circuit barkers, transformers, fuses and other interface equipment. The group is removed and replaced with the simple terminals. Its all former functionality is transferred into the HMI command cabinet. Hence, this part is significantly simplified.

3.3. PC equipment

PC equipment contains:

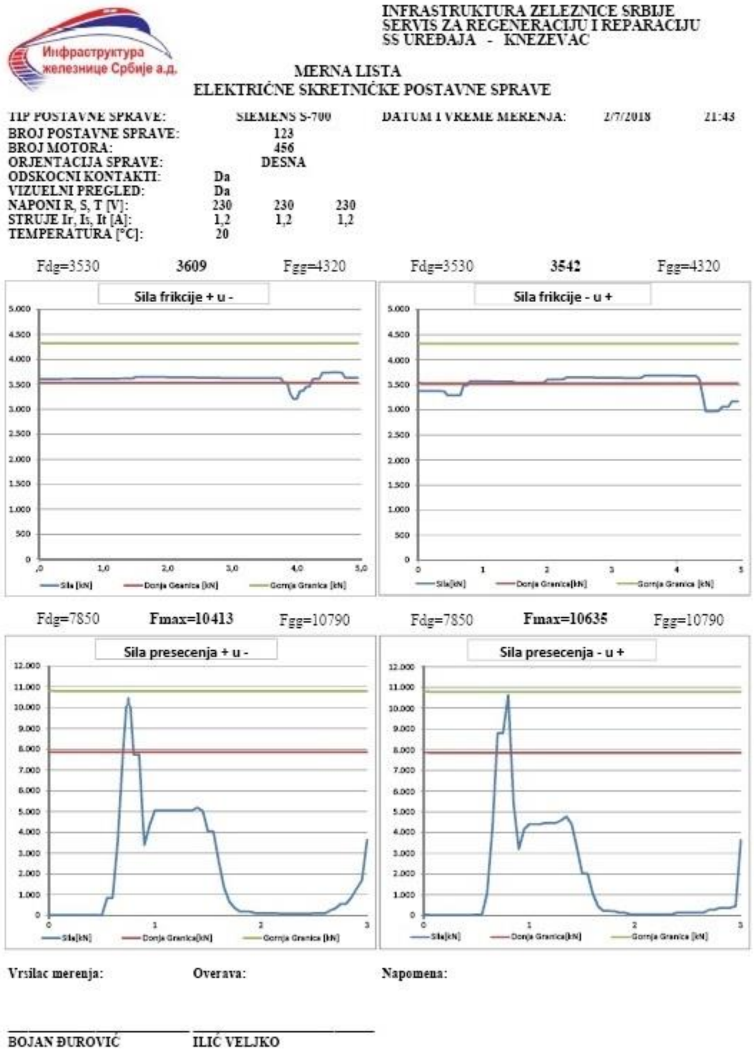
- High quality Desk-top PC with windows 10 operating system, standard communication software, Microsoft Excel program and commercial program for communication with HMI command PLC.
- 27 inches FHD monitor with fast response and
- HP A4 laser printer.

This equipment receives real-time data from HMI PLC during the measuring, automatically creates measuring list with graphics and all other necessary information and automatically saves the list with the time stamp after the measuring is finished.

The application software for measuring automatically recognizes correct or incorrect measuring and that data is transmitted to the PC software. Consequently, correct measuring lists are stored without labels and they are ready for the printing and signing and verifying. The lists with the incorrect measuring are clearly marked with a red and bold label "INCORRECT MEASURING". This allows use of these lists for correction of the adjustments of the point machines forces, but, helps in avoiding that an incorrect list get signed and issued. An example of the Measuring list is presented in Figure 4.

4. FUNCTIONALITY OF THE EPMFM

EPMFM is realized to cover the detection of the both left and right versions of the point machines, with the detection of the both end positions (normal and reverse) and automatic setup of the power supply phases for the for the direction of throwing.


Инфраструктура железнице Србије а.д.

INFRASTRUKTURA ZELEZNICE SRBIJE
SERVIS ZA REGENERACIJU I REPARACIJU
SS UREĐAJA - KNEZEVAC

MERNA LISTA
ELEKTRIČNE SKRETNIČKE POSTAVNE SPRAVE

TIP POSTAVNE SPRAVE:		SIEMENS S-700		DATUM I VREME MERENJA:	2/7/2018	21:43
BROJ POSTAVNE SPRAVE:		123				
BROJ MOTORA:		456				
ORJENTACIJA SPRAVE:		DESNA				
ODSKOCNI KONTAKTI:	Da					
VIZUELNI PREGLED:	Da					
NAPONI R, S, T [V]:	230	230	230			
STRUJE Ir, Is, It [A]:	1,2	1,2	1,2			
TEMPERATURA [°C]:	20					

Fdg=3530 3609 Fgg=4320 Fdg=3530 3542 Fgg=4320

Fdg=7850 Fmax=10413 Fgg=10790 Fdg=7850 Fmax=10635 Fgg=10790

Vrsilac merenja: Overava: Napomena:

BOJAN ĐUROVIĆ ILIĆ VELJKO

Fig.4. An example of the Measuring list

All general data are already implemented in the software. The data about the particular point machine have to be selected from the first interactive window on the HMI. The rest of the process is automatic.

Three modes of work are implemented: **manual** (separate movement of the point machine and the simulator), **half automatic** (four functions separately: the trailing resistance force for normal and reverse and the retention force from normal and reverse) and **fully automatic** (all four functions in consecutive order with the automatic creation of Measuring list).

For all measuring the equipment uses standard force sensor with the high precision < 1% for the range from 0 N to 10.000 N with the short overloading up to 50%. Conversion of the sensor signal to the force value is done by the commercial PLC module specially dedicated for that purpose.

A special feature is implemented to improve accuracy of the measuring and it is practically based on the reset of the measured force from the sensor to 0 immediately before each new measuring phase.

5. CONCLUSION

Realized EPMFM is a modern and automatic interactive measuring system with the real-time monitoring of the measuring and the automatic production of the measuring list.

The system is modular and open for the upgrades, so the new types of the points can be easily added.

ACKNOWLEDGEMENT

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LOCATION OPTIMALITY EVALUATION OF TRACK RADIO STATIONS IN SERBIAN RAILWAY NETWORK

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Goran DIMIĆ [3]
Ivan KOKIĆ [4]

Abstract *– The main goal of this paper is to present implementation railroad radio-station communication system in exploitation conditions. Installation of this system has been done during the reconstruction railway in location Rakovica –Resnik. For the purpose of this project is necessary to be done install a railroad radio-station for communication between the dispatcher BG train and the locomotive. One of the demands from costumer was that the base radio station needs to be implemented in the existing system and that meet with the required criteria for coverage of the railway by radio signaling 95% in the space and time. This paper presenting the comparison of the results obtained by calculations with results obtained by measurements made on the location. Parallel with comparison it will be done influence of the newly installed radio-station on the already existing system. This paper also shows solving prediction predicting the strength of the electric field which occur during project of implementation any radio-system.*

Keywords – Railway, radio station, installation, measurement.

1. INTRODUCTION

Locomotive Radio Dispatching System (LRDS) sheme is shown in Figure 1. is of great significance for security of railway transport and provides continuous duplex communication, by speech or coded commands, between moving locomotives and dispatching center, in the 460MHz (0,7 m) band. This system can integrate railway divisions for maintenance and arrangement services into one system. Also, it is open to public switched telephone network. The LRDS improves railway transport efficacy and is of great importance for security and safety of railway system. [1-4] The demand for multimedia communications, which operate with excessive speed using extremely large-sized wireless mobile community, has massively risen. [5, 6].

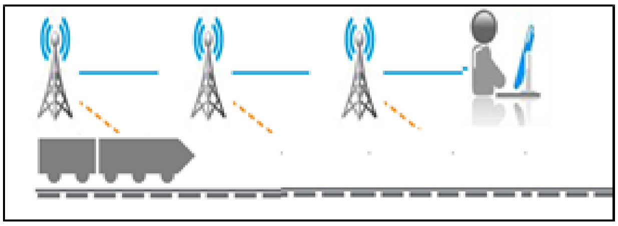

Fig.1. Functionality of Radio-Dispatcher System

The main goal of this paper is to present implementation railroad radio-station communication system in exploitation conditions. Installation of this system has been done during the reconstruction railway in location Rakovica –Resnik. [3] For the purpose of this project is necessary to be done install a railroad radio-station for communication between the dispatcher BG train and the locomotive. One of the demands from costumer was that the base radio station needs to be implemented in the existing system and that meet with the required criteria for coverage of the railway by radio signaling 95% in the space and time. [5,6]

For the needs of the railway reconstruction project in the section G -Rakovica-Resnik, it is necessary to implement the new radio-stations for the existing system in order to enable communication through the RD system in this part of the railway line, while meeting the required criteria for covering the railroad with a radio signal of 95% in space and time. In this paper we dealt with the comparison of the results obtained with theoretical calculations with actual measurements made on the ground. It will also be taken into account by measuring the impact of the newly installed radio station on an already existing system.

When designing any radio system, two basic

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problems are solved:

- Determination of the coverage area, which are the geographical zones in which the fixed radio transmitters provide sufficient strength of the electric field for the quality work of the radio receiver.
- Determination of the interference area, i.e. the minimum distance between radio transmitters operating on the same or adjacent radio channels with the permissible level of interference.

2. PROCEDURE FOR COVERING THE RADIO FIELD

As it is known from the theory of electromagnetic wave propagation, the magnitude of the electromagnetic field decreases according to the hyperbolic law by the distance of its source.

At a frequency band with of 0.7 m, it is not possible to achieve a homogeneous electromagnetic field. It could only be achieved in terms of optical visibility and in a space without reflections (Figure 2). However, due to the topography of the terrain, these conditions cannot be realized. In the case of a radio dispatch system, due to this reflection, is an important factor is that for the large number of sections they are the only way to make radio connections.

According to the laws of interference, there is a distribution of the field of maximum and minimum with a distance of about λ / 2, as can be seen in the finely explained flow of the hyperbolic propagation curve. When driving through this field, the antenna voltage changes depending on the field strength distribution. The difference between the maximum and the minimum field strength will be even greater if there is a higher proportion and number of reflections and can be up to +15 db. The range of a single station is thus limited to areas where the receiving voltage is greater than 1.9 V + 0.2 V, which is designated as a systemic range. (Figure 1).

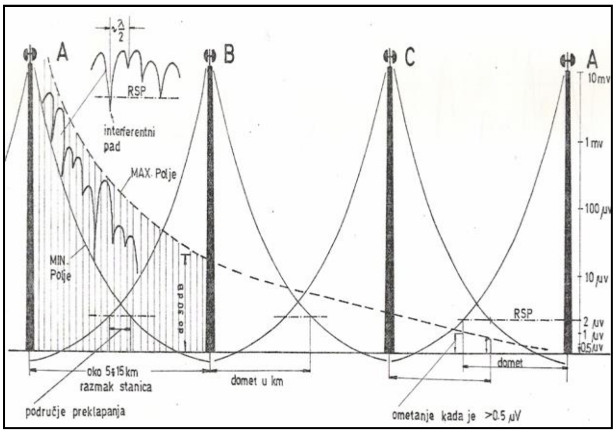

Fig.2. Procedure for covering the radio field

Theoretical calculations of the location of the radio stations are performed on the basis of the curves of the CCIR(ITU-R) for the UHF area.

Already after 35 km of probability by radio signal falls from 95% to 5%, and omissions in crossing the range, interference will occur in this area if the CCIR(ITU-R) protection value exceeding 8 dB is exceeded according to the minimum value of the useful signal. Based on this, it is only after 35 km that it will be possible to install a radio station with the same transmitting frequency.

In the area of one RD section, only three of the same shipping frequencies are used, f3, f2, f4, and again f3, f2, f4 etc. When locomotives go from the coverage area of a one radio station to the coverage area of the second, auto-switching the receiving frequency to the device in the locomotive. The receive frequency f1 is the same on all radio stations of one RD section.

For the purpose of project realization, it was necessary to determine the location for installing equipment, antenna pillar and the necessary infrastructure in order to get the coverage of the radio fields as good as possible. The total length of the track to be covered is L = 7,428 m.

Fig.3. Display of geographic locations

By analyzing the terrain and the distance between the endpoints, it has been found that this part of the track can be covered with just one location by placing the appropriate equipment (Figure 3).

The indicative position of the measured location of the antenna pillar would be in the coordinate point N: 44043'46.25; E: 20026'01.13 ".

Functioning of the system must be reliable with QoS marked as 95% coverage in space and time. Therefore, the radio field level, which depends on locations of antennas and radio waves reflection patterns, must exceed the requested value 1,9 μV + 0,2 μV throughout the coverage area, making the issue of antenna locations very important. We assume that the antenna locations include directions of radio beams, i.e. azimuth and elevation, as main factors of radio coverage. Hence, the optimality of location includes the optimality of radio beam azimuth.

3. THEORETICAL DETERMINATION OF THE LOCATION

For the preliminary and theoretical measurement, the Radio Mobile software is used, in which the necessary parameters are entered. First, the values of the base radio station are defined, such as the output power, the characteristics of the antenna system (height, amount of antenna and characteristics of the antenna itself), location as the angle of the antenna orientation, which is determined in relation to the endpoint for the necessary direction.

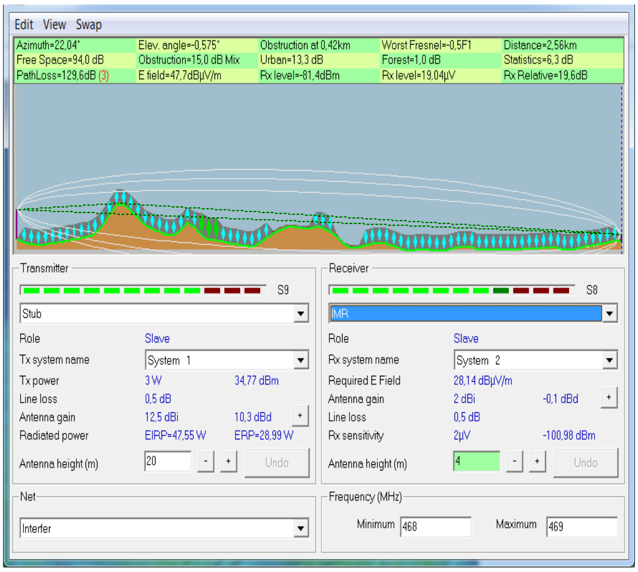

Fig.4. View the look of the measurement software with the results and the given parameters from the proposed location to Rakovica

Then, a mobile radio station (a radio station located in a locomotive) is defined, which we will call System 2. For measurement in multiple locations the defined parameters for this system remain the same, only changes the location where it is, and these are the extreme points of coverage and points without optical visibility that need to be covered.

The more defined measuring points this will result in more accurate results (Figure 4 and Figure 5). Each point is checked in two directions.

By analyzing the obtained results, we confirmed that with the proposed locations ensures the coverage of the radio-signal will be with satisfaction strength in 95% of time and space.

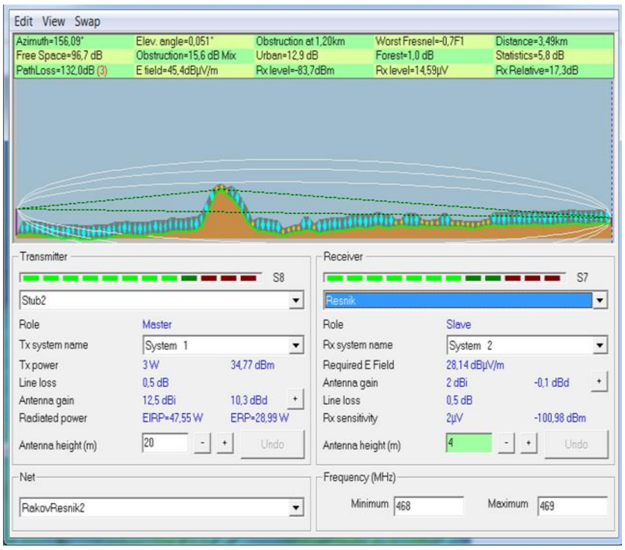

Fig.5. View the look of the measurement software with the results and the given parameters from the proposed location to Resnik

Based on these results, the installation of antenna system and equipment is planned as a simulation and measurements will be made to check the operation of the system in real time and space.

4. MEASUREMENTS IN THE FIELD

On the kilometer position 11+000. After raising the antenna, the direction of the antennas has been carried out in the following directions:

- direction towards Resnik, azimuth is 156^0
- the direction towards Rakovica, azimuth is 20^0.

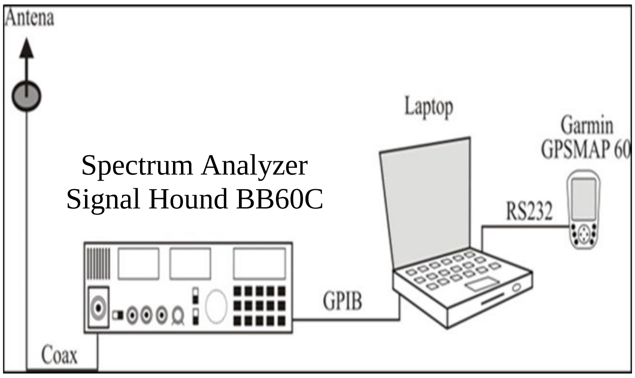

Fig.6. Measuring configuration

The frequency at which the measurement was performed is 467.775, which is the transmit frequency f1 on the 63 channel. Measuring configuration is shown on Figure 6.

To generate the signal, the FESA 2010 radio station will be used, the power of the FESA radio station is set to level 3, which is 6 W, while the following devices are used as the measuring receiver:

The origin measurement software (Figure 7) can currently measure the signal value in just one frequency, but to have a full picture or all three frequencies in order to compare and determine the overruns. So we created for these measurements, the software for the measuring instrument so that for every 3 seconds it takes the value of the electromagnetic field for the same frequency f1, f2, and f3. At the same time the time of the printing of the value is taken of the geographical position data (Table 1).

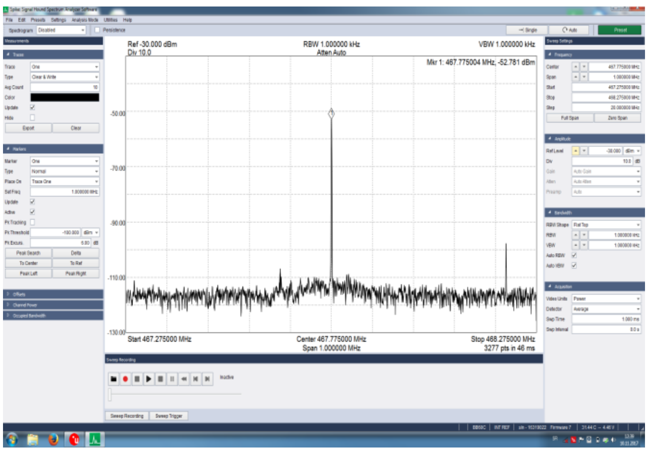

Fig.7. Measurement software

Tab.1. Measured values

Latitude	Longitude	F1 Level	F2 Level	F3 Level
44,7076	20,44615	-92,86358	-108,5662	-106,1546
44,707833	20,44605	-85,55351	-108,0218	-107,034
44,707983	20,445983	-84,20929	-107,3461	-105,1124
44,70815	20,4459	-83,14652	-107,9842	-105,3148
44,7083	20,44585	-83,36789	-108,682	-106,3908
44,70845	20,445817	-85,80376	-107,4513	-106,6894
44,708583	20,445783	-85,45592	-108,0835	-106,1983
44,7087	20,44575	-88,33687	-107,6387	-106,9722
44,708817	20,445733	-79,18292	-108,3198	-106,5086
44,708933	20,445717	-81,05209	-107,8416	-106,6388
44,70905	20,445667	-79,89371	-107,6748	-107,5934
44,70915	20,445633	-81,0747	-108,0791	-106,4525
44,709317	20,445583	-82,92093	-108,4029	-106,7745
44,709433	20,445567	-83,31532	-108,0732	-106,8971
44,70955	20,44555	-87,46712	-107,8856	-104,8159
44,709667	20,445533	-82,84109	-108,9202	-106,4467
44,709767	20,445517	-78,76736	-106,9898	-107,525
44,709883	20,445483	-78,57267	-107,8336	-105,8001
44,709983	20,445433	-91,16868	-108,7121	-107,3579
44,7101	20,4454	-94,28963	-108,2239	-107,6675
44,710217	20,445367	-88,78308	-107,9427	-107,4158
44,710333	20,445317	-88,26634	-108,734	-107,7473
44,71045	20,445283	-82,28362	-107,9592	-105,996
44,710567	20,445233	-78,9172	-108,0901	-107,4489
44,710683	20,445183	-76,13741	-108,7153	-108,0772
44,710783	20,44515	-71,34742	-108,328	-106,6834
44,71095	20,445083	-76,88191	-107,9134	-106,2601
44,711067	20,44505	-76,00262	-108,1935	-106,9485
44,711183	20,445017	-73,72744	-108,449	-106,7313
44,7113	20,444983	-72,49283	-107,8883	-106,7678
44,711417	20,44495	-70,97686	-108,6883	-107,0591
44,711533	20,444883	-73,54751	-107,1313	-106,7266
44,71165	20,444833	-76,45788	-108,0191	-105,508

Spectrum Analyzer: Signal Hound BB60 C that is connected to a PC via a USB interface. Also, the spectrum analyzer is connected to the antenna through which the signal from the interface is received. Signal reading is done in dBm units using the Spike v3.1.10 software.

GPS receiver, in order to determine the current position, the "in-block LEA-6H", connected to the computer via the USB interface. Also, the GPS receiver is connected to an active antenna via which the GPS receiver receives signals from the GPS satellite. Reading the current position is done using the u-Center v6.01 software.

After the measurement is done, the data is inserted into the diagram Figure 8. Each frequency is colored in a different color to make it more transparent. In this diagram to the left, the value of the signal strength while the time is marked at the bottom. Blue is marked frequency f1, which is a new location. This diagram shows that there is no exceeding the range with the next location with the same frequency.

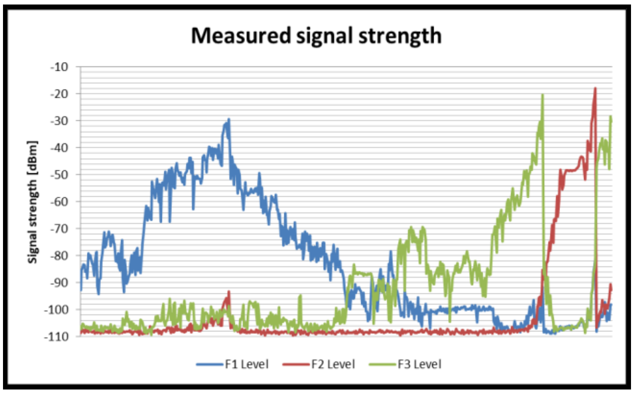

Fig.8. Diagram of measured values

5. CONCLUSION

Earlier, with paper-edged devices, which have Serbian railway it was possible to measure only one frequency and these measurements lasted for days.

The analysis of the results was also difficult, because for each measurement on one frequency on the paper strip it was very difficult to compare the overlap. In this way, it is much faster and easier to measure, because with only one movement of the rail vehicle you can get a complete picture of the whole system very quickly and reliably!

In this paper we analyzed optimality only for one, although the most versatile topographically, section of the whole radio covered railway network. We decided to apply such methodology in order to formulate the method for analysis. Nevertheless, the LRDS has been passed continuous improvement over years of its exploitation, since its beginning on 1982, we still find a room for rising of its performance. This work gave us an impetus to do so relying on more exact basis which will be the theme for our further research.

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REDUNDANCY OF THE NEW GENERATION OF RAILWAY SIGNALLING SAFETY DEVICES AS BASIS FOR ACHIEVING THE NECESSARY SAFETY

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Milan POPOVIĆ [3]
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***Abstract** – Design, manufacture, installation and exploitation of signalling safety devices shall comply with the required level of safety which must be fulfilled throughout the whole period of their use. The developments in the field of electronics and its application in design and manufacture of safety devices has led to gradual replacement of relay signalling safety devices used in railways by the new generation devices (electronic devices). This technology change required finding of new technical solutions and improvement of the existing ones in order to maintain and improve the level of the required safety of railway traffic. The existing application of redundancy in realization of signalling safety devices has been raised to a higher level with a tendency of further development.*

Keywords – redundancy, safety, SIL, CENELEC.

1. INTRODUCTION

According to a general definition used in railway terminology, redundancy represents the existence of a number of items (signals, elements, assemblies of different parts of devices) which exceeds the smallest number necessary for execution or transmission of the required information. Redundancy, understood in such a manner, has been rarely applied at the beginning, but has been used more and more with the development of the first relay signalling safety devices and has achieved its full expansion, that is, mandatory application, with the development of technology and appearance of electronic signalling safety devices.

Important terms necessary for good understanding of the lecture:

1. According to the definition from EN 50129:2003 [1], a fault represents an irregular condition which can cause a defect of device (for example resistor) which then leads to failure of that element and after that to the fault of the device itself.
2. Failure is irregular operation due to a fault, that is, impossibility to perform a proposed function because of the appearance of a fault.
3. According to the [1], reliability of a device is defined as capability to perform a function under the stated condition and stated time period.
4. According to the [1], safety represents protection from unacceptable levels of risk.

The main objective of use of redundancy during design, that is, manufacture of signalling safety devices is to improve safety of their operation (prevent that fault of an element inside the device affects the safety of the device).

There are several different ways to achieve redundancy within safety devices but the most common one with signalling safety devices in railway traffic is hardware redundancy (redundancy including repetition of function). It represents the existence of multi-item configuration "m-out-of-n" where "m" represents the minimum necessary number of items for the execution of a function, while "n" represents the total number of items ($m \leq n$).

2. HISTORICAL OVERVIEW

At the beginning of development of relay signalling safety devices and in order to achieve the required safety of their operation, first or second class

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relays were used as executive and control elements of the device. First class relays, due to their design solutions (maximum safety but also reliability in operation) are used as executive elements in the configuration "1-out-of-1". In order to fulfil the safety requirements the manufacturers, when using the second class relays as executive elements, if necessary, use hardware redundancy (repetition of function) in the configuration "1-out-of- 2" in fail stop manner of operation (if one relay fails, the function is not performed).

In order to check the fulfilment of requirements related to safety and security of operation, relay signalling and safety devices underwent a check known as "safety analysis". Only after the reception of positive results upon a safety analysis of a signalling safety device, this device was allowed to be used in practice.

An important disadvantage of relay signalling safety devices produced as presented above is the cost of their manufacture.

Rapid development of electronics, semiconductor elements and their assemblies as well as their price which has rapidly decreased following the degree of their development, led to the appearance of signalling safety devices mostly made by combining different electronic components. Signalling safety devices designed and manufactured in such a manner include a much larger number of elements which importantly increases the possibility of fault and they are generally less reliable than the mechanic ones, which requires application of additional measures in order to increase their safety. In order to improve the safety of electronic devices in the above mentioned fail stop manner of operation we use the redundancy in the configuration "2-out-of-2" (if one item fails the device stops working since the processing of both items is compared and they need to provide the same output). It is important to mention that aeronautics always use fail operate principle (if one element or item fails, the aircraft must still be certain to fly!). A similar fail operate principle exists in railways but only with the devices used to secure level crossings because the driver on the road must not be put in danger.

Hardware redundancy of relay signalling safety devices is realized, as already mentioned above, by doubling the elements while with electronic signalling safety devices this is achieved by doubling of functionally identical items. In both cases the following principle should be achieved – safety in the first place.

It should be noticed that, despite the impossibility to use the method of safety analysis with electronic signalling safety devices, as well as the higher possibility of fault in one of the items, redundancy in the configuration "2-out-of-2" can nevertheless fulfil the safety requirements defined by the existing European norms in order to achieve the higher level of safety (SIL 4).

3. MANNERS OF SOLVING PROBLEMS DUE TO THE OCCURRENCE OF A FAULT

There are three basic techniques used to improve or maintain the basic characteristics of safety systems in cases of possible faults: avoiding of faults, camouflage of faults and tolerance of faults.

Avoiding of faults is a technique on which we will not spend much time since it concerns strong processes of control regarding design, testing, quality control and similar procedures which include a much higher level of engagement of human factor.

Camouflage of faults is any technique preventing the fault of an element or assembly to produce an error which could endanger the safety of operation. An example of camouflage that will be presented in this paper and which is the most frequently used in design and manufacture of electronic signalling safety devices is majority deciding system.

Tolerance of faults relies on camouflage of faults but including detection and localization of a fault and then reconfiguration of the system (process of elimination of the faulty element and returning of the system in operational state) in order to eliminate the influence of a faulty component or module.

As it can be noticed, the process of majority deciding which basically represents the redundancy of the system is present in the techniques of camouflage and tolerance of faults.

4. HARDWARE REDUNDANCY

In order to achieve resistance to failures of a safety system today we most usually use, hardware redundancy (physical multiplication of hardware). There are three basic types of application of hardware redundancy, passive, active and hybrid, and this paper will mostly concern passive hardware redundancy which is the most frequently used with electronic signalling safety devices.

Passive hardware redundancy is based on the principle of majority voting and its main task is to tolerate the occurrence of a fault on an item. Generally speaking, the attention will be directed toward "n" modular redundancy (NMR) but through its most used subset of triple modular redundancy (TMR).

NMR, that is TMR, has the task to reconcile safety and reliability, that is, to improve as much as possible the reliability of the system without reducing its safety.

As it can be seen on the figure 1, the basis of TMR is the existence of three items on which the method of majority voting is applied and which defines the result at the output of the system. If output signals on "2-out-of-3" modules are identical, that signal will occur at the outlet of the system, while the signal of the faulty module (output signal on that module is different from the signal at the outlet of the other two modules) will be hidden and it will not affect the final result but it will be indicated as a disorder which does not affect safety.

In order to improve the safety of operation with the systems using TMR and with the occurrence of design errors during manufacture of modules, today some manufacturers of signalling safety devices chose the heterogeneity of the modules themselves (for example the use of different microprocessors in each of the modules and different software in items). This certainly provides better quality products, but does not eliminate the main disadvantage of TMR which is the occurrence of comparator failure which represents a “unique point of failure“.

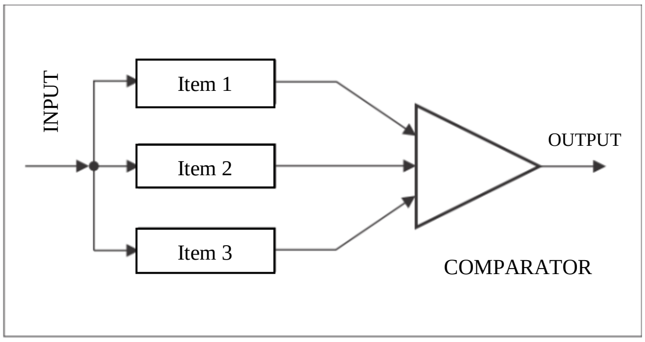

Fig.1. Example of redundancy

Certainly, there are some techniques which can moderate or completely overcome this deficiency, which will not be treated by this paper since their application by all means leads to more complex devices and therefore increases their cost.

5. SAFETY INTEGRITY LEVELS (SIL) AND THEIR APPLICATION

Impossibility to apply safety analysis while testing electronic signalling safety devices required a new approach to the problem of control of their safety and reliability before placing them on the market. The solution has been found with the adoption of European norms (CENELEC) and recommendations defining safety integrity levels (SIL) that must be fulfilled by signalling safety devices before placing them in service (EN 50128 and [1]), determining who can do the testing and issue certificates to confirm that a certain signalling safety device has a certain level of safety, as well as methods by which every railway administration defines admissibility of a risk as prerequisite for the choice of a SIL (EN 50126).

It is here also very important to mention that in all the EU member states electronic signalling safety devices used on corridors must possess a certificate confirming the highest safety level (SIL 4), issued by an independent certified body (body of type A according to ISO/IEC 17020:2012).

6. CONCLUSION

The aim of this paper was to provide a short overview concerning the application of redundancy in design and manufacture of signalling safety devices. The subject is certainly much wider and new solutions are still being developed in order to (reconcile contradictory requirements) maintain and improve the safety of the existing systems, but also to improve reliability and availability of those systems. Since [1] has not yet defined the levels of reliability of signalling safety devices, although its meaning and manner of calculation has already been determined, on the market of the Republic of Serbia can be found electronic signalling safety devices with SIL4 realized by configuration “2 of 2“,“2 of 3“ or double “2 of 2“. The end user, that is the infrastructure manager, shall decide which of those solutions is appropriate but with a mandatory requirement according to which the device should possess a certificate of the highest safety SIL4, as prescribed by the “Rule on Technical Requirements for Signalling Safety Installations“ (“Official Gazette of the RS“, No 18/16).

As another warning to the infrastructure managers, it is important to mention that when deciding on the purchase and installation of electronic signalling safety devices which obtained a licence for installation before the adoption of the Railway Safety and Interoperability Law („Official Gazette of the RS“, No 104/13, 66/15, 92/15 and 113/17) they should check with the manufacturer or provider whether they possess a SIL4 certificate issued by a certified body (before the adoption of the above mentioned law and rule, electronic signalling safety devices did not have to possess the SIL4 certificate) in order not to breach the applicable rules.

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TRANSMISSION POSSIBILITIES IN RAILWAY DATA NETWORK TODAY

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Abstract *– The major switch to new transmission technologies in large systems is much slower than the progress of research. Therefore track side copper cables in railway environment will not be easily replaced in the next 10 years due to technology of communication, rigid standards and recommendations related to traffic. In this paper we will analyze some issues of Serbian railway data network based on copper cables, comparing it to international trends. Since the overall reconstruction of communication lines along the track have not started yet, copper links for voice as well as data still depend on the use of installed cables. The xDSL technologies, mainly TC-PAM are the preferable type used for data transmission along the railway lines. Bonding (using n pairs instead of one) and improvements in rate (variations of TC-PAM) foresee yet a decade at least for use of this technology. Standards related to mentioned transmission systems and media dealt with standard diameter wires, that most telecom operators use. Since railway owns cables with pairs/quads with a better low frequency characteristics and a greater diameter this paper deals with estimations of possible range and linerate of existing transmission system in railway environment. Regarding existing standards, their theoretical consideration and achieved rates on certain cable spans this paper analyze the possibilities of copper cables, quantitatively. The aim is to help in the process of increasing effectiveness of systems as well as to point out the weak links of the systems.*

Keywords – railway trackside copper cables, xDSL, transmission.

1. INTRODUCTION

Although optics brought so much bandwidth and opportunities to operators, they still tend to use the copper that is already in the ground and have satisfactory characteristics. Since the overall change of railway transmission systems have not started, the trackside (line side) copper cables intended for baseband communications is still an option. The single-pair high speed digital subscriber line (draft name of the standard was G.SHDSL) was described in ITU-T 991.2. The main difference of this transmission system from the rest of the members of xDSL family is a Trellis Coded PAM modulation used. The TC PAM uses frequencies in the baseband transmission ragne. The data rates are symmetrical in upstream and downstream [1,2].

When the odds were severely against the SHDSL and pro fiber, additions came to light, bringing possibilities for expansion of data rate. Using several pairs at the same time the data rates could be significantly increased. Applying new TC PAM modulations involving 32 and 64 states (now even 128) combined with multi pair bonding could enable the streams comparable to fiber transmission (depending on the actual span distances, TCPAM used and number of pairs). Since the fiber evolution of Serbian Railway Infrastructure is still on hold this could provide the survival with moderate increase of capacities for existing network and it will make a small but efficient backup for certain small linerate consuming applications in the near future. The copper cables still have their purpose in communication of traffic oriented staff and maintenance staff, it survival and future is certain as long as the regulations in this area are not changed (Rule books in various areas of railway, recommendations, etc.) [1-5].

Dealing with the negative influence of traction

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system (25kV, 50Hz) is another task characteristic for railway environment. Close proximity of copper cables used for transmission to overhead contact line also presents danger for employees involved in maintenance [6].

The rest of the xDSL family has its use in the railway environment but the SHDSL transmission is the dominant type used. The VDSL and VDSL2 are applied in larger stations and are supported by local copper cable networks as transmission media. These types of modems have their use in forming an environments resembling campus structure. The ADSL is used only as a connection to public network and is slowly approaching retirement. Among mentioned members of the xDSL family solutions as well as modulations vary but TC PAM is among other benefits, the modulation able to withstand harsh railway conditions and still reach a significant distance.

2. SHDSL LINES IN RAILWAY ENVIRONMENT

Modems using modulation TCPAM 16 are in use on the entire data network of Serbian Railway Infrastructure. Devices are connected to symmetrical pairs contained in the last layer of railway trackside copper cable. This layer also incorporate symmetrical pairs (quad) for TDM transmission systems (12 channels) and coaxial pair for 300 channels transmission system on some lines. All this lead to the conclusion that some interference, crosstalk and noise is inevitable.

2.1. Modems

Modems used in network of Serbian Railway Infrastructure are mostly type Watson 5 (Schmid Telecom) TC PAM 16 based. In stations along the railway lines these modems are installed in train dispatcher rooms which are occupied 24/7. No special environmental conditions were applied so a table top variant is chosen in order to achieve better cooling conditions in racks. Modems have adapters for power supply AC/DC 240V, 48DC, 15W. The ground of this version of modem is normally floating when referenced to earth (tip and ring of the telephone connection) [7].

There is a possibility to use remote Monitoring through Telnet on the Watson 5. After connection is established, the main menu offers several possibilities: performance management, fault and maintenance management, configuration management and security and remote management. Modems used could achieve up to 2048kbps (nx64kbps) rate. Line rate is calculated using following equation

$$Linerate = n \times 64\ kb/s \tag{1}$$

where n is a number of time slots per pair (for TC PAM 16; n=3,4,..). When multiple are used this equation becomes

$$Linerate = m \times n \times 64\ kb/s \tag{2}$$

where m is a number of pairs used in the span. Previous leads to the overall physical DSL synchronization rate

$$Syncrate = n \times \frac{64kb}{s} + OH\ [\frac{kbits}{s}] \tag{3}$$

and OH represents *SHDSL Overhead* (8kbit/s including 3.2kbit/s of the EOC – Embedded Operations Channel, channel for management purposes). Sync rate determines the SHDSL reach.

Signal quality (SQ) is several times addressed in this paper representing the calculated noise margin (merit of transmission quality) and defined as follows

$$SQ = SNR1 - SNR0, \tag{4}$$

where SNR1 is a signal to noise ratio calculated by the transceiver by analyzing the error correction bits (trellis bits) in the line code and SNR0 is the signal to noise ratio that gives a bit error rate of 10^{-7} in presence of average Gaussian noise. For TC PAM 16 the theoretical value for SNR0 is 27.7 dB [7].

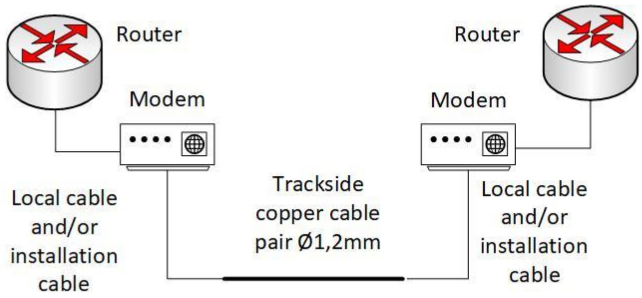
2.2. Copper pairs

Copper cables are so called STKA and STA cables, custom made for railway use, consisting mostly of pairs (quads) for the use in baseband (voice band for various dispatching and party lines along the railway tracks). First layer consists of quads with wires of 0.9mm diameter. Second layer is similar to first having more of the same quads. Third layer is larger and incorporates symmetrical quads (pairs) of 1.2mm diameter and coaxial pair 1.2/4.4mm (300 channels transmission systems, STKA cable) or high frequency quad (12 channel transmission systems, 120kHz, STA cable). Cable is with air/paper isolation, Al sheath, armature made of two Fe strips and external protection based on PVC. Depending on needs (different for every line) certain number of quads/pairs is loaded in order to achieve better transmission characteristics in voice band.

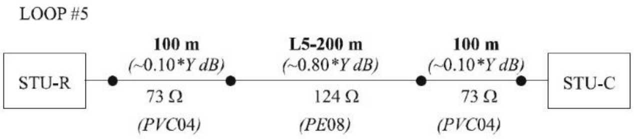
Pair used for SHDSL transmission is symmetrical of 1.2mm diameter with no load (sometimes if needed for smaller distances up to 5km is used pair with wires of 0.9mm diameter – mostly in urban areas). These pairs are terminated in buildings for signaling and telecommunication equipment in stations. From here pairs in local subscriber cables are used. This scenario is similar to one represented in ITU-T 991.2 (Annex B, tet loop #5) Fig.1 [3].

To its similarity is adding the fact that cables shown in the recommendation are of the wire diameter

0.8mm which is the largest diameter addressed in this recommendation.



a)



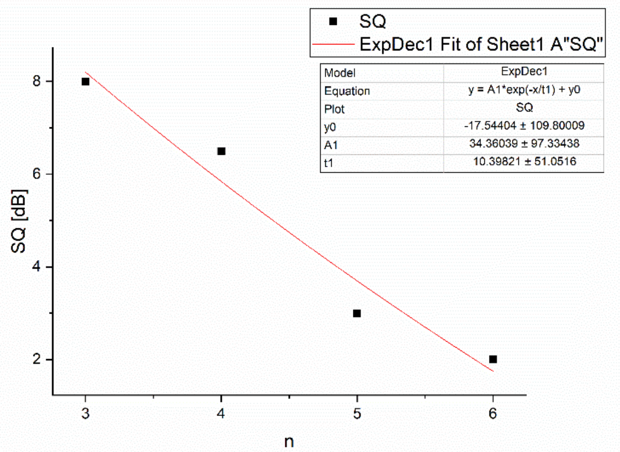
b)

Fig.1. Typical configuration in stations (a) corresponding to ITU-T G.991.2 Annex B test loop #5 (b)

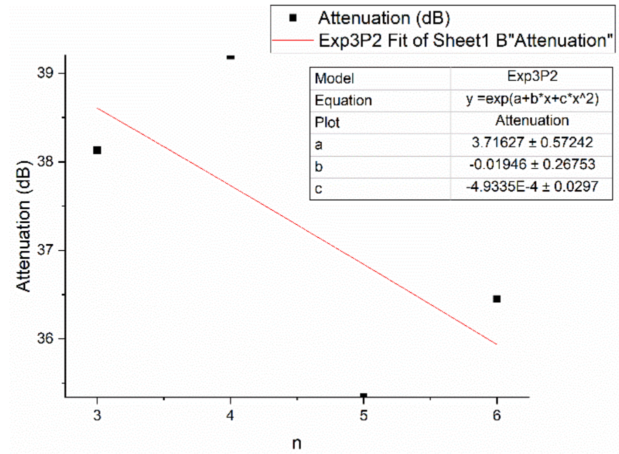
3. RESULTS AND DISSCUSION

Since different lengths of cables (spans) could be found across the network, different linerates and conditions of cables, a comparison of these differences could provide valuable information about the possibilities of network. By changing the linerates of modems (nx64kb/s) i.e. number of timeslots used the results of different conditions are presented in Fig. 2. for span Kosjerić – Valjevo. Deterioration of SQ and attenuation are mostly following exponential or polynomial (linear or square - in smaller number of cases) curves so these dependancies are used for fitting of data.

Comparison of different spans and achievable linerates on these spans is presented in Fig.3.



a)



b)

Fig.2. Characteristic of transmission on span Kosjerić – Valjevo (~39km) for different n (number of 64kb/s quants) of a) signal quality (SQ) and b) attenuation

When Fig. 3. is compared to the one obtained using recommendation data, Fig. 4. the similarities can be quantitatively evaluated. It is yet a task to collect enough data for these cables in the light of SHDSL transmission, since this was not their primarily intended use.

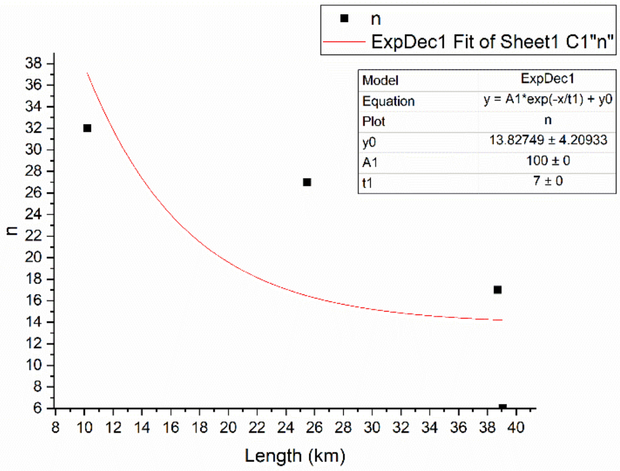


Fig.3. Achieved number of timeslots (linerates) vs different cable lengths

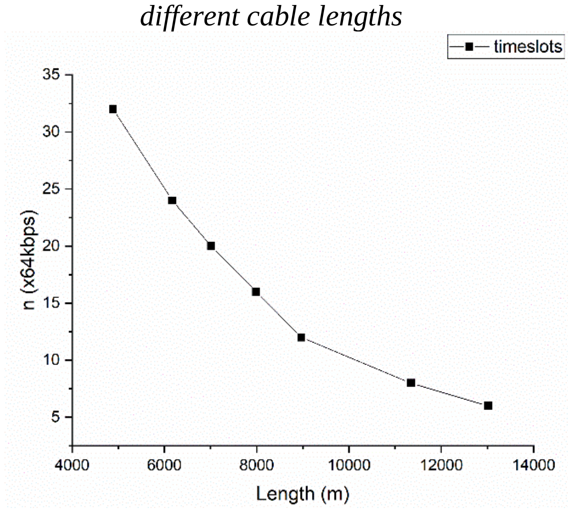


Fig.4. Linerate vs distance curve obtained using data from the ITU-T G.991.2 noise model B,C,D [3]

Fig 3. and 4. compared indicate trackside copper cables have significantly better transmission characteristic concerning SHDSL modems.

It is also a task to determine the advantage achieved with air/paper isolation since recommendation is strictly oriented towards subscriber cables using PE or PVC as insulator.

Regulations dealing with copper cables (baseband, mostly voice band used) clearly show that cables with air/paper isolation compared to those with plastic mases isolation have lower attenuation coefficient and relative attenuation (relative to 800Hz – since their primary use in the voice band) [2]. Railway trackside cables also have significantly wider wires diameters (0.9 and 1.2mm) compared to subscriber cable wires diameters (0.4; 0.6 and 0.8mm) so a better characteristics than those given in recommendation were expected.

4. CONCLUSION

Customary copper cables used on railway having air/paper isolation shown very good characteristics in SHDSL network installed during previous decade. Comparing to subscriber cables using mostly plastic masses better transmission characteristics were shown. One of the best aspects of STKA/STA cable was reduction factor minimizing the influence of traction system.

It seems that SHDLS technology improved with mentioned possibilities, has a future in railway environment. Existing lines could increase its possibilities providing users better connections to railway centers in the means of higher linerates or increasing signal quality. It could also be improved by adding equipment in smaller stations between already equipped stations, although this is not justified at times. Certain stations are not staffed and the trends show that this will continue thus having a larger area of control from larger stations. Since the SHDSL network is mostly oriented towards train dispatchers and administrative use it is reasonable to expect that the trend of decrease of staffed stations, will replicate itself to network here explained.

If stalling of fiber optics era continues, railway multiplication of bonds between stations is expected, but only as a means of network survival. SHDSL network will certainly still be applicable in the fiber era since old copper cables have reached even the smallest objects along the lines with its numerous branches (APB block buildings, Ground train radio RDV buildings, Level crossing buildings, remote block building in stations, junctions…) and it is not expected to make a similar number of branches covering all the places previously covered (with copper cables), on future broadband oriented fiber optic cables. Railway trackside power cable (PNK) is present in most of the previously mentioned locations so powering doesn’t have to be remote through communication copper cable, which would be a noise and interference source influencing other communication systems using trackside copper cable.

Entering every point of interest along the tracks with fiber optic cable would be extremely costly and it would deteriorate the characteristics of the cable. However, the fiber will cover most of the spots along the line, thus shortening the spans of future SHDSL links, what will have a significant impact on the achievable linerates and signal quality for future uses.

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UNIVERSAL RAILWAY LED MODULE LL-000

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Abstract *– This paper presents the Universal LED module LL-000* **-** *an electronic module with LED light source, intended for the use as a single, coloured light source in railway signals in the relay interlocking system SpDrS-JŽ. LED module is designed as a replacement for dual filament incandescent lightbulbs on main, shunting and limit track signals. Light signals represent one type of an output information from the interlocking and are required to return to the interlocking the information about their operating state. In the SpDrS-JŽ system, this information is obtained from current loop of the signal's light source power supply. LED module is intended for the mounting in the standard signal housings in use on Serbian Railways, instead of a lightbulb support bracket. Mounting of the LED module requires minimal modifications to the housings. Other than that, LED module does not require modifications in the interlocking system, and supports all the operating modes and states that an incandescent lightbulb had – day-time and night-time mode, blinking operation, alarm and error state. Given that the bulk glass lens and the scattering glass of the original optical system are retained, optical characteristics of the signal are at least the same as in the case of a lightbulb. In comparison to lightbulbs, LED technology offers considerably longer lifetime, thus reducing operation costs.*

Keywords – LED module, relay interlocking, railway signal, incandescent lightbulb.

1. INTRODUCTION

Railway interlocking systems were historically primarily based on well-tested and robust electromechanical relay technology, while signalling devices used incandescent lightbulbs as the light sources. One example of such interlocking is SpDrS-64-JŽ, which is in use on Serbian Railways. Regarding the modernization of railway systems, rather than replacing the complete relay interlocking with an electronic one, it is often the case of retrofitting only a part or a subsystem of an existing interlocking system with a modern, electronic equipment.

One of such parts, which are often replaced by a more modern alternative in a railway system, is an incandescent lightbulb used in railway signal lamps. At the time when the development of LL-000 device was initiated, neither of major European manufacturers of railway signalling devices had to offer an electronic module based on LED technology as a replacement for two-filament lightbulbs in SpDrS-64-JŽ which could be used without major modifications in the interlocking system.

2. FUNCTIONAL DESCRIPTION

LL-000 ("000" is replaced by the nominal diameter of the specific signal lamp which uses the device, e.g. "136" or "70" on Serbian Railways) is an electronic module with LED light source intended for the use in SpDrS-64-JŽ relay interlocking. The device is designed as a replacement for two-filament incandescent lightbulbs (12 V / 20 W or 30 V / 15 W) on main, shunting and limit-track signals. LL-000 retains the functionality of the lightbulb and supports:

- Day-time and night-time operation
- Blinking operation
- Cold testing of the auxiliary filament
- Alarm state and error state.

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LL-000 is designed to be powered by AC voltage, but can also operate on DC voltage when used on some specific signals (e.g. red signals on automatic signalling block (ASB)). LL-000 is connected to the interlocking via 3-wire or 4-wire power cable. 4-wire interface is used on red main signals, since they require auxiliary filament cold testing and the interlocking implements galvanically isolated circuits for each filament. 3-wire interface is used on all other signals, since they have common return line for both filament circuits, while the interlocking automatically breaks auxiliary filament circuit when it detects that main filament is active. Detection of an active filament in SpDrS-64-JŽ interlocking is performed by the current loop in the signal power supply circuit. Functional diagrams of 3-wire and 4-wire interfaces are shown in Fig.1.

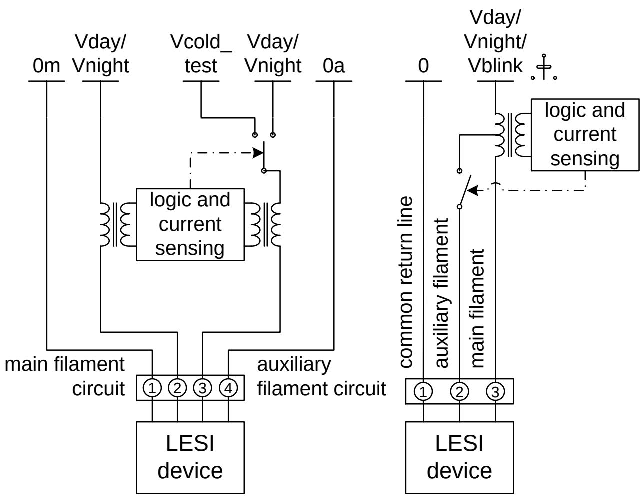

Fig.1. LL-000 connection in SpDrS-64-JŽ

A light source of LL-000 device consists of two discrete LEDs, which are controlled separately by the module's internal logic unit.

The device enters nominal operating mode when a regular input voltage is detected and the light source is fully functional (i.e. both LEDs are operational). The interlocking sets day-time or night-time operation mode by setting the input voltage of the LL-000. In day-time mode, device produces light signal of nominal intensity. In night-time mode, light intensity is reduced to 50% of nominal. LL-000 also supports blinking operation (in both, day-time and night-time mode), with nominal blinking frequency of 1 Hz and 50±5 % light pulse width. One of peculiarities of SpDrS-64-JŽ interlocking is a requirement for the signal lamp to return specific current to the interlocking even during the dark phase in blinking operation when the voltage applied to the lamp is under 2 V. Although incandescent lightbulbs could naturally meet this requirement (since the resistance of a cold filament is very low), system design of LL-000 had been significantly constrained by it.

In the case of a single LED failure, LL-000 enters an alarm state and internally breaks the main filament circuit using a latch relay. This action results in breaking of main filament current loop and is detected by the interlocking which in turn activates auxiliary filament circuit. LL-000 remains in alarm state and operates on the auxiliary filament circuit. In order to maintain signal light intensity, the average drive current of the remaining LED is doubled (which is still less than nominal average drive current for chosen LED's).

In case of any other irregularity of LL-000 system, or a second LED failure, the device enters an error state in which only a microcontroller remains active. In error state, total current of the device is less than interlocking's detection threshold and the signal lamp is considered as "burned".

3. DETAILED DESCRIPTION

LL-000 consists of a single printed circuit board and dissipating resistors mounted on the housing lid, and can be divided in three logical units: processing unit, input unit and LED unit, as shown in Fig.2.

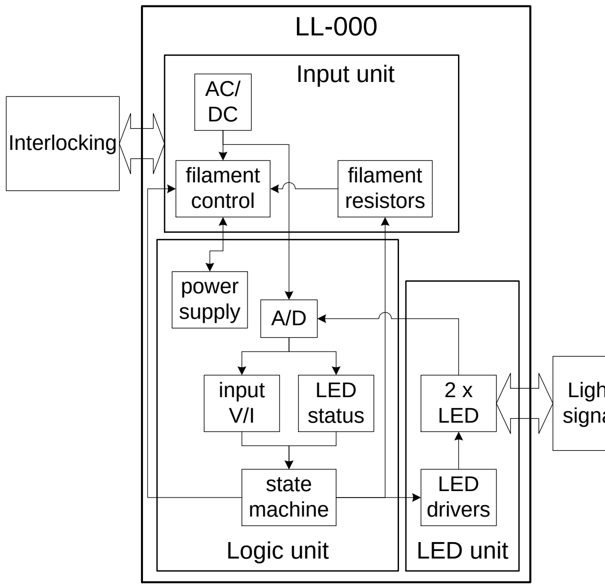

Fig.2. LL-000 Block Diagram

Input unit performs simulation of two-filament lightbulb and consists of diode bridge rectifiers (entire LL-000 system is in DC domain and is powered by AC voltage), latch relay for main filament breaking in alarm state and dissipating resistors that simulate filament resistance. Since lightbulb filament is a thermally dependent resistor, at least one discrete resistor is needed to model its resistance for each operating mode – day-time, night-time and cold-testing or dark phase blinking. Since the total power consumption of the rest of LL-000 system is negligible compared to the power dissipated on these resistors, characteristic input impedance of the signal seen by the interlocking is still predominantly resistive, as in the case of a lightbulb.

Logic unit is organized around safety microcontroller from *Texas Instruments*' *Hercules* family, which implements finite state machine in software, using infinite main loop and timer interrupts. Microcontroller periodically performs A/D conversion of various electrical values in the system and monitors states of each LED. Based on these input parameters, state machine switches operating states which correspond to the device's operating states – day-time, night-time and blinking operation depend on measured input voltages; active filament depend on measured input currents; and alarm or error state depend on the detection of LED or any other failure. For each state, specific set of control signals is generated by the microcontroller, which drive LEDs and appropriate dissipating resistors, and latch relay if needed. All of control signals are dynamic signals – in the form of square wave, in order to ensure an inactive – steady signal state, in case of microcontroller's malfunction or hardware error on the signal path.

LED unit of LL-000 device consists of the light source (two LEDs), their power supply, and constant current drivers (each LED is controlled separately through its designated current driver). LED drivers are driven by the square wave signal of sufficient frequency for the human eye to perceive constant light signal, so that the average luminosity of LEDs is controlled by the control signal's pulse width. LED unit allows a series connection of two LEDs in each controlled branch (four LEDs in total). Two additional LEDs are located on another printed circuit board, which forms a separate light source, controlled by the main module. This configuration is used on limit track signals which originally had two sets of two lightbulbs of the same colour connected in series (two red and two white lights). Control signals for LEDs are multiplexed in time, i.e. only one LED is be driven at any time. This enables the detection of the single LED failure to be performed by measuring total LED current (which detects LED open circuit) and voltage drop on each LED (which detects LED short circuit).

4. SPECIFICATIONS

LL-000 device is mounted in the standard signal lamp housings which are in use on Serbian Railways, instead of a lightbulb support bracket. Mounting of the device requires minimal mechanical modifications to the housings to allow for the thermally effective mounting of dissipating resistors on the lid of the housing. These modifications do not interfere with an operation of a lightbulb. Other than that, LL-000 does not require modifications in the interlocking system. One LL-000 module fully installed in the standard housing is shown in Fig.3.

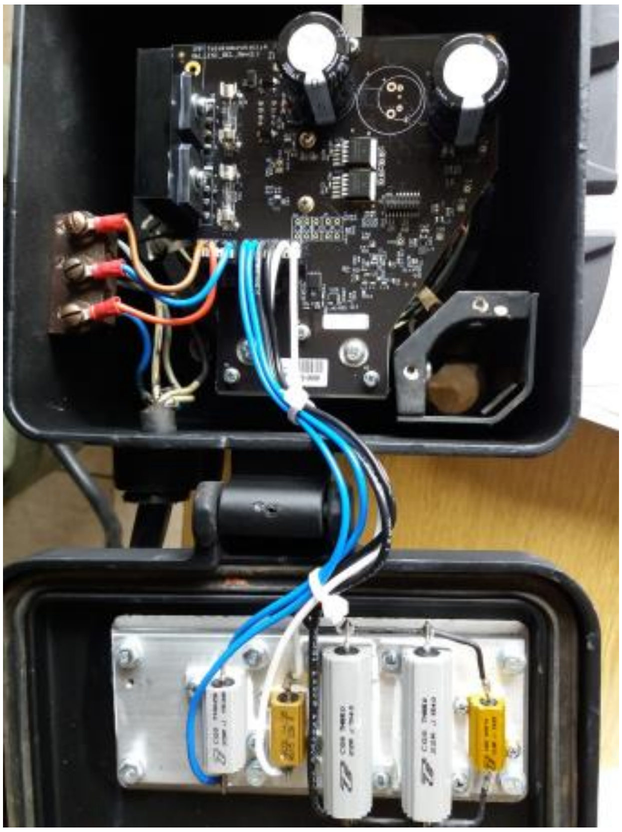

Fig.3. LL-000 Block Diagram

LL-000 operates on the AC voltage with nominal frequency of 50 Hz. Absolute maximum operating input voltage is 70 V for main signals and 100 V for shunting and limit track signals. Electrical specifications for LL-000 devices used in SpDrS-64-JŽ interlocking are provided in Tab. 1.

Tab.1. Electrical specifications

LL-000 type	**Day-time**		**Night-time**	
	Voltage [V]	**Current [A]**	**Voltage [V]**	**Current [A]**
Red	14	1.3	9	1.1
Yellow	20	1.3	11	1.1
Green	24	1.3	14	1.2
White	14	1.3	8	1.2
Red/White Shunt	35	0.5	24	0.42
Red/White Limit track	60	0.5	40	0.42

Original optical elements – bulk glass lens, diverging glass lens and the protective glass – in signal housings are retained when LL-000 is used. Since LL-000 uses coloured LEDs, coloured glass filters are not required and are removed. LL-000 has two, high-brightness LEDs, positioned closely together. Mounting of the module ensures that the position of LEDs is set so that they occupy the same space as a main filament of the lightbulb did. In this way, light images produced by the LL-000 devices are satisfactorily similar to the original lightbulb images and conform to the requirements in [1]. Colours of LEDs used in LL-000 devices conform to the requirements in [2] and have the following chromatic coordinates:

- Red: x = 0.676, y = 0.320;
- Green: x = 0.198, y = 0.700;
- Yellow: x = 0.572, y = 0.426;
- White: x = 0.295, y = 0.315.

5. CONCLUSION

LL-000 railway LED module is designed as a replacement for two-filament incandescent lightbulbs in relay based SpDrS-64-JŽ interlocking system. The module is mounted in existing signal lamp housings with minor mechanical modifications. No other modifications to the interlocking are required. Modified housings retain parts of the original optical system and the placement of the module inside a housing ensures that optical characteristics of the system are maintained. LED module supports all of the operating modes and states required by the interlocking, as well as an operation in the auxiliary filament circuit. The alarm state is entered when a single LED failure occurs while the second LED is still operational. Alarm state is equivalent to the breaking of the main filament circuit. Error state, or breaking of the both filaments, is entered when both LEDs fail, or any other failure is detected by the module’s control logic. LL-000 also supports day-time, night-time and blinking operation as well as a cold filament testing on auxiliary filaments on red lamps on main signals.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '18

TRANSFORMATION OF PETROVARADIN-BEOČIN RAILWAY TRACK INTO A GREENWAY

Ljiljana MILIĆ MARKOVIĆ [1]
Ljubo MARKOVIĆ [2]

Abstract *– The paper presents a transformation of a public railway track Petrovaradin-Beočin into a greenway for pedestrian and bicycle traffic at the territory of the Town of Novi Sad and the Municipality of Beočin, which is intended for recreation, sporting, cultural, tourist and other servicing activities to the citizens of the Town of Novi Sad and the Municipality of Beočin.*

Keywords ***– railway track, transformation, path, cyclists, pedestrians.***

1. INTRODUCTION

In 2016 the joint-stock company Serbian Railway Infrastructure reached a decision to suspend public transport of passengers and goods on a part of railway infrastructure which consists of 24 railway tracks amoutning to the total length of 669.2 km. These include Petrovaradin-Beočin railway track, 17.1 km long, which had been in public railway traffic since 1908. It was in service for both passenger and cargo traffic, and since 1965 only for cargo traffic.

The traffic along this track was completely suspended in 2007 for safety reasons, since certain elements of railway infrastructure were worn out.

Late in 2017 the workgroup of the Ministry of Construction, Transport and Infrastructure and the Government of the Autonomous Province of Vojvodina decided to make a pilot project – the so called concept of a greenway, in other words the transformation of Petrovaradin-Beočin railway track into a pedestrian and bicycle path.

2. INSPIRATION AND GOOD EXAMPLES

The inspiration for greenway urban design has been found among the projects already implemented in the region, Europe and worldwide. The first of them is High Line project in New York (Figure 1), which is the most famous example of conversion of a railway track space in the heart of the city. This example was used to recognize good methods of forming a user-friendly area with a lot of greenery and urban mobile objects.

Fig.1. High Line, New York, USA

The second example is the project called Cycling through History, which is actually the revitalization of the old narrow-gauge railway Ćiro through Bosnia and Herzegovina and Croatia, from Neum to the Municipality of Konavle (Figure 2). The implementation of this project includes developing and marking of about 200 km long bicycle path. The bicycle path is intended for both road and mountain biking. The longer part of the path is asphalt, while certain sections are macadam and are adjusted for mountain biking.

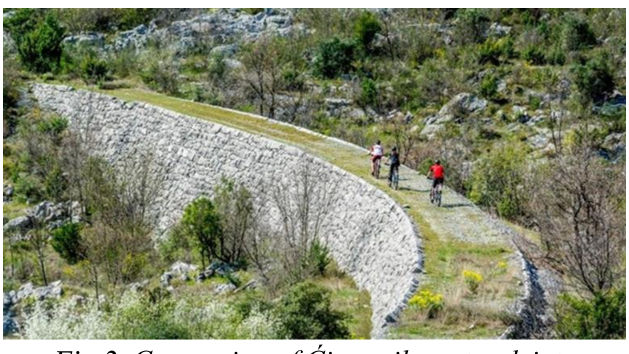

Fig.2. Conversion of Ćiro railway track into pedestrian-cycling path

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The example of Schöneberger Südgelände industrial park in Berlin, Germany, was also taken into consideration. This park has preserved the elements of railway mobile objects, while the space in the park was converted for use primarily for sports and recreation (Figure 3).

The insight into the good practice examples was used to identify spatial guidelines which would be implemented into the subject space and which would influence the creation of ambient atmosphere and continuity of its use.

Fig.3. Schöneberger Südgelände Park, Berlin, Germany

3. CONCEPT OF SPACE REVITALIZATION

The transformation concept included planned development and marking of the route for pedestrians and cyclists in the area of Petrovaradin-Beočin railway track. The path was treated conceptually as a part of the park complex, the green road which connects two settlements and is 17.1 km long.

The path was designed as multifunctional with various contents, the area for art installations, outdoor gym, children playgrounds, and similar. The visitors and recreational sportsmen, in addition to enjoying sports activities, are also given information on tourist attractions in a wider area of the location, such as the information on Petrovaradin fortress, the moneasteries of Fruška Gora as well as archeological sites.

By keeping the elements of rail traffic at some parts of the greenway the main characteristics of industrial landscape design are also maintained, while the disassembled elements of the railway track superstructure will be used for fences, paving, urban mobile objects and equipment.

Designing of roadway structure was made by segregation of pedestrian and bicycle traffic and putting laybys at establishments and at locations where the path intersects waterways. The roadway at laybys is designed to integrate pedestrian and bicycle traffic with the additional contents for sports, recreation and amusement.

Exits from pedestrian-bicycle path and junctions to paths and sidewalks in the nearby settlements have been provided, as well as exits to bus stops.

The connections of the greenway to sidewalks and roadways in the settlements are made by staircases of underpasses with a part of narrow bicycle ramp (Figure 4).

Fig.4. Image of descending from pedestrian-bicycle path at underways

The connection of bicycle path with surrounding road network will be established by 23 existing intersections of railway track and local roads in the same level.

During the further lifetime of the path it is possible to predict the additional points of intersection in accordance with the development of additional contents in the direct vicinity of the path.

The points of intersection of pedestrian-bicycle path with other roads in the same level are marked with the corresponding horizontal and vertical traffic signallization intended for both motor vehicle drivers and cyclists and pedestrians. It is also predicted to instal mounting forced speed bumpers which would reduce the motor vehicle speed.

Public lighting, which is planned to be put along the entire path, will enable motor vehicle drivers to see the path users in time in the conditions of night driving or reduced visibility. There will be 497 new 6 m high poles with LED lights of 20 W. The total installed capacity of the lighting is 10 kW.

As for traffic equipment, there will be parking poles installed along the greenway which would prevent the motor vehicles to enter the greenway.

Five types of driveway structures have been defined within the pedestrian-bicycle path. Figure 5 presents the typical profiles at the path with layers of construction and defined dimensions to separate bicycle from pedestrian path.

The landing spots will be covered with mulch, decking or Tartan. Such changes would indicate the users that it is a place where they can make a break – and in this way linear continuous space timely discontinues and is no longer just a flowing space. The roadway structure at landing spots is shown in Figure 6.

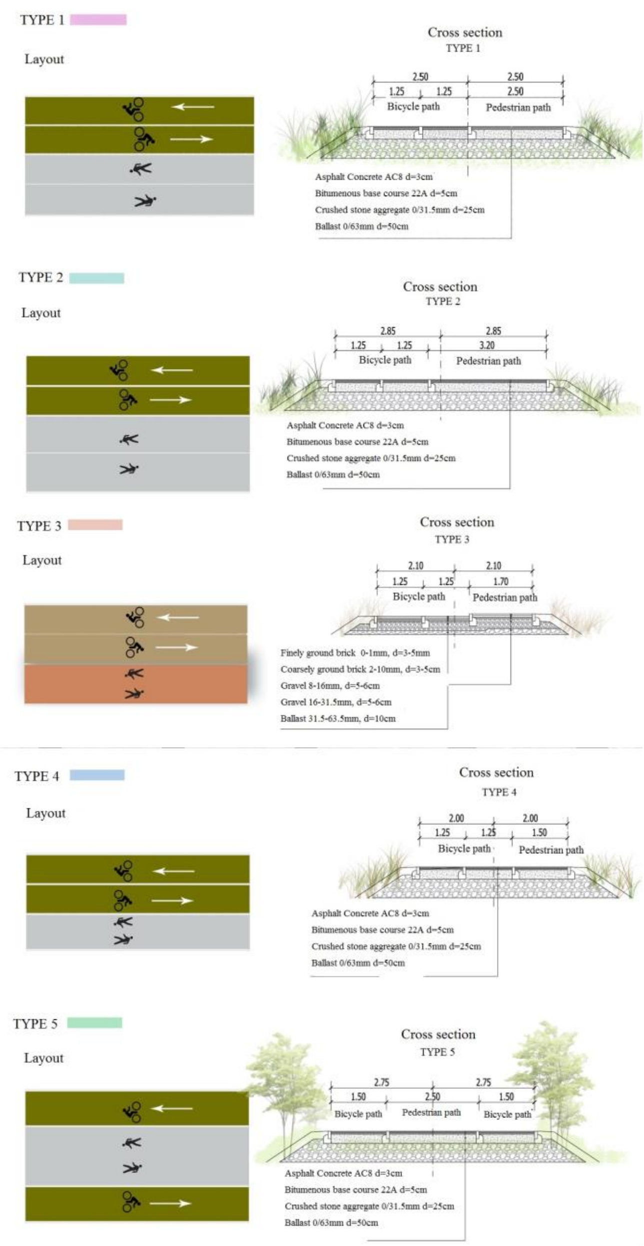

Fig.5. Typical cross-sections along the greenway

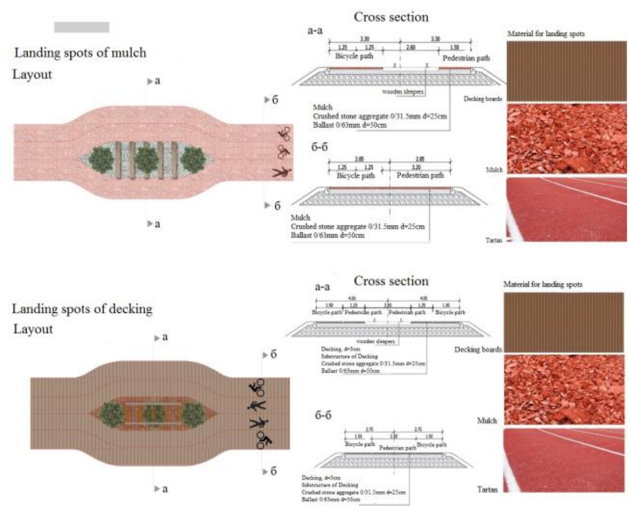

Fig.6. Type of roadway structure at landings

The landings outside establishments will be equipped with drinking fountains, benches, solar panels and service pumps (Figure 7).

Fig.7. Appearance of a landing

The concept of formation of contents within establishments is based on maximum use of rails and ties of the existing tracks. One type of mobile objects within establishments includes the deckchairs on tracks (Figure 8).

Fig.8. Deckchair on tracks

There are 35 culverts along the railway track, six underpasses and five bridges. In these locations, due to insufficient width of the facilities, the principle has been adopted to integrate pedestrian and bicycle traffic.

Railway track grid on concrete structures (underpasses and bridges) will be disassembled and crushed stone removed, and then it will be covered with a coat of insulation material and then a 3 cm thick layer of poured asphalt will be made.

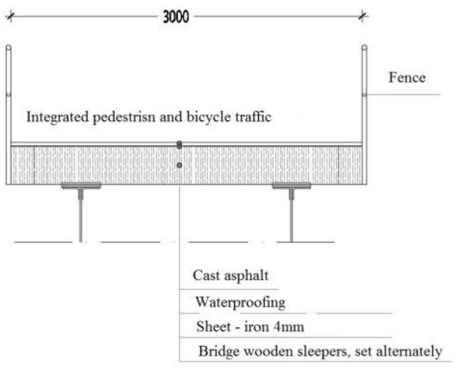

Fig. 9. Suggested reconstruction of steel railway bridge

As for steel bridges, one suggestions is to do the reconstruction by removing tracks and putting 4 mm thick steel sheet over the existing wooden ties, coated with Bridgemaster or some other type of insulation. Then 3 cm thick poured asphalt layer will be made over the insulation (Figure 9).

There is lush wild greenery along the majority of the route considering that the railway track has not been in use for over 10 years. It is predicted to keep and maximally preserve the existing autochthonous vegetation by appropriate care and protection.

The planned greenery would accompany the planned solution of pedestrian-bicycle path and would contribute to the overall appearance and recognition of the location. Green surfaces are designed as: linear greenery and green portals along the bicycle path; groups of high trees in landing zones; decorative greenery (both high and low) in the establishment zones.

The suggested seedlings are of high esthetic value without being invasive or allergenic, and they also provide a change of colours according to seasons.

4. CONCLUSION

The transformation of the public railway track Petrovaradin-Beočin into a greenway for pedestrian and bicycle traffic in the territory of the Town of Novi Sad and the Municipality of Beočin has resulted in creation of ambient entities, which should attract various groups of users.

In addition to comfort and safety in pedestrian and bicycle traffic there is also animation of users by additional contents, which contribute to the improvement of quality of social and recreational life of the residents in these areas.

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METHODS FOR DETERMINATION OF RESIDUAL STRESS IN RAIL

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Miodrag MALOVIĆ [3]

***Abstract** – The residual stresses in rails are generated during the manufacturing process and have uneven distribution in rail cross section. The residual stress is a part of basic tensile stress in rail foot. For used rail, the residual stress value of 80 MPa is commonly used in the engineering calculations. On the other hand, the standard EN 13674 prescribes residual stress values up to 250 MPa and destructive method using electrical strain gauge for measurement of rail residual stress. Since destructive measurement methods are unsuitable for use in the track, the possible non-destructive in situ methods for measuring of residual stresses in the rails are discussed in this paper. The fundamentals of X-ray diffraction, ultrasonic, magnetic and electromagnetic methods are explained, as well as, their advantages and disadvantages.*

Keywords – railway, residual stress, strain gauge, X-ray diffraction, ultrasonic measurement, magnetic measurement.

1. INTRODUCTION

For conventional and high speed railway tracks, the usage of Vignole railway rails of 46 kg/m and greater linear mass is specified in European Standard EN 13674-1 [1]. This standard applies to rails of 46 kg/m and greater linear mass and specifies 23 rail profiles. Furthermore, nine pearlitic steel grades are specified covering a hardness range of 200 - 440 HBW and including all types or heat-treated and non heat-treated alloy and non-alloy steels.

The destructive method for determination of longitudinal residual stress in rail foot is defined and described in [1]. In accordance with [1], the maximum longitudinal residual stress in the rail foot shall be up to 250 MPa for all steel grades. The maximum prescribed value of residual stress refers to the new or used (corroded) rail. Figure 1 shows the values of the residual stress in the corroded rails.

The residual stresses in rails are generated in the manufacturing processes: during hot rolling, uneven cooling, as well as, roller straightening and levelling. The mass of Vignole rails is concentrated in the rail head and the middle of the rail foot (Figure 1) affecting the cooling speed of rail profile and distribution of residual stresses. Furthermore, Figure 1 presents the distribution of residual stresses in rail head, web and foot for used rails [2].

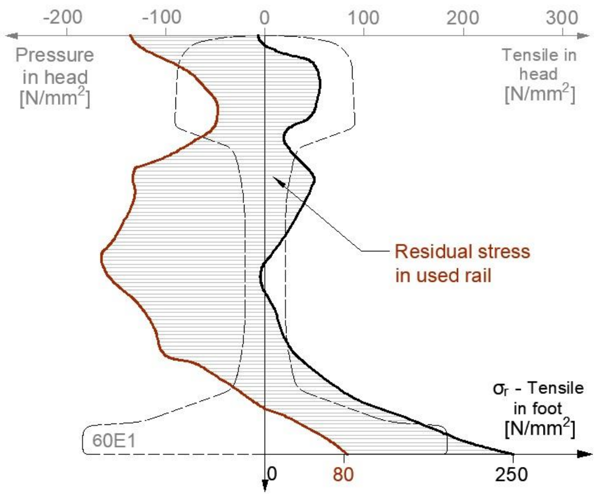

Fig.1. Distribution of residual stresses in rail profile

Residual stress in rail foot is a part of basic tensile stress in rail foot (Figure 2). In the engineering calculations, the residual stress value of 80 MPa is commonly used [3].

In this paper, we present a destructive measurement method in accordance with EN 13674. Non-destructive measurement methods for residual stress measurements that could be applied to rails

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installed in the track are also presented.

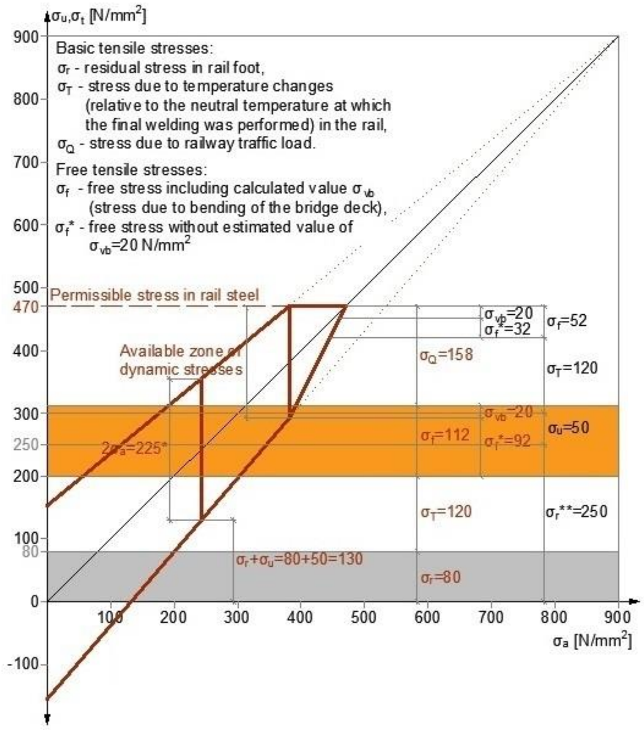

Fig.2. Smith diagram for corroded rail 60E1/900

2. METHOD FOR THE DETERMINATION OF RESIDUAL STRESSES IN ACCORDANCE WITH EN 13674

In accordance with [1], residual stresses are determined on one-meter long rail that is set aside for this purpose. The electrical strain gauge is attaching to the foot surface in the middle of the rail in the longitudinal direction, as presented in Figure 3.

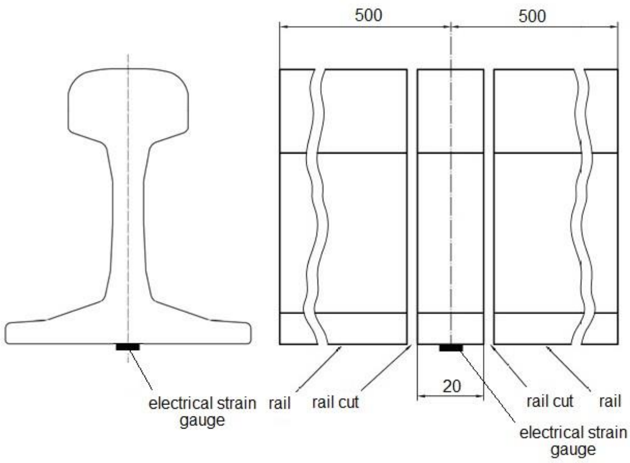

Fig.3. Preparation of rail and rail slice

The gauge is 3 mm long, encapsulated type, and its gauge factor accuracy must be better than 1%. It measures average strain along its length. The first strain measurements are taking in that state. After that, two saw cuts are performing in order to remove a 20 mm thick slice from the middle of the rail. (Figure 3), while cooling the rail to maintain on the constant temperature. A second set of strain gauge measurements is taking on that rail slice as relaxed strains. The relieved strain is estimating from the differences between the first and second sets of measurements. That value with changed sign is multiplying by 2.07 x 105 MPa in order to calculate residual stress.

3. NON-DESTRUCTIVE METHODS FOR THE DETERMINATION OF RAIL RESIDUAL STRESSES

Besides destructive, there are methods for nondestructive evaluations of stress in steel. Some of them like laboratory and synchrotron X-ray diffraction and neutron diffraction are suitable for laboratory use only. Portable instruments based on X-ray diffraction (XRD), ultrasonic, magnetic and electro-magnetic principles could be used for in situ measurements.

3.1. X-ray diffraction

The most used non-destructive method for evaluating residual stresses is XRD. It is based on the interactions of the wave front of the X-ray beam, and the crystal lattice of investigated material. In real ferromagnetic materials, there are domains with different orientation of crystallographic planes as presented in Figure 4.

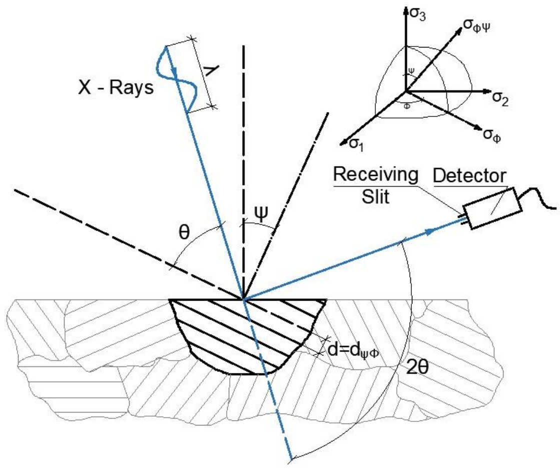

Fig.4. X-ray diffraction method geometry

When X-ray beam of wavelength λ incidents on the material atoms at angle θ to the atomic planes (Figure 4) the diffracted rays from the different planes at distance $d=d_{\psi\phi}$, will constructive interfere at the detector and thus have maximums in detected signals for angle θ obeying Bragg’s law (1) where z is an integer.

$$2 \cdot d \cdot \sin\theta = z \cdot \lambda \tag{1}$$

From practical measuring angle equals 2θ, between the directions of incident and diffracted rays d can be estimated. Since orientation of crystallographic planes is not parallel to the material surface, angle ψ, between incident ray and a normal to the material surface and an azimuth angle ϕ have to be measured in order to define the beams directions connected to main coordinates of the material primary strains and stresses σ_1, σ_2 and σ_3 (Figure 4). At XRD graph of signal intensity versus 2θ, maximums correspond to distances $d_{\psi\phi}$ of various directions [4].

In a case of residual stress there is a difference between the distance $d_{\psi\phi}$ and corresponding distance d_0 of non-stressed material. By changing the incident angle ψ, X-ray wavelenth or using two detectors the strain and then residul stress σ_ϕ can be evaluated even without known d_0. This is cheap and quick method for obtaining surface biaxial residual stresses in small measuring volumes. For the high intensity residual stresses the nominal accuracy is 20 MPa for steel. The main disadvantage is small penetration depth that is up to 30 μm and unknown elastic constants of steel crystall latice for all directions. In order to calibrate system and apply appropriate modelling for residual stress estimations the same slice samples are measured with more accurate and deeper penetration laboratory destructive and not destructive methods.

3.2. Ultrasonic technics

The speed of ultrasonic waves travelling through a material are affected by the direction and magnitude of the present stresses. Base on this acoustoelastic effect, ultrasonic waves in a frequency range (2 - 10 MHz) are using for measurement of applied and residual stresses. The average velocity of ultrasonic waves is measured along some path and this method is most sensitive when the path and material particle motions are parallel to the direction of stress [5].

Different types of waves can be employed but the commonly used are the longitudinal critically refracted (*Lcr*) waves [5] which travel just beneath and parallel to the specimen surface. The measurement equipment for the time of flight (TOF) measurement consisting of one transmision and one or more receiving ultrasonic sondes connected in plexigal wedge at fixed distance is presented in Figure 5. The *Lcr* waves are passing fixed length L for TOF $t=L/v$ in stressed material, and for $t_0=L/v_0$ in stress-free material, where v and v_0 are corresponding wave velocities. In the range of elasticity, the average residual stress along the path compared to stress – free material, σ is given by equation (2)

$$\sigma = \frac{1}{K \cdot t_0} \cdot (t - t_0) \tag{2}$$

The constant K, an acoustoelastic constant, depends on the type of waves, elastic properties of material, direction of wave propagation and should be known from some calibrating tests on the same or similar samples. For increase in stress of 10 MPa TOF difference is about 10 ns for the rail steel.

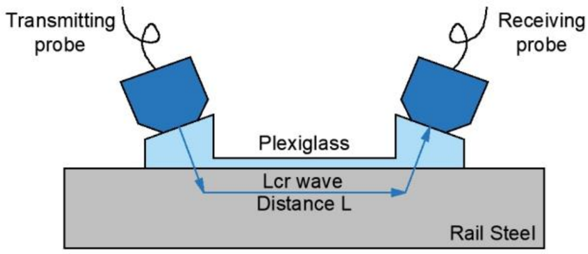

Fig.5. Ultrasonic method

The speed of ultrasonic waves also depends upon temperature and microstructure changes of the steel. Changes in temperature can be corrected by simultaneous temperature measurements. The acoustic methods enables accurate tri-axial high residual stresses measurements, at penetration depth up to 150 mm. Required stress-free reference, sensitivity to microstructural changes, average stress measuring over relatively large gauge volume and difficult to specify spatial resolution are dissadvantages of the method. It is suitable for in situ residual stress changes detection on the same rail.

3.3. Magnetic and electro-magnetic measurements

The most of the magnetic characteristics of ferromagnetic materials are influenced by mechanical stresses. In the non- stress ferromagnetic material each domain is magnetized in one direction and during magnetizing-demagnetizing process the volume and magnetic orientation of domains are changing. The magnetic flux density or induction vector B in a material is changing versus applied magnetic field in cycling procces, presented with magnetic hysteresis loop in Figure 6 [6]. The characteristic values on graph B_r (remanence) and H_c (coercetivity), permeability $\mu=B/H$ and others can be evaluated as a non-stressed material parameters. In case of applied or residual stresses in material, the boundaries between domains called domain walls are moving [6], and the magnetization orientations of the domains are changing. Under tensile stressess the domains with the same magnetization orientation as stress are enlarging and thus increase magnetization in that direction. The compressive stresses enlarge domains with transverse magnetization orientation and increasing magnetization in the direction perpendicular to stress directions. So, the residual stresses lead to change in the magnetic characteristics, and the hystersis loop. This is the foundataion of one of mobile type instruments, MAPS (Magnetic Anysotrophy and Permeability System) for residual stress measurements [6] designed for manual probe manipulation that measures simultaniously a large number of magnetic parametars from hysterezis loop. The penetration depth of measurements is from 0,1 - 5 mm controlable by the frequency of applied magnetic field and spatial resolution is from 5,2 – 15,5 mm depending of a probe type. Obtaining complete biaxial stress measurement lasts less then 2 minutes.. This system has to be calibrated against known stress levels for the investigated material [6].

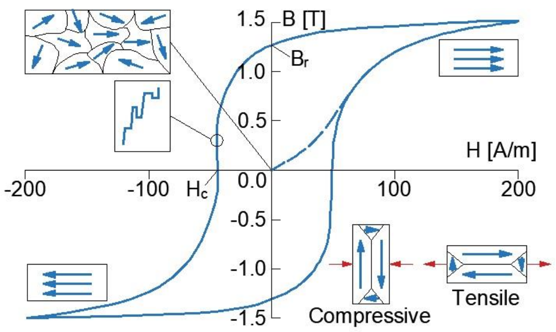

Fig.6. Magnetic domain alignment during magnetisation and under stress

The MBN (Magnetic Barhauzen Noise) method is based on Barkhausen effect. In the insertion in Figure 6 it is presented that changing of B is happening in discrete steps (Barkhausen jumps). Those sudden changes in B can be measured with pick up coils above the surface of a material and the typical voltage pulses in the signal are obtained. The variation of MBN signals shape, the number and values of peaks, the RMS (root mean square value) of the overall MBN signal over a number of cycles indicate the changes of magnetic material structure due to stress. If the frequency of applied alternating field frequency is higher than 10Hz the depth of this measurements is 20 μm, while for low frequency (0.1 - 1Hz) the penetrating depth is of order of 1 mm, and can be used for evaluation of subsurface stresses.

The ACSM (alternating current stress measurements) technique of stress measurement is based on ACFM (Alternating Current Field Measurement) technique of defects detection. The coil with alternating current induces currents in the metal surface that are unidirectional and uniform in the non-stressed material without defects. These induced currents produce the magnetic field above the surface which is measured in two directions. Small changes measured in the strength and the direction of those magnetic fields by array of magnetic sensors or sensing coils can be related to changes in stress state of a material and ACSM output signal is almost linear versus applied stress. This is non-contact, rapid technique, sensitive to both tensile and compressive stresses and does not need special surface preparation. It is better for stress changes measurements than for absolute stress measurements [7].

4. CONCLUSION

Because of higher speeds, as well as increased axle and traffic loads, measurement of residual stresses in new and used rails has assumed great importance on modern railways in recent years.

Residual stresses in rails can significantly influence the risk of the rail break, track stability, railway superstructure design as well as the life span of rails in track.

In accordance with [1], residual stresses shall be estimate during destructive cutting method. This standard method is not applicable to control the rail residual stress in the track. There are several non-destructive methods for measurement of rail residual stresses in situ such as X-ray diffraction, ultrasonic, magnetic and electromagnetic methods. The physical principle of each method is presented in order to explain their advantages and disadvantages. All that methods have to be calibrated and compared with laboratory destructive and non-destructive methods.

ACKNOWLEDGEMENT

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Vehicle and infrastructure maintenance

XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

STATIONARY AND ON-BOARD DIAGNOSTICS FOR RAILWAY VEHICLES

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Abstract *– Monitoring and inspection of railway vehicles is an essential part of vehicle maintenance. Maintenance of the railway vehicles is one of the most important tasks to guarantee the safety and efficiencies of railway transport. Because modern day maintenance is based on high quality diagnostics and in the analysis of the measured data, modern diagnostic systems are presented in this paper. Those systems can be on-board systems and stationary diagnostic systems. On-board diagnostic systems are positioned on the vehicles and they are used for their continuous monitoring. Stationary diagnostic systems can be positioned near the tracks (wayside diagnostic systems) and in the workshops (this type is used during the maintenance service of the vehicle). Both solutions are used for periodical vehicle inspection. Whether it is about of on-board or stationary diagnostic system, proper information about correctness and efficiency of railway vehicles or their components and parts are provided. These information could be later analyzed and used in order to predict failures of vehicle components and according that successful and effective maintenance of vehicles can be performed.*

Keywords – Railway vehicle, maintenance, monitoring, on-board diagnostic, stationary diagnostic.

1. INTRODUCTION

Maintenance activities on the railway vehicles are necessary to maintain their functionality and availability [1].

Maintenance of the railway vehicles in Serbia is not on the required level as it is in the developed world countries. Vehicle maintenance has been covered by law order list of repairs given the vehicle status (years in service and mileage), or in the case of breakdowns.

Given the stage of reconstruction and modernization of the railway vehicles and procurement of the new modern vehicles, old and conventional maintenance methods must be overcome and replaced.

The following text of this paper will show flaws and imperfections of the conventional methods that are in use and present the possibilities and advantages of modern-day systems (on-board and wayside detection system) as well as their applications with their further development.

2. CONVENTIONAL MAINTENANCE METHODS

Periodical inspection of the railway vehicles is required in order to prevent any dangerous situation [2].

Maintenance of railway vehicles is divided into:

- Preventive (before break down) maintenance and
- Corrective (after break down) maintenance.

Regular or preventive maintenance consists of actions, planned in order to prevent break down or other problem occurrence of equipment [3].

One of the actions is visual inspection of technical correctness of the equipment, which is done:

- During the preparation of the vehicle for its usage;
- During the vehicle is in use, and
- After it has finished working.

This control is under the jurisdiction of the trained technical personnel and they are responsible for correctness of all parts, assemblies, devices and aggregates of the vehicle. Most of these activities are

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manual.

The other type of vehicle maintenance is irregular maintenance. This type of maintenance is present when vehicle has suffered accidental failure [3]. This condition can be caused by crash or by some other extraordinary event (failure of some element of the vehicle or its worsening).

One of the main reasons of maintenance irregular maintenance performing is absence of automatic monitoring system, which could predict equipment and device failures of railway vehicles. This has direct impact on the transport planning integrity.

Parallel to modernization and procurement of new modern railway vehicles, new maintenance methods, as well as the diagnostic systems, should be developed and applied.

3. MODERN DIAGNOSTIC SYSTEMS

Diagnostic systems are mainly used to support the maintenance process [4].

Modern diagnostic systems (fig 1) can monitor the vehicles in operating conditions on different terrains, to check correctness of parts, to predict services and provide users with data bases, which could be used for further analysis. Newer railway vehicles already have embedded some standard diagnostic systems. Numerous sensors and information technics enables computer control of the vehicle. Also, vehicle management is possible even from outside of it.

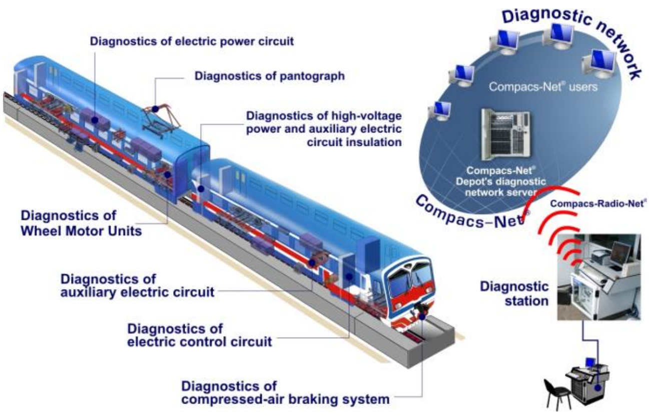

Fig.1. Modern diagnostic train systems [5]

This way, monitoring of the whole system is constant, quick, reliable and safe.

Automatic diagnostic system can be:

- On-board diagnostic systems, which are mounted on the vehicles, or are its basic part.
- Wayside systems, which are stationary systems, positioned near the railway infrastructure.

The distinction between stationary and on-board diagnostic systems is made on the basis of diagnosis frequency and vehicle suitability; with stationary systems being used for periodic inspections and on-board equipment for continuous monitoring of operational status [4].

3.1. On-board systems

Diagnostic systems that are positioned on the vehicle (on-board diagnostics) can provide users with endless flow of information about targeted vehicle components while operating. Those systems can enable constant safety and comfort supervision.

This means that monitoring of chosen parts is constant; computer analysis of collected database is provided; early detection of possible irregularities on monitored components; adequate assessment of occurred damage, as well as the possibility of the fast response in rectifying current defect [3].

On-board diagnostic systems can be used for monitoring various parts and assemblies, such as: contact pantograph – contact line; wheel-rail contact; bogie; axle bearings correctness; diesel and electric motors; breaking system; side doors; air conditioner and ventilation systems, etc [6].

The most important characteristic of the on-board diagnostic system is that it provides status information on a train's current running behavior [4].

Amini et al [7] has suggested an acoustic emission (AE) condition monitoring system for on-board detection of railway axle bearing defects.

Deterioration of the structural integrity of axle bearings can increase the risk of failure and hence the possibility of delays, costs and derailments, increased levels of vibration, noise and temperature. All of these negative effects can be a sign of a developing defect.

Following system has been developed in order to prevent such negative impacts to occur (fig 2).

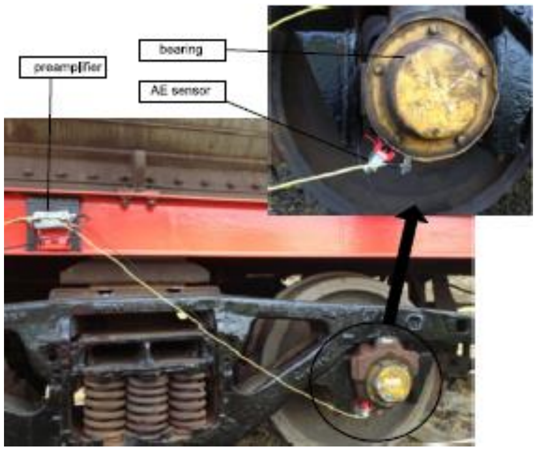

Fig.2. AE sensors on the axle bearing [7]

This system can detect an axle bearing faults especially at an early stage of its problem evolution. Proper axle bearings are producing sounds of certain frequencies, given by the manufacturer. AE sensors, closely mounted to the source of sound (as close as possible to the bearing) can measure the produced sound, while being in use, and record those results for further analysis. Defected axle bearing will show deviations in sound frequencies (fig 3).

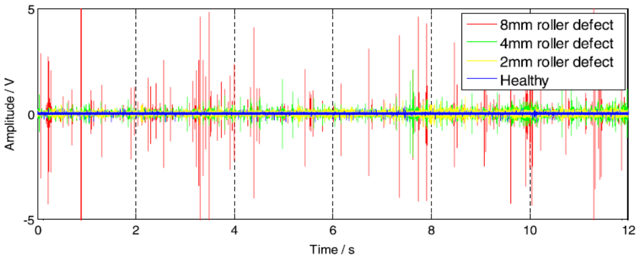

Fig.3. AE data comparison of the bearings with different defect sizes [7]

The results given by the acoustic analysis can show which axle bearings are safe and which are potentially dangerous.

Bosso et al [8] measured acceleration on the axle-box of a vehicle and analyzed collected data in the time domain in order to detect wheel flats.

A wheel flat is one of the defects occurring to the wheels of railway vehicles during service life. This defect is related to the occurrence of anomalous braking events leading to the locking of axle rotation, with the consequence of a complete sliding at the contact and heavy wear of the wheel surface.

The used method for prevention of wheel locking during braking is given by the limitation of the brake force in relation with the weight acting on the bogie and measured with a device usually linked to one of the suspensions (fig 4).

Fig.4. AE data comparison of the bearings with different defect sizes [8]

Wheel corrugation and wheel flat play an important role, also in noise generation. The immediate detection of the flat formation can be also correlated to the braking occurrence if the braking system is also monitored, in order to develop strategies to reduce the occurrence of this event [8].

3.2. Wayside systems

Wayside diagnostic systems are stationary diagnostic systems, which are used for periodical inspection of correctness of the railway vehicles. These systems are installed near the tracks. Stationary diagnostic systems can also be installed in the workshops.

Stationary diagnostic systems that are installed inside the workshops can be used for the inspection of the certain assemblies of the vehicles, which are excluded from the traffic. On the contrary, wayside systems that are installed outside, on the railway infrastructure, can be used for the inspection of the certain components of the vehicles, which are used in railway traffic [9].

Basic principle in which these systems function is that railway vehicle is passing diagnostic part of the system at some slow speed in order to collect necessary data from inspection part of the system. After the data is collected, the further analysis can be made to predict the scale of intervention that needs to be done [3].

The main role of the wayside diagnostic systems is monitoring of the contact between the wheel and the rail. Failures that occur in this contact can lead to catastrophic consequences.

Lagneback [9] points out two types of wayside diagnostic systems:

- Reactive and
- Predictive systems.

Reactive systems detect annual faults on the vehicles; many of these faults are hard to predict or have very short failure to fault time. In most cases the information from these systems is not suited for trending, but is of importance to protect the equipment from further damage due to the fault. The systems also have reactive characteristics and they do not use the information in a trending way, even if the information could be used in a reactive way.

Some examples of reactive systems are: detectors for detecting the parts of the carrying wagons that exits from the load profile; overheat detectors of the axle bearings and heat detectors of the wheels; detectors of creep wheels, etc [3].

Predictive systems are capable of measuring, recording and trending the ride performance of the vehicle and its specific components. From the collected information, it is possible to analyze the condition of the equipment to predict possible failures and faults that may occur in a near or distant future. This makes it easier to plan the maintenance activates ahead and also to utilize the equipment in a more efficient way [9].

Some examples of these systems are acoustic detection of axle bearing failure; monitoring of vehicle performance; monitoring of wheel condition and video supervision of the vehicle [3].

Bannasch et al [4] describes a system that is currently in use for detecting the extent of wear on the brake pads of disk brakes. This system has recognition software that detects type of vehicle and prepares inspection unit (wheel sensors) for it. As the train is passing by a speed of 5-8km/h, diagnostic equipment starts individual cycles for every wheelset (around 400 brake pads). The relevant wheel geometry parameters, i. e. wheel flange height, wheel flange thickness, transverse dimension, flange gauge and clearance dimension are measured. The concentricity module is responsible for measuring radial runout and any wheel flats defects (fig 5).

The results from the every inspection are stored and can be accessible and analyzed.

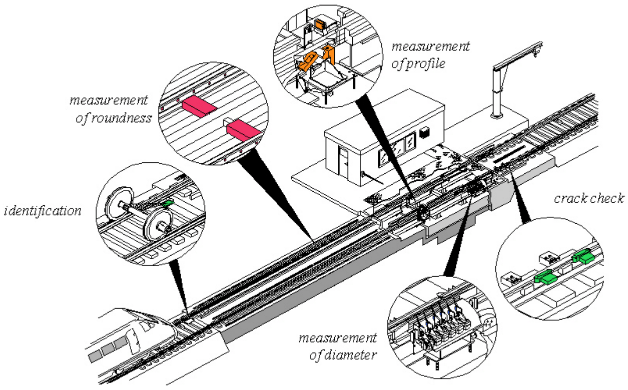

Fig.5. The wheelset diagnostic facilities [4]

The most important characteristic of this system is that it allows a complete wheelset inspection to be carried out as the train travels by it at its low speed.

Zhang et al [10] has proposed a wayside acoustic diagnosis system for detecting possible defects of bearings on the railway vehicles.

Conventional train has hundreds of wheelset bearings to support his entire weight. In addition, those bearings need to rotate at high speed.

Defective train-bearings may cause serious accidents. In order to prevent such accidents from happening, systems like the proposed one are developed and installed.

System that is presented by Zhang [10] is based on non-contact measurement technology. It consists of a set of microphones array near the track (fig 6).

This system acquires acoustic signals and detects bearing faults that the acoustic signal generated by the bearings contains relevant diagnostic information.

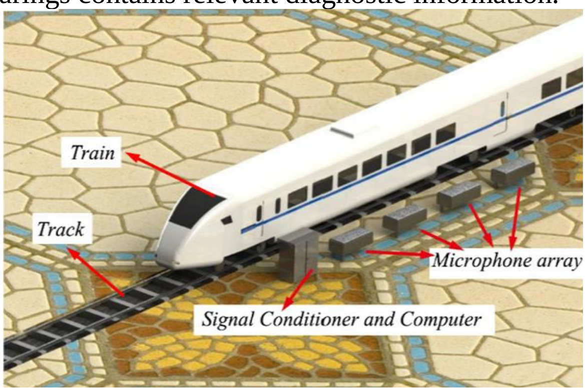

Fig.6. Model view of the presented system [10]

The main problem of a system as such is Doppler effect and multiple acoustic sources along with the sounds generated by defected bearings. Those two problems are overcome by the usage of enhanced computer software.

Problems such as this do not affect same on-board system (which are contact based devices), but in addition to wayside system, they can cover much wither field of observation.

4. CONCLUSION

A major step towards improving the quality of railway sector services, i. e. higher level of operational safety and availability, can be taken by employing intelligent stationary and on-board diagnostic techniques and integrating these with intelligent, applications-driven data analysis and management systems.

The governing statement that must be followed is that modern day maintenance is based on high quality diagnostics and in the analysis of the measured data.

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BREAKING OF COUPLING OF TRAINS ON THE SERBIAN RAILWAYS

Marija VUKŠIĆ POPOVIĆ [1]
Saša RADULOVIĆ [2]

Abstract *– This paper proposes an analysis of breaking of train coupling which occurred on the Serbian Railways (ŽS) in the period since 2007. by 2011. The problem of longitudinal dynamic forces, especially in freight trains, is most evident in the Serbian Railways, and for the reference period breaking of coupling of freight train occurred on a total of 201 cases (an average of 40.2 cases per year). Analysis of breaking of freight train coupling will be done based on number and place of breaks relative to the length of the freight trains, driving regime of trains, speed before breaking of coupling, damaged parts, causes of train breaks, etc. This analysis will identify the main factors that affect more frequent emerge of freight trains breaking of coupling, in order to prevent accidents and improve safety in freight railway traffic.*

Keywords – railway, trafic safety, accident, breaking of train, breaking of coupling, break couplers, train breaks apart.

1. INTRODUCTION

The basic indicators of railway traffic safety are the number and types of accidents [1]. According to Regulation 19 [2] registration, statistical monitoring and publishing data of the accidents and incidents occurring in rail transport and other cases relevant to the safety of railway traffic were obligatory in reference period. The provisions of Regulations [3] define concept and types of accidents on the Serbian Railways. Accidents are defined as cases in which one or more persons were killed or injured, or caused damage to property, or there has been a disruption, danger or obstruction of railway traffic.

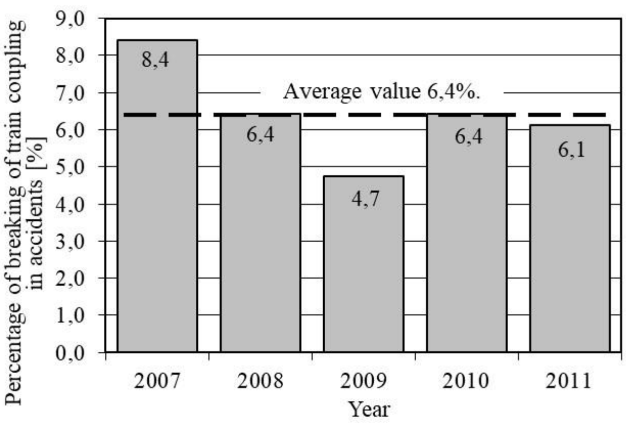

Fig.1. Percentage of breaking of train coupling in accidents on ŽS in period 2007-2011.

The number and types of accidents, reported in nominal and relative terms, are the primary indicator of railway traffic safety. The number of accidents per millions of tonne-kilometres (million tkm) is relative number of accidents.

The average number of accidents on the Serbian Railways in the period 2007. - 2011. is 558,2 accidents. During this five year period, there were a total of 210 cases of breaking of train coupling which amounts to an average of 42 cases per year (Fig.1). Breaking of coupling of trains in total number of accidents of reference period is approximately 6,4%.

2. BREAKING OF COUPLING OF FREIGHT TRAINS

Average 95,8% of breaking of coupling occurred on freight trains in the last five years, which amounts to a total of 201 cases or 40,2 cases per year (Fig. 2). Less than 2 cases per year 4,2%, occur on passenger trains. Therefore, further analysis will be performed in cases of breaking of freight trains coupling.

There are two types of trains breaks apart according to cause and consequences:

- when freight trains have only one traction (pulling) locomotive,
- when freight trains have two locomotives, one pulling and other pushing.

Breaking of freight train coupling with only one locomotive occurs in 80,6% and with two

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locomotives, (one pulling and other pushing) in 19,4% of relevant cases in reference period (Fig. 3). In the analysis were taken into consideration only the relevant cases e.g. breaking of freight trains coupling with only one locomotive, and disregard breaking of semi-automatic coupling as well as other special cases.

Fig.2. Breaking of train coupling for passenger and freight train

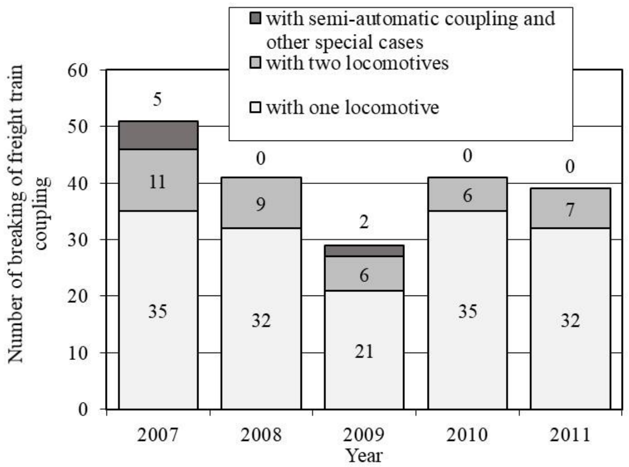

Fig.3. Number of breaking of freight train coupling

Breaking of freight train coupling with pulling and pushing locomotives occur, in most cases, when it comes to forced braking on the pushing locomotive, whether the cause is human or technical error. Trains breaks apart in two or more places, more frequently (approximately 30% of cases) with this typ of traction. Primarily cause of the breaks in this cases, were poor synchronization of pulling and pushing locomotives.

Breaking of trains coupling is result of a large longitudinal dynamic forces in trains, due to traction or braking forces. Large longitudinal dynamic forces in a composition that lead to breaking of trains coupling depend of circumstances, such as state and type of traction and braking devices, the conditions of exploitation etc.

Factors that increase the longitudinal dynamic forces in the train, and thus the occurrence of potentially breaking of coupling of trains, among others are [4]:

- Braking regime (G/P) - P braking have a shorter braking time, i.e. braking force is rapidly evolving and increase longitudinal dynamic forces;
- Length of train - with increasing length of trains (at the same train weight) the longitudinal dynamic forces were increased;
- Composition of the train - empty or two-axle car at the front of the train increasing longitudinal dynamic forces;
- State of coupling - the loose coupling in train increase longitudinal forces approximately 25% relative to thight coupling;
- Mass of the train - with increasing mass of the train longitudinal dynamic forces are increasing;
- Draw gear etc.

3. ANALYSIS OF BREAKING OF FREIGHT TRAINS

Breaking of trains coupling analysis should point out when and where to expect the occurrence, in order to apply preventive measures to reduce the number of breaks.

Analysis of train breaks apart can be done in respects of:

- Number and position of breaks relative to the length of the trains (compositions),
- Driving regime of the train,
- Speed of the trains,
- Composition of the trains, (number of wagons, the length and weight of the trains, etc.),
- Causes of breaks,
- Result of a breaks (economical and logistic),
- Damaged parts etc.

3.1. Number and position of breaks

Freight trains with only one locomotive, have train breaks mostly at one place (i.e. train breaks apart in two parts) in 91% of relevant cases in reference period. Only in 7,1% of cases there are breaks at two places on the train (i.e. train breaks apart in three parts), or in 1,9% of cases train breaks at three places (Fig. 4).

Breaking of freight trains coupling operating with only one locomotive relative to the length of the train (composition) show that 59,1% of breaks occur in the first third of the train length, with 32,9% between locomotives and first wagon (Fig. 5); 17,7% of trains breaks usually occur between first third and second third of the train length.

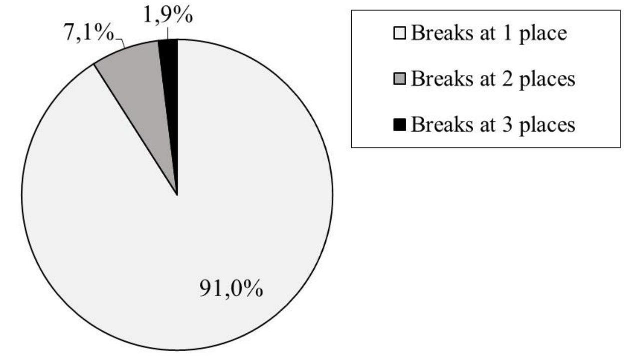

Fig.4. Percentage of places of freight train breaks

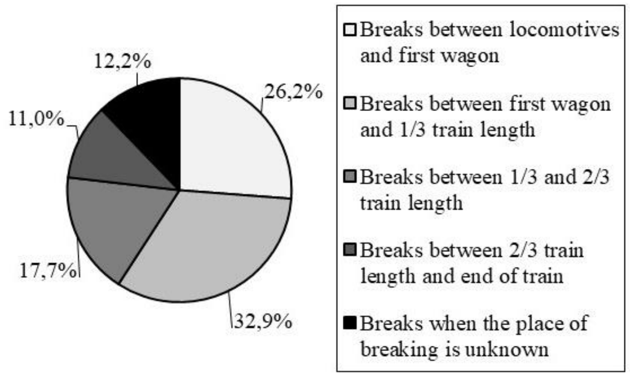

Fig.5. Position of breaks relative to the train length

3.2. Driving regime before breaking

Breaking of freight trains coupling operating with one locomotive mainly occur during braking - 53% and pulling – 22% (Fig. 6), while only 9% of breaks occur during driving. In 11% of break cases driving regime wasn`t determined. In several cases there was a breaking during train pushing with one locomotive (5%).

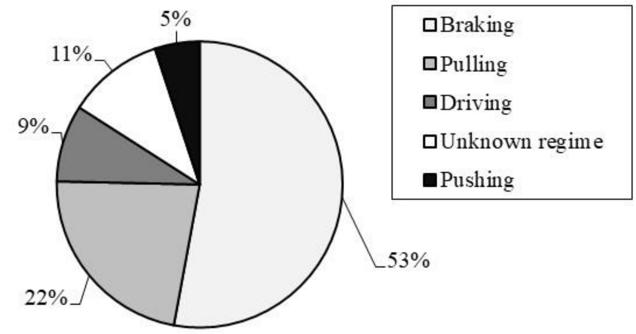

Fig.6. Driving regime before breaks

Correlation between driving regime and position of breaking relative to the train length show that dominant driving regime before breaks, between locomotives and first wagon, are pulling and braking (Fig. 7), and in the rest of the train length most dominant is braking.

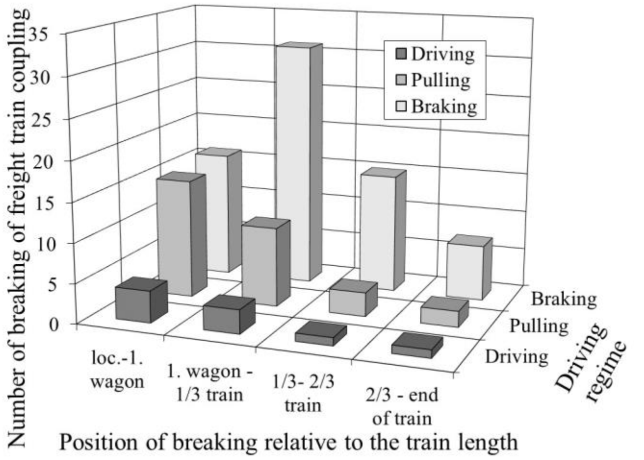

Fig.7. Correlation between driving regime and position of breaking relative to the train length

3.3. Train speed before breaking

In most cases, train speed before breaking was below 30 km/h (70,4%, Fig. 8). As the low speed and number of starts and stops (traction and braking) more frequent in the railway station and railway yard, approximately 45% of trains breaks occurred in this area.

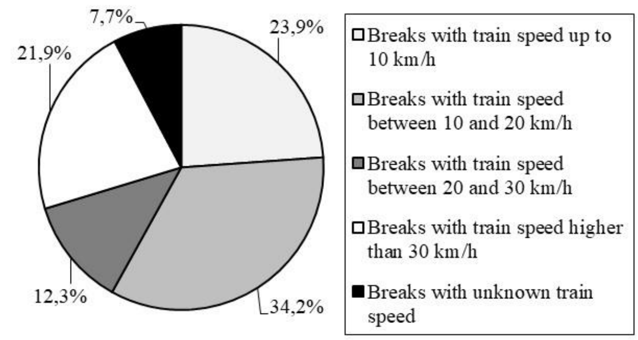

Fig.8. Train speed before breaks

Correlation between driving regime and train speed demonstrate that most dominant driving regime before train breaks is braking (Fig. 9) in all train speeds, exept speed up to 10 km/h.

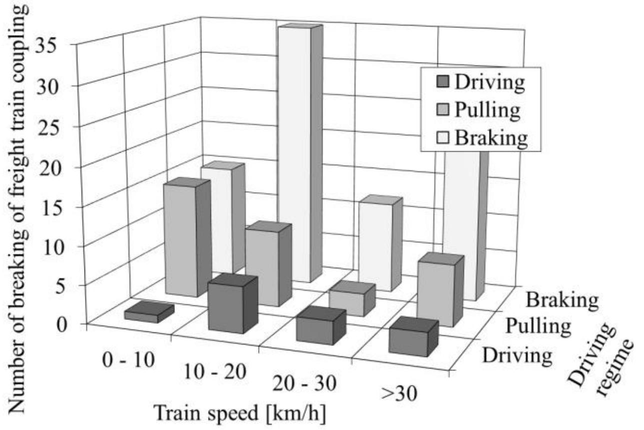

Fig.9. Correlation between driving regime and train speed

3.4. Damaged parts

Most damaged parts in train breaks are (Fig. 9):

- Coupler in 30,8% of cases and
- Draw gear in 46,2% of cases.

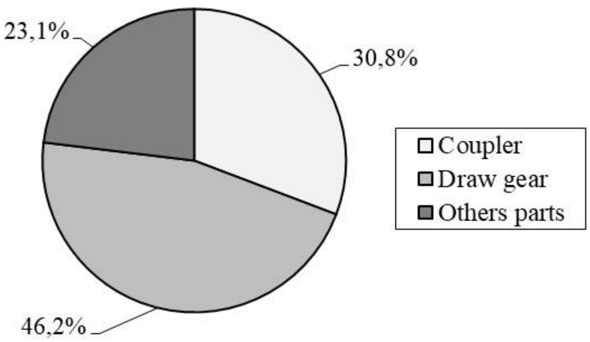

Fig.10. Damaged parts in train breaks

Damage to other parts were occured in 23,1% cases. Mainly was damageed either coupler or draw gear, and rarely, in approximately 12% thay were damageed at the same time.

3.5. Causes of train breaks

Most mentioned cause, of trains breaks apart was state of the material of damaged part, in 50,8% of cases (Fig. 10). Very present were uncorect driving of train with 15,5% and inadequate composition of train and uncorect coupling (according to regulations [5]) with 19,9% of cases. Other and unknown causes makes 13, 8% of cases.

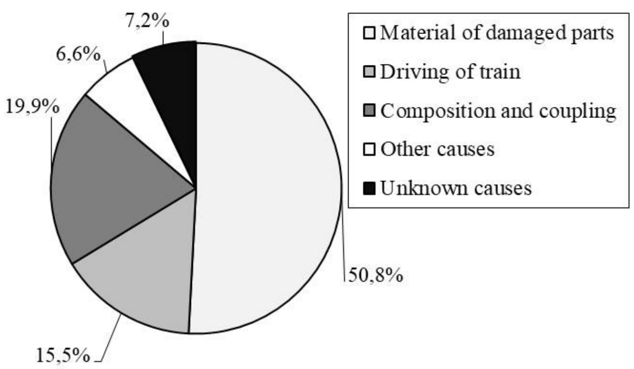

Fig.10. Causes of breaks

3.6. Other factors of train breaks

Other factors of train breaks, such as composition of the trains or product of a breaks are not clearly distinguished.

Analysis could not confirm dependence of train composition on the train breaks, because the breaks occurred on composition either it was in accordance with the Serbian Railways regulations [5] or not nearly in the same number.

Correlation between length and mass of the train is not distinguished, because the length of the trains breaks ranged from 152 m to 720 m, with averige lenght of 394,6 m. The minimum number of wagons in freight trains who broke apart is 10, and the largest number of wagons is 51. It should be noted that the average freight train in reference period have 26,7 wagons. Correlation between mass of the train wasn`t defined, mass of trains that broke apart was from 527 t to 2333 t. The average mass of a train in reference period was 1347,6 t [1].

Direct material damage of train breaks was approximately 100,000 dinars, and traffic delay was approximately 3 to 4 hours by train breaks.

4. CONCLUSION

In order to deliver appropriate conclusions and propose concrete measures to reduce the number of train breaks on Serbian Railways we perform analysis of break cases in a five-year period from 2007. to 2011. Actual value of the longitudinal dynamic forces in the freight trains corresponds to the current state of trains, therefore thay can deviate from values obtained in some tests, e.g. ERRI [4] from 90's.

In cases of freight train with one locomotive primary cause of the train breaks apart was state of the material of damaged part, as data collected according to Regulation 19 [2] show (Fig. 10). Secondary cause of the train breaks was uncorect driving of train and third inadequate composition of train and uncorect coupling.

In 58,1% of cases, train speed before breaking was below 20 km/h, and approximately 45% of trains breaks occurred in railway station and railway yard as result of frequent number of starts and stops (traction and braking). That conforms manner of train driving as one of significant causes of train brakes.

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CURRENT SITUATION CONCERNING RAILWAY MAINTENANCE REGULATIONS IN THE COUNTRIES OF THE FORMER YUGOSLAVIA

Tatjana SIMIĆ[1]

***Abstract** – Improving connectivity within the Western Balkans, as well as between the Western Balkans and the European Union, is a key factor for growth and jobs and will bring clear benefits for the region's economies and citizens. However, it is not only infrastructure that will enhance connectivity. Implementation of technical standards is of significant importance, as well as national regulations and soft measures such as aligning and simplifying border crossing procedures, railway reforms, information systems, railway safety and maintenance schemes, railway unbundling on the operator and infrastructure and third party access. The infrastructure manager has the obligation to maintain the elements of the railway infrastructure so that they are reliable and available for safe and competitive railway traffic on the railways. During the maintenance, all elements of the railway infrastructure are exposed to the procedure of inspection, repair or improvement of some elements of the infrastructure, thereby removing the fault, improving the existing condition and extending the working span. Compliance with maintenance regulations and defined criteria (limits permitted) are the responsibility of Infrastructure managers in order to make railway infrastructure technically reliable, technologically available and safe for rail transport. In the past period, countries of the former Yugoslavia have made the modification and adaptation of the existing national regulations (which have been prepared based on the existing regulations for the maintenance of the Yugoslav Railways Union) according to the railway standards of the European Union. Through the set of agreements signed in the last years, regarding the reconstruction and modernization, some of these parts cover the future maintenance. The following text will present the research of the current state of the Rulebooks and general criteria, which are extracted from the Rulebooks, as one of the important factors in making decision when, where and how to start railway maintenance in the countries in region.*

Keywords – railway maintenance, regulations, Infrastructure Manager, criteria.

1. INTRODUCTION

It should be pointed out that in EU legislation, the issue of rail maintenance has been tackled through the recast Directive 2012/34/EU on establishing a single European railway area. The Directive contains provisions relating to development plans (short and midterm), including maintenance, contractual relations between the state and the infrastructure manager (securing sufficient capacity during maintenance work) as well as provisions on the financial sustainability of the IM. The infrastructure manager has the obligation to maintain the elements of the railway infrastructure so that they are reliable and available for safe and competitive railway traffic on the railways. All elements of the railway infrastructure during maintenance are exposed to the procedure of inspection, repair or improvement of some element of the infrastructure, thereby removing the fault, improving the existing condition and extending the working span.

Maintenance of infrastructure elements basically needs to respect two opposing requirements:

1. to achieve minimal maintenance costs;
2. to achieve the maximum reliability of infrastructure elements.

Harmonization of these two requirements at the same time would be very difficult, so the Maintenance and Renewal (M&R) are based on a compromise, that is, an attempt to achieve as much security and reliability as possible with minimum costs, while respecting national regulations within the framework of M&R. These regulations define the minimum standards that must be met in order to make the railway infrastructure technically reliable, technologically available and safe for rail traffic.

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1.1. Main observations about the current M&R practices in countries of the former Yugoslavia

Information on real manner in which M&R is performed and with respect to the relevant regulations, makes one of the inputs for the definition of strategy for M&R. Based on the strategy, the infrastructure manager should further adopt a Business Plan (BP), including investments and financial programmes. The BP should be designed so as to ensure optimal and efficient use, provision and development of the infrastructure, while ensuring financial balance and providing means for M&R.

The Current maintenance plans are being prepared on an annual level within the construction and electro works, based on an analysis of the current state of the infrastructure in the field. The analysis of the existing condition is done mechanically or manually, by checking the state of the electrical devices and equipment, as well as the elements of the substructure and superstructure of the line. Disagreement between the planned and accomplished works within the maintenance plan that contributed to the present poor state of the railways, and according to the information of the RP, it is recognized through the following common items:

- Lack of funding received for the draft maintenance plan and proposed works:
- Lack of human resources and qualify staff
- Lack of mechanization

1.2. Criteria by types of works under the National Regulation

The application of regulations in maintenance practice (railway infrastructure) is directly related to data measured and recorded on the field, classified by type of works. Deviations from the defined criteria (in the part of maintenance of existing elements) which are taken from the Rulebooks are the first step to initiate the requirement for the preparation of the maintenance plan.

The main task of analyzing and reviewing the national regulations adopted by RPs was to establish a correlation between the existing regulations in order to allocate common criteria, in defining the existing state of the infrastructure. In accordance with the regulations, basic groups of works with their subgroups are highlighted as shown in Figure 1.

For each of the listed subgroups of works, in accordance with the valid regulations, common maintenance criteria have been selected. The current situation on the ground is determined by regular field visits by expert services and manual or mechanic measurements, depending on the needs. The expert services prepare the Report based on the defined borderline values (Paragraphs about maintenance from the valid Regulative prescribe the minimum values of the elements, by which the reliability is maintained or failure of system is confirmed). In addition to the information on the current state of the infrastructure in the field, the report contains a proposal and a list of required maintenance works.

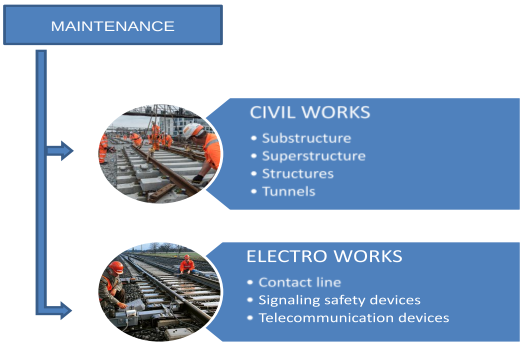

Fig.1. Basic group of work

The following text is an overview of the current situation related to the compliance with the regulations and criteria, which is the part of maintenance of the railway infrastructure of countries in former Yugoslavia.

Common criteria are presented in the table below:

Subtypes of works CIVIL	Individually elements per subtypes of works	Criteria derived from the regulations that can be the basis for the start of maintenance work
Substructure	embankment	- deformations till 1m - deformations > 1m
	subgrade	deformations (no limitation)
	slopes	no defined criteria only general description
Superstructure	head of rail	wear of rail head (criterias are shown in the table)
	the composition of the rails	allowed deviation for spacing and stiffness
	expansion compensating device and switches	the value of the allowed deviation is prescribed
	ballast	the pollution criteria of the built-in ballast is shown in%
	sleepers	till 10% sleepers "players"
	fastening	no defined criteria only general description
Structures (bridges, culverts, retaining walls)	Walls	no defined criteria only general description
	Bridges - concrete	no criteria for deflection, cracks,settlement
	Bridges - steel	rivets >20% defective
Tunnels		(no criteria for cracks, deformations, gauge, system for ventilation, drainage system from the tunnel is stated)

Subtypes of works ELECTRO	Individually elements per subtypes of works	Criteria derived from the regulations that can be the basis for the start of maintenance work
Contact line		no defined criteria only general description
Signaling safety devices	Point-machine	state
	Signal	state
	Track circuit	state
	Axle-counter	state
	Command desk	state
	Internal relay SS device	failure/no failure
	Internal device of electronic signal conditioning	
	Power supply device	failure/no failure
	Automatic block	failure/no failure
	Devices of level crossings	failure/no failure
	Devices telecommand	failure/no failure
	Cables and cable's accessory	failure/no failure
Telecommunication devices	Cables and cable's accessory	failure/no failure
	WiFi devices	failure/no failure
	Telephone line devices	failure/no failure
	Radio devices	failure/no failure
	Commutation devices	failure/no failure
	Information devices	failure/no failure
	Feeder devices	failure/no failure

Fig.2. Common criteria

2. REVIEW OF VALID NATIONAL REGULATION

The Western Balkans Comprehensive Network is strategically located with regard to the European transport system. It constitutes a physical transport corridor that enables the continuity of different parts of the TEN-T Network, providing connections for the Central European countries to the Black Sea and further beyond to Asia. In June 2015, the transport infrastructure related to Ministries of the WB6 and the EC (DG NEAR and DG MOVE) indicatively identified the main transport axes that will be connected to the existing TEN-T CNCs (as considered by Article 8 of the Regulation 1315/2013) Figure below. The indicative extension of the TEN-T Network to the WB Region is articulated in the EC Regulation 2016/758, which amended the TEN-T Regulation (Regulation (EU) 1316/2013). Extending the TEN-T core network corridors to the Western Balkans ensures closer integration with the EU as well as the possibilities for leveraging investment in infrastructure. Namely, that is EU support through the Western Balkans Investment Framework (WBIF) and the Connecting Europe Facility (CEF).

Fig.3. TEN-T core network

An overview of the current regulations in the section dealing with the maintenance of the railways was carried out and the following conclusions were prepared by countries.

2.1. Bosna and Herzegovina

Railway Regulatory Board (RRB) (Regulatorni Odbor Željeznice BiH - ROŽBiH) was established in accordance with the Law on Railways of BiH as of June 30, 2005, the following recommendations of the EU Directive 14/2001 and 49/2004. Their jurisdiction covers: general oversight, licensing, security and safety certificates. At the same time, The Regulatory Board prescribes technical standards and technical specifications and controls the railway sector in BiH, taking into account the EU directives on railways and it issues instructions for the safety and interoperability of the railway system, monitors the observance of these instructions and it approves the railway equipment necessary for safety and interoperability.

Railways of Republika Srpska (RRS) and Railways of Federation of Bosnia and Herzegovina (RoFBiH) and their railway regulations (separately per entities) have been modified in accordance with the strategy and Business Plan of development of BiH. The criteria are taken from the valid National regulations[1]. They are distinguished by types of works and they are basic elements of the infrastructure with defined borderline values for reliability and safety of the entire system. The infrastructure team has confirmed that the above criteria are fulfilled and checked according to the defined borderline values, that is, they record all deviations in relation to the allowed minimum values.

2.2. The former Yugoslav Republic of Macedonia

National railway regulations had several adaptations in period 2013-2016, including Law on the railway system, Law on the safety of the railway system, Law on interoperability within the rail system. Maintenance of the railway infrastructure is supported by the PE Infrastructure Macedonian Railways -MR-I(JP MZ Infrastruktura (MR-I)) according to the regulations, strategy and plans. At the moment they are working on supplementing the Rulebook on the method of maintenance [2], the manner of keeping records and using the data from the records of the Upper Machine Line (Rulebook for the manner of maintenance, the manner of keeping records and data use from records for superstructure). Updating and the changes are estimated to have been finished in the period of 3 (three) months.

2.3. Kosovo [1]

The Railway law, regulations, as well as administrative instructions by the Ministry of Infrastructure, a valid regulation by the Railway Regulatory Authority were prepared in accordance with European standards. As far as M&R is concerned, the railway regulations [3] and instructions of the Yugoslav Railways Union, as well as the existing maintenance rulebooks, are reported to be implemented in practice. They are distinguished by types of works and the infrastructure team has confirmed that the criteria are fulfilled and checked according to the defined borderline values, that is, they record all deviations in relation to the allowed minimum values

2.4. Montenegro

Railway Directorate is the state authority of Montenegro for the sector of railway transport. The Directorate was established to carry out the work of investment in maintenance, development and modernization of railway infrastructure, regulatory affairs and safety on the railways. It has an important role in the preparation and drafting of technical regulations, norms and standards on the railways, as well as when making the plans for development, construction, reconstruction, modernization, maintenance and protection of the railways of Montenegro. The above-mentioned National

[1] *This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.*

Maintenance Regulations [4] have been fully used in practice in the paragraphs for which there was not a problem found to use special machinery or an estimated large investment for maintenance. The criteria are distinguished by types of works and the infrastructure team has confirmed that the criteria are fulfilled and checked according to the defined borderline values, that is, they record all deviations in relation to the allowed minimum values.

2.5. Serbia

Directorate for Railways is a special organization of the Republic of Serbia for the field of railway transport. It was established in accordance with the Law on Railway of the Republic of Serbia, enacted by the National Assembly of the Republic of Serbia (came into effect on 1st March 2005). The Directorate is responsible for issuing by-laws on the basis of the authorization from the Railway Law and the Law regulating the safety and interoperability of rail transport. In the past period, the Ministry of Construction, Transport and Infrastructure and Public Enterprise "Railways of Serbia", in cooperation with other participants in the railway reform process, worked intensively on the preparation of documents and acts. Joint Stock Company for Public Railway Infrastructure Management "Infrastructure of the Railways of Serbia - IoSR", seated in Belgrade is responsible for the maintenance works and management of the maintenance of traffic, construction and electrical infrastructure. JSC IoSR has actively participated in the preparation of valid regulations in the part of maintenance.

In practice, when planning and performing M&R, valid regulations are obeyed in those parts of M&R where the necessary conditions are met, with respect to the available mechanization and staff. Based on the information from the manager, the problem of regular maintenance in recent years has occurred due to the lack of overhauls/renewals (due to the wartime situation during 1990s). Since then, a system of regular maintenance has not yet been established. However, urgent maintenance was carried out on short parts of the railway. It was noted that due to the lack of financial resources planned for regular maintenance, durability of the available mechanization and reduced number of trained workers have contributed to the current state of "poorly maintained existing infrastructure".

According to the type of maintenance of railway infrastructure, the existing National regulations [5] specify the criteria defined by the borderline values, which should ensure the reliability and safety of the entire system. The infrastructure team has confirmed that these criteria are fulfilled and checked, i.e. they record all deviations in relation to the allowed minimum values.

By entering the European Union, **Croatia and Slovenia** have harmonized the Railway National Regulation with European standards.

3. CONCLUSION

In order to review the existing national regulations in the area of the M&R of railway infrastructure, a table with common criteria was created in accordance with the existing regulations which are valid in countries of the former Yugoslavia. Recommendation for all countries of the former Yugoslavia to undertake updating of their regulations, either on their own, or ideally within the framework of some of the future Projects asap. Whichever the manner in which the countries of the former Yugoslavia would undertake this task, its content should be the following:

- Analyse thoroughly the key regulations and rulebooks documents and compare/benchmark with the modern European and international best practice, as well as with the relevant CEN norms and perform gap-analysis
- Establish priorities in updating regulations
- Update regulations

Depending on the extent of the project, its duration would vary. The estimate is that in order to update all documents 4 years of work would be needed.

ACKNOWLEDGEMENT

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[5] National regulations in the field of maintenance - Serbia

CONDITION MONITORING TECHNOLOGIES IN RAILWAY MAINTENANCE

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Miloš MILOŠEVIĆ [3]

Abstract *– Condition monitoring of track and vehicles is very important activity in railway maintenance. Condition-based maintenance operations should be planned on the base of real time measuring data in order to prevent failures. Monitoring process consists of periodical or continuous inspection of track or vehicles. Infrastructure managers use specialized track monitoring vehicles to assess the state of infrastructure and operators use wayside or on-board detection systems for monitoring the vehicles state in service conditions. Possibility of use the real time locomotive vibration measuring for assessing the state of vehicle and track was the purpose of the performed research, which is described in this paper.*

Keywords – Railway maintenance, condition monitoring, on-board diagnostic, vibration measuring.

1. INTRODUCTION

Maintenance of railway infrastructure and vehicles is very important due to rail traffic efficiency, safety and costs. In order to improve the maintenance and availability of rolling stock, on-board and stationary diagnostics are introduced [1]. Stationary diagnostic systems are used for a casual-periodic inspection of railway vehicles and these are installed near the track [2]. On-board systems are installed on vehicles and used for continuous monitoring of vehicles in service conditions. Using the collected information from on-board diagnostic systems it is possible to analyze the condition of the vehicle components, but also the condition of the railway infrastructure can be assessed.

Tsunashima et al [3] describe the tests which were conducted in Japan Railway in order to research the possibility of condition monitoring of railway track using in-service vehicle. This track-condition-monitoring system based on measuring the vertical and lateral acceleration of the car body, as well as measuring noise in vehicle cabin. The field results showed that the condition monitoring of railway track using the developed probe system provide the useful information for condition-based-maintenance.

Sakellariou et al [4] present the method for vibration based fault diagnosis for railway vehicle suspension. The similar subject was researched by authors in the papers [5, 6]. They describe the research and development of rubber springs for locomotive primary suspension. In this project the measurement and data acquisition system is developed in order to analyze the railway vehicles dynamic characteristics.

Failures of axle bearings are often the cause of great wagon damage like derailment. The paper [7] describes onboard acoustic emission measurements carried out on freight wagons with purposely damaged axle bearings. Acoustic emission signal envelope analysis has been applied as a means of tool to detect and evaluate the damage in the bearings.

The purpose of the paper [8] is investigation of methods for condition monitoring in railway applications. The focus of the work is the condition monitoring of vehicle running gear and track condition. Authors investigated the use of different sensors and fault detection methods for vehicle and infrastructure condition monitoring.

This paper describes the condition monitoring process in railway maintenance. Further, the paper presents the vibration measurements obtained on Serbian railway electric locomotive in regular service, in order to investigate the transfer of vibrations from the wheels to the locomotive body. Vibrations were measured at the axle box, at the bogy frame that is under the primary suspension and at the locomotive body that is under the secondary suspension.

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2. MONITORING PROCESS IN RAILWAY MAINTENANCE

Condition monitoring is the main activity in condition-based maintenance of technical means. Frequently inspection of equipment or component and analyze the real time data are the base of planning the maintenance operation which can be performed just in time to prevent faults. Condition monitoring can be performed as periodic or continuous. Condition monitoring on railway infrastructure and vehicles are both important in railway maintenance.

2.1. Inspections in process of track maintenance

Track inspection is an essential task in railway maintenance and periodically it is performed. Inspection was manually operated by trained human operator who walking along the track searching for visual anomalies. This manual inspection is slow and unsafe, and the results depend on the capability of the observer to detect possible track failure.

Today, infrastructure managers use specialized track monitoring vehicles with a variety of advanced measurement equipment that are used to monitor the track, often on an annual or semiannual infrequent basis. By passing the measurement vehicle on a certain track section and performing measurements, a software package analyzes the measured data and generates a report. The report contains data about specified section of the track for the certain geometrical parameters like track width, track construction, cant deficiency and other track faults.

With the growth of the high-speed railway, automatic inspection systems are developed. These systems are able to detect rail defects thus increasing the ability of the inspection and reducing the needed time.

Some kind of track faults can be detected by measuring the vibrations of railway vehicles, some faults can be detected by visual or ultrasound detection. Visual inspection can be used to detect and monitor defects originating on the surface and to monitor the growth of defects in the track. Ultrasound scanning can be used to detect certain internal defects [6].

2.2. On-board detection of railway vehicle

Development of electronics, sensor and computer technology enabled development of on-board and stationary diagnostic systems, which are in use in rolling stock inspections in process of maintenance.

On-board systems are installed on the vehicles and they are used for vehicle's components continuous monitoring in period of regular service. In that way, by condition monitoring the maintenance activities can be planned and the out of service time can be minimized. However, these diagnostic systems are very expensive because of the fact that each component need own diagnostic equipment. Installation of these systems is economically justified for locomotives and trains or for traction units, but not for freight cars.

Wayside detection systems (stationary diagnostic systems) are used for a casual-periodic inspection of rolling stock and these are installed directly on the track or very near track. Condition monitoring of vehicles is performed in time of regular service, without stopping. Wayside detection systems are much more reasonable in terms of expenses. There are different types of wayside detectors as: hot bearing detectors, wheel impact load detectors, overload and imbalanced load detectors, truck performance detectors, wheel profile detectors, hot wheel detectors, acoustic bearing detectors, etc.

Most of the condition-monitoring systems (wayside and on-board detectors) for railway vehicles are focused on the wheel and bogies. The wheel-rail interface is one of the most important parameters in the vehicles' operating condition. It is important to monitor condition of railway vehicles and infrastructure to avoid accidents, as a derailment which is very costly and may cause injuries.

One of the challenges with implementing condition monitoring is to find the right measurement technologies, since reliable and valid measurements are a necessity for an effective condition monitoring approach. There is the question of finding relevant and correct parameters that can be measured to provide the most relevant measuring data, because the measurement data must then be transformed into relevant and understandable information that can be used as decision support in the maintenance management process. Vehicle vibration in running condition is parameter which can authentically present the real state of vehicle's running gear but also the state of track. Because of that measuring of the vehicle vibration in service condition can be very useful.

3. CONDITION MONITORING USING VIBRATION MEASURING

Wheel-rail interaction depends on wheel and track geometry state, wheel condition, track irregularities, vehicle suspension condition etc. However, measuring of vehicle vibrations and comparing measuring data with referent data or measuring data in past period we can assess the state of vehicle's integral parts and state of track.

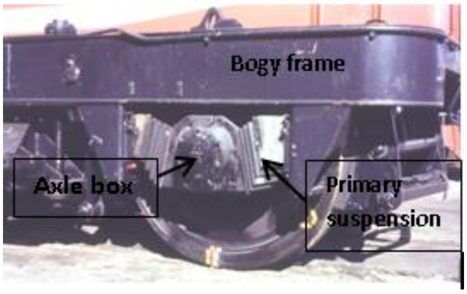
Research team from Faculty of mechanical engineering in Nis performed the measuring of vibration on electric locomotive type 444 owned by of Serbian Railways. The measuring and data acquisition system was designed for measuring vibrations in three axes and at six autonomous points, traveled distance and vehicle speed.

Vehicle vibrations are a result of dynamic forces that are caused from roughness of the rails, gaps on the joints between the rails, cone of the rolling area of the wheels, presence of unevenness on the rolling area of the wheels, physical properties of the materials of the rails and the wheels, type of suspension, changes of the speed of the vehicle, etc. Suspension of the railway vehicles reduces the influence of dynamic forces and ensures a stable motion. Defects of the suspension may cause an unstable contact between wheel and rail and increased vehicle body oscillations, thus increasing the wheel and rail wear, and may lead to a failure of some bogy parts, and in the worst-case to derailment.

Two field tests were performed with the same locomotive (Figure 1a) on the same Serbian railway line Nis-Leskovac (40 km distance) in regular service pulling the freight trains (1076 t in the first field test and 1145 t in the second test) and measuring data are analyzed.

The primary suspension of electric locomotives type 444 consists of the rubber-metal springs of the type "shevron". Figure 1 b) shows the locomotive bogy. Secondary suspension of this locomotive consists of coil springs and hydraulic absorbers.

a)



b)

Fig.1. The electric locomotive 444-017 (a) and the locomotive bogy (b)

The developed measuring-acquisition system for analysis of dynamic characteristics of consists of six sensor modules with triaxial accelerometers, microcontrollers, a local memory, a system for synchronization of measurements, the Global Positioning System (GPS) and a communication module data acquisition. A special computer application (CALMNESSdrive - Figure 3) for acquisition and processing the measurement data in real-time, permanent storage in a database, filtering, displaying and generating reports on the recorded results has been developed. Six triaxial sensor modules were installed on the locomotive at three levels (first level-axle boxes, second level-bogy frame and third level-locomotive body). Triaxial accelerometers installed on axle box and bogy frame are presented in Figure 2. The GPS receiver was placed on the roof of the locomotive cabin. The sampling frequency was 200 Hz.

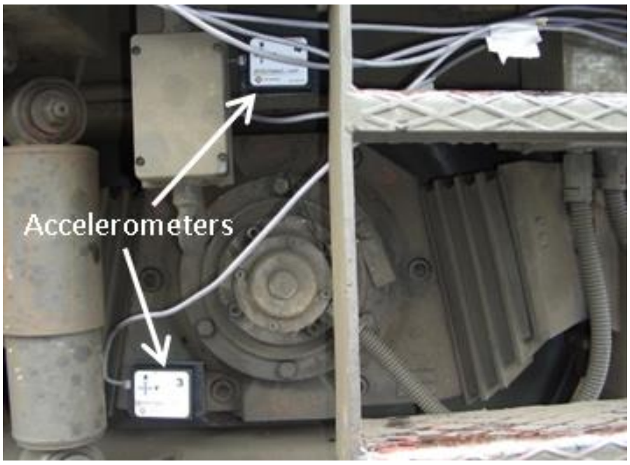


Fig.2. Triaxial accelerometers installed on axle box and bogy frame of locomotive 444-017

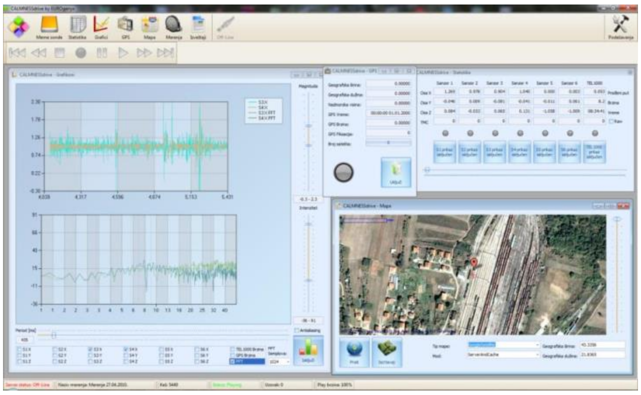


Fig.3. Software CALMNESSdrive for data acquisition and data analysis

The experimental plan was to research the locomotive's dynamic behavior in relation to the position of the locomotive on the railroad and its current speed. In this way, direct connection can be identified between locomotive's dynamic behavior and properties of the railway tracks. In addition, state of primary and secondary suspension can be evaluated.

The figure 4 shows measured vibrations on locomotive axle box in vertical, lateral and longitudinal direction on rail section of 250m. As expected, the acceleration in vertical direction is the largest. The figure 5 shows measured vibrations on locomotive bogy frame in vertical, lateral and longitudinal direction measured on the same rail section. Accelerations in vertical and lateral direction are larger than in longitudinal direction.

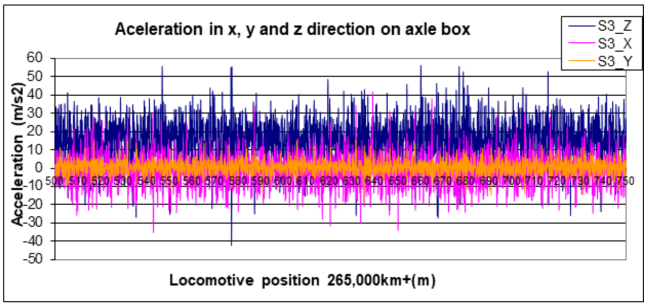


Fig.4. Measured vibrations on locomotive axle box

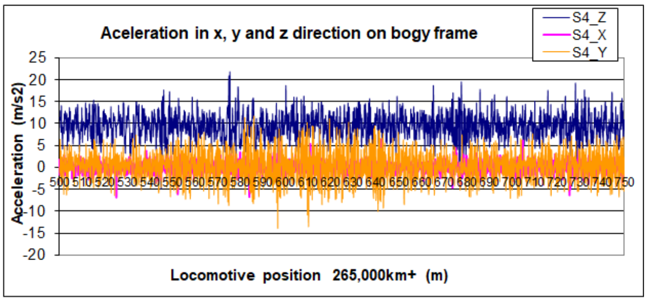


Fig.5. Measured vibrations on locomotive bogy frame

Acceleration in vertical direction measured on three locomotive levels (axle box, bogy frame and locomotive body) during train running on rail section of 250m long is presented on Figure 6. It can be seen that acceleration on axle box is significantly larger than on the bogy frame and locomotive body. It means that primary suspension is performing its function properly as absorbs vibrations significantly.

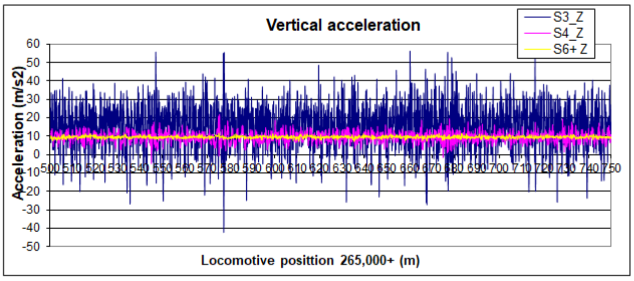


Fig.6. Vertical vibrations on axle box, bogy frame and locomotive body

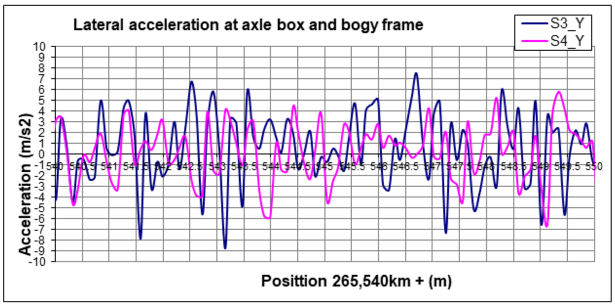


Fig.7. Lateral acceleration at axle box and bogy frame

Figure 7 presents the lateral accelerations measured on axle box and bogy frame at 10 m long rail section at 75 km/h speed.

4. CONCLUSION

Condition-based maintenance is new concept of technical means maintenance which main activity is condition monitoring. There are many methods for condition monitoring like visual, acoustic, temperature inspection. Measuring of vibrations is method, which can detect a malfunction in early stage.

Based on performed research some conclusions can be established:

- The most effective maintenance of railway vehicles is a common control without interrupting operation.
- Testing of equipment and vehicle components is the most proper in service condition.
- On-board diagnostic systems are installed in a vehicle in order to perform continuous monitoring of vehicle components in period of regular service. This system controls only one vehicle, but it also controls the state of track on service line.
- Measuring of vehicle vibration in running condition can provide useful data of vehicle components state and of track state.

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TESTING OF RAILWAY DISTRIBUTOR VALVE WITH TEST BENCH TYPE DISTRITESTER 1018TR

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Abstract *– Test bench DISTRITESTER 1018TR is designed and development with team of experts from the field of railway engineering, pneumatics, electronics and software. DISTRITESTER 1018TR is actually, six-channel Data Acquisition System. Test bench DISTRITESTER 1018TR designed to automatic control, measure, recording and analysis pneumatic parameters of railway brake distributer (with or without relay valve).*

Testing is performed full automatic, with assisted by operator in setting up the distributor on carrier and determining the necessary testing parameters.

After starting testing procedure on DISTRITESTER 1018TR, control unit automatic make a change of pressure in brake pipe (BP(L)). During the test, measurement, recording and analysis of pressure changes are performed automatically in real time on six channels: in brake pipe (BP(L)), brake cylinder (BC(C)), fictive brake cylinder (FBC(Cv)), auxiliary reservoar (AR(R)), control reservoar (CR(A)) and weight valve pipe (WV(T)).

Test bench DISTRITESTER 1018TR is designed with variable volumes of auxiliary reservoirs and control chambers.Tests are performed with brake pipe (BP(L)) volume of 20 liters and brake cylinder 14". For simulate the brake cylinders 10", 12" and 16", change of the stroke of the cylinder is performed.

Keywords – Test bench, railway distributor valve, measurement, DISTRITESTER 1018TR

1. INTRODUCTION

The test bench DISTRITESTER 1018TR is intended for testing the operation of the railroad vehicle distributor after the overhaul.

The test program is applied to graduated-release dispensers (three-way distribution). The test program is also applicable to the relay valves as an integral part of the scheduler. This standard also applies to distributors with and without a built-in safety valve.

Typical and serial testing of the dispensers on the test desk is done automatically. Automated testing is done interactively via a central computer unit and with the assistance of an operator.

Test results are stored in a computer and can then be published in the form of a measuring sheet with diagrams of the scheduler (change/dependence of pressure from time).

2. REQUIRED CONDITIONS FOR PERFORMING THE TEST ON THE TEST BENCH

The room, where test bench DISTRITESTER 1018TR is placed, should be air-conditioned (temperature 25 ± 3° C). The climatic space ensures the correct operation of the test table without the influence of temperature differences and consequently the uniformity of the results of measuring the characteristics of the dispensers. Air conditioning also ensures acceptable air humidity.

The alternating current must be grounded, not zeroed, because it protects electronic equipment, ensures the proper operation of electronic equipment on the test bench as well as the operator's safety against electric shock. The alternating current must be within the characteristics of 220V ± 20%, 50Hz / 60Hz ± 5%[1].

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The quality of the compressed air must be in accordance with ISO 8573.1, class 4.3.4. Insufficient air can cause damage to the electro-pneumatic valves and affect the correct operation of the test bench.

3. PNEUMATIC SCHEME OF THE TEST BENCH DISTRITESTER 1018TR

The DISTRITESTER 1018TR test bench connects an armor installation that must provide a compressed air pressure of minimum 8 bar.

The Electronic Pneumatic Valve (VHL) is used for interrupting or securing air supply under pressure by pneumatic controllers (EPK1L). In principle, this valve is open during all tests, except when testing the seal ability of the dispenser when it is closed and interrupted by the pressure air supply. The opening and closing of this valve is carried out via control electronics.

The Electronic Pneumatic Controller (EPK1L) serves to supply the main water and provides pressure ranging from 0-7 bar. The Electronic Pneumatic Controller (EPK1L) supplies the carrier or air distribution device under pressure. The pressure is variable and depends on the test being carried out. It practically simulates the pressure changes in the main water.

The operation of the electric pneumatic controller (EPK1L) is carried out by software via control electronics.

The electronic pneumatic valve (VLL) serves to interrupt or provide air supply by pressurized main lead to the dispenser. In principle, this valve is open during all tests, except when adjusting the initial test conditions when it is occasionally closed and interrupted by the supply pressure of the air. The opening and closing of this valve is carried out via control electronics.

The electrical pneumatic valves (VR1-VR4) are used for interrupting, or the possibility of supplying the auxiliary reservoir R waters with air, depending on which volume the test process is being carried out. These valves are normally closed until the operator chooses through the computer and control electrics the volume of the promotional reservoirs he wants to test. The opening and closing of these valves is carried out via control electronics. During the test process, the status of these valves does not change, it remains as intended at the start of the test.

The Electronic Pneumatic Valve (VLR) serves to rapidly supplement the auxiliary tank water at a pressure of 5 bar, after the unpacking tests have been carried out. Its purpose is to speed up the creation of initial conditions before the test. During the test process, he is always closed. The opening and closing of this valve is carried out via control electronics.

Electrical pneumatic valves (VA1-VA2) are used for interruption, or the possibility of air supply of the water of the working chamber, depending on which volume the test process is being carried out. These valves are normally closed until the operator chooses the computer through the computer and control electrics with which volume the work chamber wants to test. The opening and closing of these valves is carried out via control electronics. During the test process, the status of these valves does not change, it remains as intended at the start of the test.

The Electronic Pneumatic Valve (VLT) serves to quickly recharge the water of the measuring valves (T) at the pressure T1 or T4 depending on the test being carried out. Its purpose is to speed up the creation of initial conditions before testing. During the test process, he is always closed. The opening and closing of this valve is carried out via control electronics.

The 16" (C16) brake cylinder serves to simulate the necessary operation of the brake cylinder. The testing of different types of cylinders (10", 12", 2x12", 14", 2x14" and 16") is provided by adjusting the brake cylinder stroke.

The electronic pneumatic valve (VC3l) serves to stop the power supply of the brake cylinder and to provide the volume required to test the schedulers configured to only supply the relay valve control. The opening and closing of this valve is carried out via control electronics.

The Electronic Pneumatic Valve (VCE) is used to simulate the loss of air in the brake cylinder (artificial insulation) in this type of test. The opening and closing of this valve is carried out via control electronics.

The pressure sensors in the main line (L), the auxiliary tank water (R), the working chamber water (A), the brake cylinder (C), the distributor fictitious brake cylinder (Cv) and the measuring valve water (T) are registered. The pressure sensors (L, R, A, C, Cv and T) transmit signals to a measure of acquisition electronics.

The temperature sensor installed in the test table registers the changes in the ambient temperature of the test bench.

Figure 1 shows the pneumatic diagram of the test bench connection DISTRITESTER 1018TR.

4. WORK WITH TEST BENCHES DISTRITESTER 1018TR

Before start working, the operator opens the drain cock and discharges condensate from the condensate separator. After that, operator should be identified through ID cards on test.

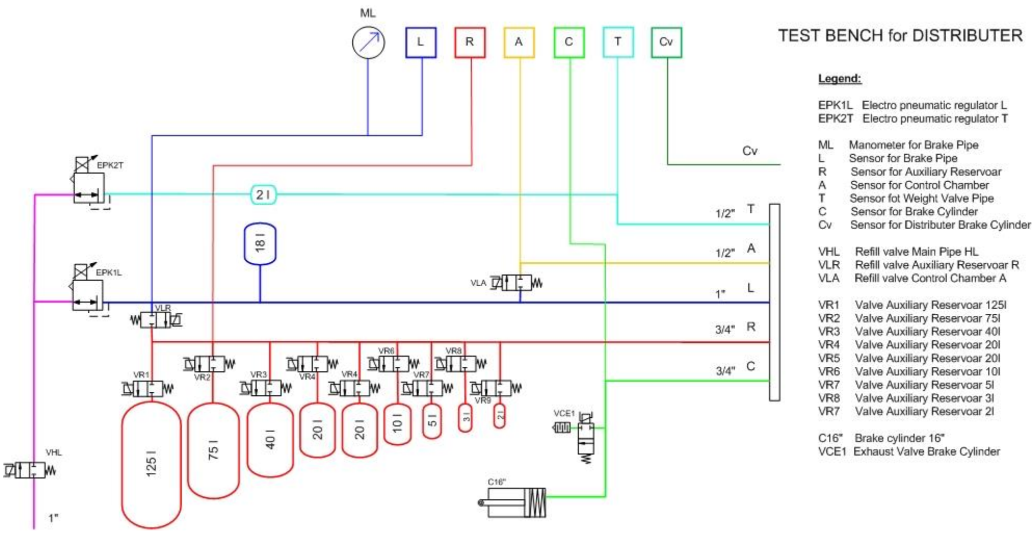


Fig.1. The pneumatic diagram of the test bench DISTRITESTER 1018TR

Operator sets the distributor and pneumatic clamping on the bracket and conected cable to automatic release valve. Then access setting the required testing parameters on the home page software interface.

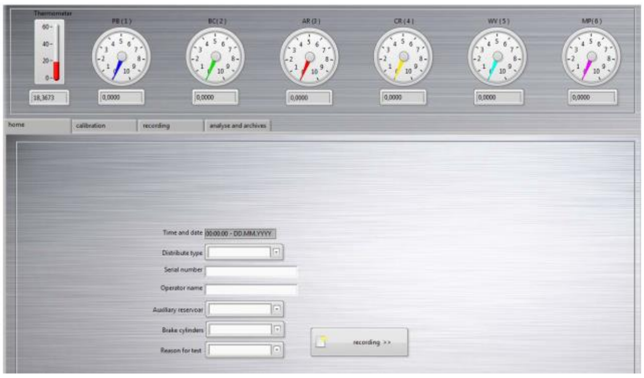


Fig.2. Appearance of the home interface

From the drop-down menu selects the volume of the auxiliary reservoir with which to work (available to him of volume 100 l, 110 l, 125 l and 135 l).

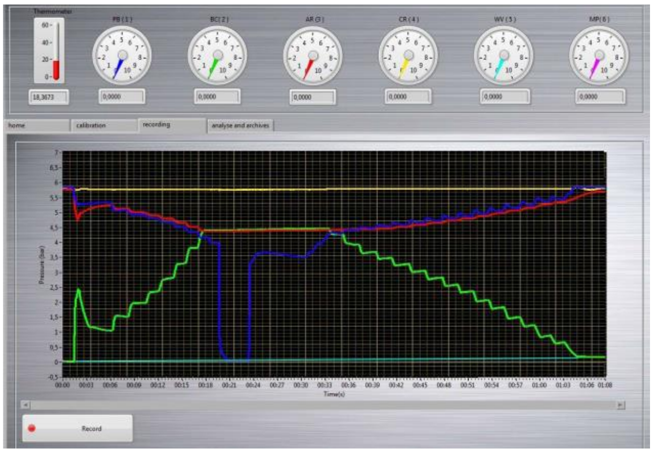


Fig.3. Recording interface

Also, from the drop down menu selects the brake cylinder with which it will perform tests (12 ", 14" or 16 ").

After selecting from the dropdown menu operator receives a message with the value of the length of the insert, which should be inserted behind the piston brake cylinder.

The software is already automatically fill the date and time of test, name operator took over the ID card and record the ambient temperature in performing the test. From the drop-down menu, the operator selects the "reason for test". We offer him the following reasons: testing after overhaul, testing for reclamation. It remains that the operator enters the serial number distributor. The following figure shows the appearance of the home interface.

The operator now run button „recording“ an automatic test distributor. Test bench DISTRITESTER 1018TR lights up semaphore with red colour. On next picture (Fig.3) you can see recording interface.

Estimated duration of the test distributor was about 30 minutes. After completing the automatic test, test bench lights up semaphore with green colour and print the Test Report, according with UIC (with or without diagram of distibuter work, depending on customer requirements).

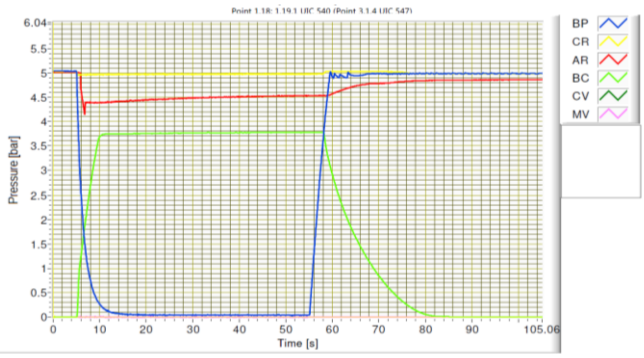
The results of UIC test of distributer which are within the limits prescribed, are registered in measuring list with blue colour. The results which are without the limits prescribed, are registered in measuring list with red colour.

5. FUNCTIONAL TEST ACCORDING TO ML-631.501Z AND TEST REPORT

In practice, measuring of the Braking time ie. cylinder charging time and Brake cylinder release time are performed in two different testing mode (postion) P and G.

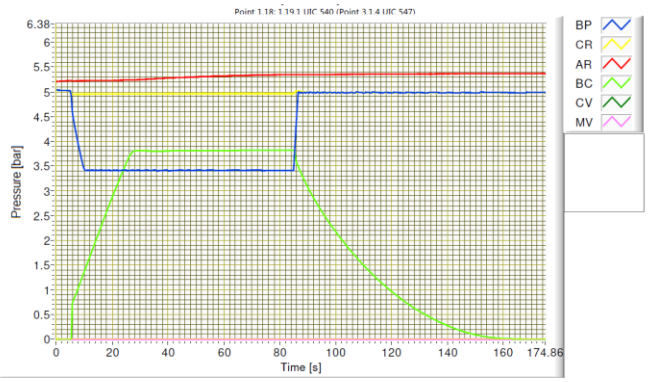
For measuring of braking time - cylinder charging time (test 3 of ML 631.501Z) in P – position (Fig. 4), the brake pipe, control tank and auxiliary tank are set exactly to 5.0 bar. With FD 1, a fast braking application is introduced, which is recorded with the stopwatch. The stopwatch stops when the brake cylinder pressure increases to 95% of the maximum (4). Time is needed within 3 to 5 seconds.

For measuring in G – position, release the compressed air from the test lead according to the test instructions 2 and set the test to test as a test 1. Transfer the G-P loop on the distributor valve to position G and place the control lever FD 1 in the charging position. Wait until the meter (5) (6) (7) does not read accurately 5.0 bar, then close the tap (46) and use the tap (54) quickly reduce the pressure in the brake pipe shown on the meter (7) to 3.50 bar, at the same time with stopping time of the brake cylinder to increase to 95% of the maximum. The time taken must be within 18 to 30 seconds. (Fig. 5).



Braking time = 4.53 (s); Releasing time = 15.95 (s); Inexhaustibility of AR = 4.82 (bar);
max BC pressure at P-loaded= 3.78 (bar);
BP=Brake pipe; CR=Control reservoir; AR= Auxilary reservoir; BC=Brake cylinder; MV= Measuring valve

Fig.4. Test report in testing position P



Braking time = 20.24 (s); Releasing time = 50.08 (s);
Inshot = OK; max BC pressure at G-loaded= 3.82 (bar);

Fig.5. Test report in testing position G

The test of Brake cylinder release time (test 5 of ML 631.501Z) in P position is obtained in conjunction with test 3 when the G-P valve on the distributor valve is set to position P. Set the control lever FD 1 to the charging position when the pressure of the brake cylinder is released through the fan valve, the start-up time starts to be measured. Measurement is carried out respecting the pressure drop to 0.40 bar in the brake cylinder. Time takes 15 to 20 seconds (Fig. 4).

The G-position test is performed as in the P-position with the only difference that the G-P valve on the distributor valve is set to position G. The time must be within 45 to 60 seconds. See fig. 5.

6. CONCLUSION

For each manufacturer of brake equipment, suitable test report can be prescribed in which the most important points are harmonized in accordance with the prescribed UIC regulations.

DISTRITESTER 1018TR, does not require special maintenance, beside the prescribed measures to control the correctness and accuracy of measurements - calibration of pressure sensor.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

DETERMINATION OF OPTIMAL LOCATIONS OF STRAIN GAUGES ON INSTRUMENTED WHEELSETS

Milan BIŽIĆ [1]
Dragan PETROVIĆ [2]

Abstract *– This paper presents one universal method for determination of optimal locations of strain gauges on instrumented wheelsets for measurement of wheel-rail contact forces and contact point position. The method is based on development of wheel model and systematically analysis of results of FEM calculation. The procedure is shown on standard 22.5 t wheelset for freight wagons. For analysed wheel, 4 optimal radial distances for measurement of 3 parameters (vertical force Q, lateral force Y and location of contact point position* y_{cp}*) are determined. Placing strain gauges on optimal locations is one of the main preconditions for high measurement accuracy of instrumented wheelset. The proposed method is verified with the experimental tests on real object.*

Keywords – Strain gauges locations; instrumented wheelset; wheel-rail contact forces; contact point position.

1. INTRODUCTION

The instrumented wheelsets have very important role in testing of running safety of rail vehicles [1, 2]. One of the key problems in their development is determination of the most suitable locations of strain gauges. For different wheel types, optimal locations are different and their determination is one of the main prerequisite for obtaining a high measurement accuracy [3]. The way of determination of optimal locations of strain gauges is generally unavailable for most people who are dealing with development of instrumented wheelsets. With motivation to contribute to this area, this paper propose one universal method for determination of strain gauges locations. The content of the paper can be helpful for people involved in research and development of instrumented wheelsets, as well as those who deal with the design of wheelsets and problem of wheel-rail contact.

2. TROUBLESHOOTING

The wheel strains which should be measured are consequence of influence of various parameters. There are vertical, lateral and longitudinal wheel-rail contact forces (Q, Y, X), contact point position (y_{cp}), wheel wear (w), wheel angular velocity (ω) and wheel temperature field (T). Therefore, unknown values of Q, Y and y_{cp} must be determined on the basis of the mixed signals from Wheatstone bridges located on the wheel. In design of instrumented wheelset, the primary aim is getting the highest possible values of signals (increase signal-to-noise ratio) and thus provide greater measurement accuracy. In this sense, it is necessary to identify locations (radial distances) in which the wheel is the most sensitive to the effects of parameters to be measured. In this approach, the whole problem of design of instrumented wheelset is based on the wheel model and appropriate analysis of results of FEM calculation. In the model, the influence of X force should be neglected while influences of ω and T should be neutralized in later phases through intelligent layout and way of connection of strain gauges into Wheatstone bridges [4, 5]. Since the wheel is in zone of elasticity, there is a linear correlation between given force in wheel-rail contact and strains (signals from Wheatstone bridges) caused by that force. So, for arbitrary contact point position, overall strain in any point of the wheel can be expressed as a sum of individual strains caused by individual actions of forces Q and Y. This provide that wheel strains can be analysed for individual actions of forces Q and Y in different contact points.

3. WHEEL MODEL AND FEM CALCULATION

The standard 22.5 t wheelset (made of Bonatrans) is used for demonstration of the method in this paper. The model consists of 193495 finite elements and 322197 nodes. The calculation is performed in

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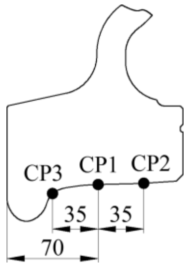
ANSYS for 3 contact point positions y_{cp} and 6 load cases, as shown in Fig. 1.



Load case	Q [kN]	Y [kN]	y_{cp} [cm]	
1Q	100	0	CP1	0
1Y	0	50	CP1	0
2Q	100	0	CP2	3,5
2Y	0	50	CP2	3,5
3Q	100	0	CP3	-3,5
3Y	0	50	CP3	-3,5

Fig. 1. The contact point positions and load cases taken into account in FEM calculation

The calculation results are confirmed that wheel has a great safety factor for all loads cases, while disc is the most sensitive part and it is further analysed. The reference coordinate system for strain analysis on disc surface is shown in Fig. 2.

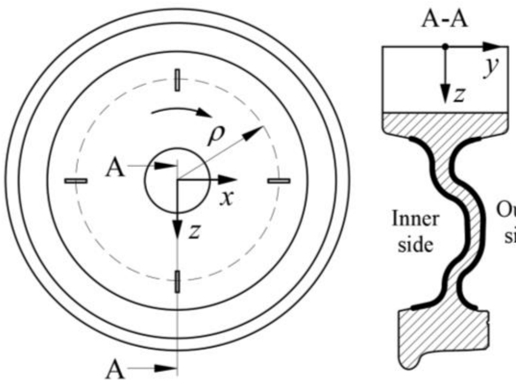


Fig.2. The reference coordinate system for strain analysis on disc surface

An example of obtained results of relative equivalent strain ε_e is shown in Fig. 3.

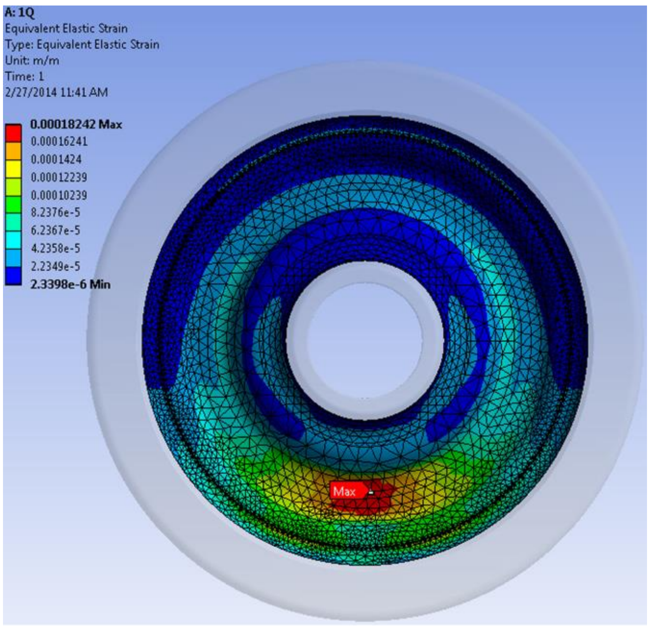


Fig. 3. The equivalent strain at inner side of disc (1Q)

In the next step, 24 diagrams of change of ε_e in function of coordinate z at inner and outer side of disc are formed for section A-A. These diagrams are combined in two comparative diagrams shown in Figs. 4 and 5.

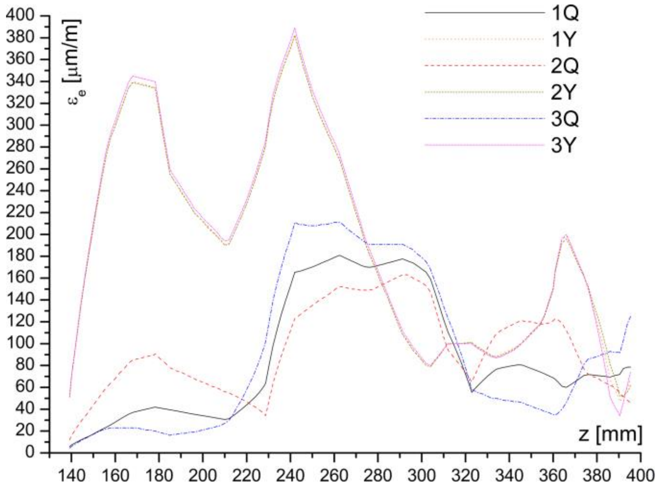


Fig.4. The comparative diagram of change of equivalent strain on inner side of disc

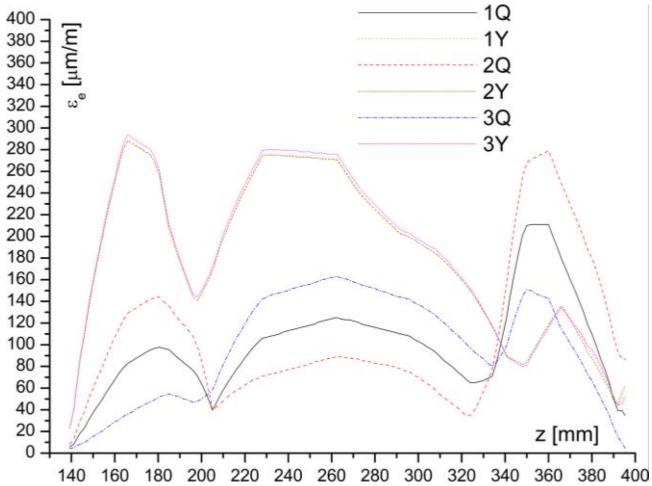


Fig.5. The comparative diagram of change of equivalent strain on outer side of disc

4. DETERMINATION OF OPTIMAL LOCATIONS OF STRAIN GAUGES

The maximum sensitivity of disc on Q force is at radial distance ρ=262 mm on inner side and ρ=360 mm on outer side (Figs. 4 and 5). At this stage, it can be concluded that these radial distances are the most suitable for placing strain gauges for measurement of Q force. Simultaneously, there is a question whether the output signal from this Wheatstone bridge is influenced with parameters Y and y_{cp}.

The maximum sensitivity on Y force is at ρ=168 mm and ρ=242 mm on inner side, as well as ρ=166 mm and ρ=236 mm on outer side of disc (Figs. 4 and 5). These distances are the most suitable for placing strain gauges for measurement of Y force. Also, there is a question whether the output signal from this bridge is influenced with parameters Q and y_{cp}.

The results have shown that strains on inner and outer side of disc are independent of change of contact point position of Y force (Figs. 4 and 5). Accordingly, this influence is neglected. On the other side, the location of Q force significantly affects the strains. There are only few radial distances in which this influence is small and they are the most suitable for placing strain gauges of Wheatstone bridge for measurement of Q force, if aim is to compensate the error due to the change of contact point position. However, there are important issues related to a low disc sensitivity on Q force in given distances, as well as possibility of mixing with influence of Y force. Since aim is measurement of contact point position, of special importance is finding distances with the largest influence of this parameter. There are following: ρ=180 mm, ρ=262 mm and ρ=354 mm on inner side, as well as ρ=180 mm, ρ=262 mm and ρ=360 mm on outer side. They are the most suitable for Wheatstone bridge for measurement of parameter y_{cp}. From given six, three distances (ρ=262 mm on inner as well as ρ=262 mm and ρ=360 mm on outer side) are in correlation with distances with the highest sensitivity on Q force. Since y_{cp} is determined on the basis of strains caused by Q force, there is a question whether the output signal is affected by influence of Y force.

The obtained results have shown that in all radial distances on inner and outer side there is crosstalk or mixing of influences of parameters to be measured. For analysed wheel there are no distances which are in the same time sensitive to Q force and insensitive to Y force, and vice versa. Consequently, it is not possible to establish a simple relations between output signals and parameters to be measured. So, the method which enables determination of individual influences of parameters to be measured based on mixed output signals from Wheatstone bridges should be applied. One of the most suitable is method of Blind Source Separation (BSS) using Independent Component Analysis (ICA). In this case, final selection of optimal radial distances should be performed according to the criteria of maximum sensitivity to the effects of parameters being measured, regardless to crosstalk or degree of mixing of their influence in output signals from Wheatstone bridges [5].

On the basis of previous results it can be concluded that mixed strains on inner and outer side of disc depend from lateral force Y (regardless of contact point position) and whether vertical force Q acting in tread zone near nominal running circle (environment of CP1), tread zone near outer side of wheel (environment of CP2) or flange zone (environment of CP3). Accordingly, for accurate determination of values of unknown parameters Q, Y and y_{cp} minimum 4 independent measuring signals or 4 Wheatstone bridges are necessary.

The values of equivalent strains on determined radial distances with highest sensitivity are given in Table 1. Optimal distances are those with maximum sensitivity or with largest strains at the effects of parameters to be measured. The finally selected optimal radial distances are shaded in the Table 1.

Tab.1. The values of equivalent strains on radial distances with highest sensitivity and finally selected optimal radial distances

Parameter	ρ [mm]	Disc side	ε_e [μm/m]		
			CP1	CP2	CP3
Q	262	inner	181	152	211
	360	outer	211	279	143
Y	166	outer	289	288	294
	168	inner	340	339	345
	236	outer	275	275	280
	242	inner	383	382	389
y_{cp}	180	inner	87	41	19
	180	outer	144	98	51
	262	inner	181	152	211
	262	outer	125	89	163
	354	inner	118	74	40
	360	outer	211	279	143

5. EXPERIMENTAL TESTS

The experimental tests were carried out in laboratory for testing of railway vehicles at the Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Serbia. The experiment is realized with 3 independent Wheatstone half-bridges placed on the previously determined optimal radial distances. There are the following measuring points (Fig. 6): MP-1 (on outer side of disc at radial distance z=360 mm for measurement of Q force), MP-2 (on inner side at distance z=168 mm for measurement of Y force) and MP-3 (on inner side at distance z=262 mm for measurement of y_{cp}).

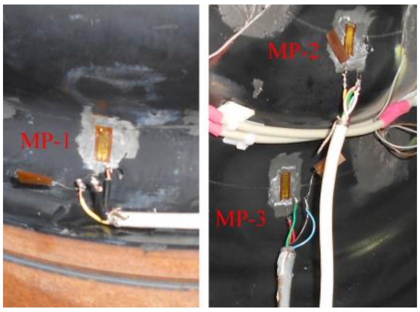


Fig. 6. Strain gauges at three measuring points

At measuring points, strain gages are placed in one vertical plane containing the wheel-rail contact point. This corresponds with cross section A-A in Fig. 2, so numerical and experimental results can be compared. Each of 3 strain gauges is connected into a half-bridge configuration using one additional strain gauge for temperature compensation. The 120 ohms strain gauges of HBM's production are used. The relative strains in vertical direction ε_z are measured and compared with the same obtained by the FEM. For a given radial distances, strains ε_z are almost identical to relative equivalent strains ε_e. Strains ε_z are measured for 3 different contact points that correspond to those from numerical calculation (Fig. 7).

Fig.7. The three contact points in experimental tests

The experiment is performed on special stand for testing and calibration of instrumented wheelsets [4] (Fig. 8). Data acquisition is carried out by using 8-channel universal amplifier QuantumX MX840A by HBM.

Fig.8. The detail from experiment on the test stand

The results of experimental tests for different loads cases and their comparison with FEM results are given in Table 2.

Tab.2. The comparison of experiment and FEM

Load case	Source	Strain ε_z [μm/m]		
		Measuring point		
		MP-1	MP-2	MP-3
Q=40 kN,	Exp.	–83	10	–65
Y=0, CP1	FEM	–85	12	–73
Q=60 kN,	Exp.	–123	14	–95
Y=0, CP1	FEM	–127	18	–109
Q=40 kN,	Exp.	–102	23	–58
Y=0, CP2	FEM	–114	31	–61
Q=40 kN,	Exp.	–147	34	–86
Y=0, CP2	FEM	–171	47	–92
Q=0,	Exp.	–47	–101	–76
Y=15 kN, CP3	FEM	–36	–100	–79
Q=0,	Exp.	–101	–233	–162
Y=35 kN, CP3	FEM	–84	–232	–185
Q=40 kN,	Exp.	–109	–141	–163
Y=20 kN, CP3	FEM	–103	–140	–190
Q=60 kN,	Exp.	–197	–276	–302
Y=40 kN, CP3	FEM	–179	–277	–338

It can be seen that results obtained by experimental tests are very similar to results obtained by the FEM. Generally, it can be concluded that deviations between numerical and experimental results are about 10÷15%. It can be concluded that experimental results confirm the validity of wheel model and numerical results.

6. CONCLUSION

This paper presents a method for accurate identification of optimal locations of strain gauges on instrumented wheelsets for measurement of wheel-rail contact forces Q and Y, as well as contact point position. The method is applied on standard wheelset with 22.5 t axle load and normal track gauge, intended for freight wagons. Problem solution is based on development of wheel model and systematically analysis of strains distribution on wheel disc for individual action of vertical and lateral forces in different contact point positions. Four optimal radial distances for placing the strain gauges for measurement of three parameters are identified. The validity of model is confirmed with experimental tests performed on special stand for testing and calibration of instrumented wheelsets. Proposed method is universal and can be successfully applied to any wheelset which is selected to be instrumented.

ACKNOWLEDGEMENT

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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VISUAL MONITORING SYSTEMS IN AUTOMOBILES AND TRAINS: A COMPARISON

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Abstract *– In recent years, with the rapid development of visual monitoring systems and infrastructure, more and more intelligent monitoring systems have been created based on computer vision and pattern recognition techniques. One of the applications of these systems is to provide our vehicles, roads and railway to be more secure and to make our travel more enjoyable. In this paper, some visual monitoring systems used in cars will be discussed with comparison to the similar systems in trains.*

Keywords – Visual monitoring, intelligent drive, safety systems, railway inspection.

1. INTRODUCTION

Rapid growth of human population has led to an increase in the number of vehicles used every day. With such increase of vehicles, road and rail traffic management is facing an accumulation of ever-growing pressure. To confront this issue different systems have been developed. On one side intelligent surveillance systems employing computer vision and pattern recognition techniques have appeared. These systems can provide intelligent video analysis, such as the cases of illegally turning around or jumping the red light, to improve the efficiency of traffic management. The most used of these systems is automatic license plate recognition (ALPR) used in specific occasions like finding the parking lot or automatic toll payment [1]. The problems with these systems are that they are usually based on centralized infrastructures where cameras and sensors are implemented along the roads to collect the information on traffic and send it to a central unit to process it and make appropriate decisions, which can lead to a long reaction time. In addition, this kind of system needs large investment for large-scale deployment and requires periodic maintenance that can be expensive. On the other side, rapid evolving of wireless technologies led to a development of a new decentralized (or semi-centralized) architecture based on vehicle-to-vehicle and vehicle-to-infrastructure communications. This type of architecture relies on a distributed and autonomous system and is made up of the vehicles themselves without the support of a fixed infrastructure for data routing. This network (*Fig. 1*) is called vehicular ad hoc network (VANET), and is a specific application of traditional mobile ad hoc networks (MANET) [2, 3].

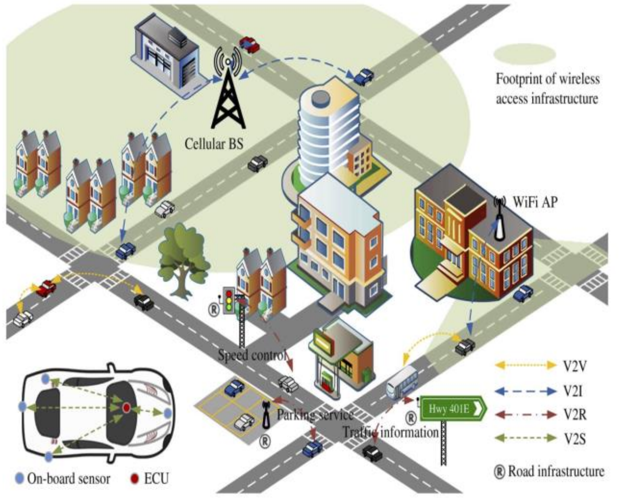

Fig.1. Example of VANET network

The fundamentals of this system are the intelligent vehicles, which are able to collect and interpret the

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collected information about the surroundings of the vehicle with the purpose of helping the driver to make a decision and if the vehicle belongs to the VANET network forward the information to other vehicles. In this paper, some visual monitoring systems as part of intelligent vehicles will be presented with comparison to the similar systems in trains.

2. VISUAL MONITORING SYSTEMS IN CARS

The new developments in car industry aim to create the safe experience during the drive. One of the more recent developments is the collision avoidance technology. Some new cars get equipped with technology that helps the driver to avoid a collision in a number of ways. By combining cameras, radars, lasers and other sensors, cars are getting safer for drivers and for the environment. Safety systems in cars that rely on visual monitoring systems are:

- Traffic sign recognition,
- Pedestrian detection,
- Driver drowsiness detection,
- Lane departure warning system
- Night view assist

2.1 Traffic sign recognition

Traffic sign recognition is a technology where a vehicle can recognize the traffic signs put on the road e.g. "speed limit" (*Fig. 2*) or "children". This is part of the features collectively called Advanced driver-assistance systems or ADAS, systems which are intended to help the driver in the driving process.

Fig.2. Speed limit recognition

System works using front-facing cameras installed in modern vehicles. First, the image from these cameras is acquired and preprocessed and after that, the input image goes to three stages recognition process, which consists of color segmentation, shape classification and pattern recognition [4, 5]. At the end, the recognized traffic sign appears on the car board.

2.2 Pedestrian detection

Pedestrian detection is a technology where a vehicle can recognize both pedestrians and cyclists and if a collision risk is imminent, the system can sound an audible alarm and then automatically apply the brakes (*Fig. 3*). The system consists of radar integrated into the car's grille, and a camera embedded in the interior rear-view mirror. The radar detects objects and tracks the vehicle's distance to them, taking the vehicle's speed into account, while the camera determines the type of object based on its movement pattern, height and size [6, 7]. Methods used for the detection of objects on acquired image usually are Integral Channel Feature detector and pre-trained model using a convolutional neural network [8, 9].

Fig.3. Pedestrians and cyclists detection

2.3 Driver drowsiness detection

The aim of this system is to locate, track and analyze the face and the eyes (*Fig. 4*) of the driver and then compute a drowsiness index, working under varying light conditions and in real time. The image acquired from the camera facing the driver, is sent to the clasificator which from the eye-blinking frequency, eye-gaze movement, head movement and facial expressions [10] can determine the level of driver's drowsiness and if necessary warn the driver. For instance, this system will be introduced in London to trams as percaution for drivers to detect fatigue or distraction [11].

Fig.4. Face and eyes detection

2.4 Lane departure warning system

Lane departure warning system is a mechanism designed to warn the driver when the vehicle begins to move out of its lane unless a turn signal is on in that direction. The system uses the principle of Hough transform and Canny edge detector (*Fig. 5*) to detect lane lines from realtime camera images fed from the front-end camera of the car. If the driver does not respond to the warning, the system can take the steps to ensure the vehicle stays in its lane.

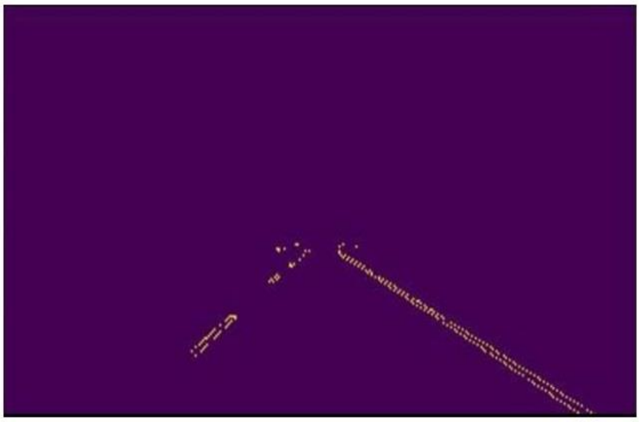

Fig.5. Detection of lane lines

2.5 Night view assist

The system consists of a camera, which is paired with two LED infrared sensors. The system can recognize less noticeable objects, and display them on the instrument panel. In addition, the system can flash at any pedestrians and animals it detects in order to warn both the driver and the pedestrians and animals [12]. The flashing light is directed in such way that other vehicles in traffic are not dazzled.

3. VISUAL MONITORING SYSTEMS IN TRAINS

Railway inspection is the preventive examination for defects that could lead to the catastrophic failures. During this periodic inspection damage can be detected at an early stage so that in several cases the service life of the rails can be greatly prolonged through preventive measures. This examinations could include track inspections aswell as overhead line inspections.

3.1. Rail corrugation detection

The system for rail corrrugation detection consists of 2 subsystems - image acquisition subsystem (*Fig. 6*) and corrugation identification subsystem. The main function of the image acquisition subsystem is to capture rail images in real-time. The corrugation identification subsystem analyzes the obtained rail images and judges whether an image contains corrugation or not [13].

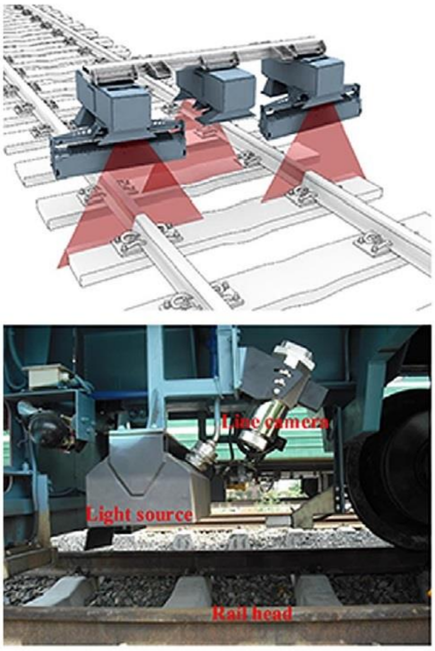

Fig.6. Image acquisition subsystem

3.2. Fastener inspection system

The main purpose of this system is to detect damaged and loose fasteners. The system consists of four commercial structured light sensors, which are mounted on a special mechanical trolley, a single-board computer, a data storage module, a synchronization unit, an encoder and an auxiliary power module (*Fig. 7*). Firstly, precise and extremely dense point cloud of fasteners are obtained. Using a decision tree classifier, the defects of the fasteners are classified. After that, the centerline of the metal clip of normal fasteners is extracted. Lastly, the looseness of the fastener is evaluated based on the extracted centerline of the metal clip [14].

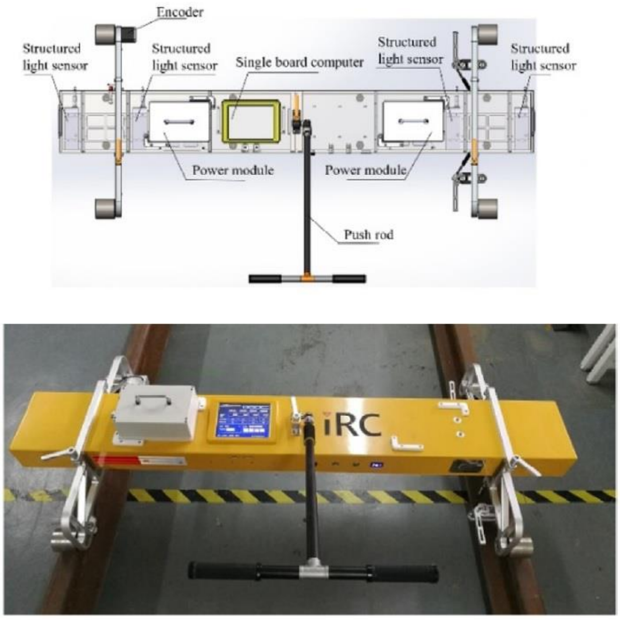

Fig.7. Fastener inspection system

3.3. Catenary inspection system

This system inspects catenary (suspension guy, suspender, clamps) and catenary cross span (clamps, insulator, pipes). The system can also inspect if there are any foreign bodies or missing parts. The sensor system (camera and laser-based illumination unit) is installed in device modules on the roof of the measuring vehicle on both sides. The recorded data is compared automatically with the previously stored reference values assigned via the track chainage [15]. Software analyses the differences between the actual status and reference status and determines the degree of severity of the fault (*Fig. 8*).

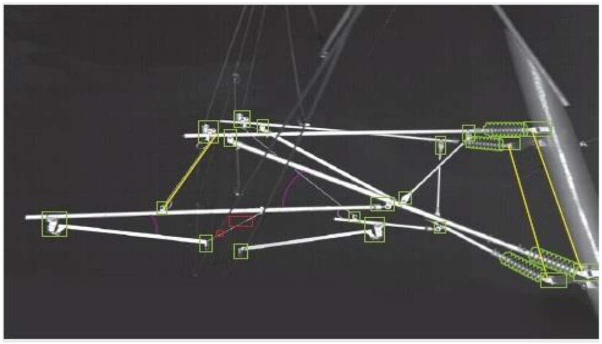

Fig.8. Result of catenary cross span check

3.4. Vegetation inspection

This system inspects the entire area of the rail bed structure, the periphery and track for the presence of the vegetation. Cameras are mounted on the train and coupled with headlights that illuminate the inspection area (*Fig. 9*). The obtained pictures are evaluated using image processing algorithms. The fault patterns are classified automatically and the results are provided in a fault protocol immediately after inspecting the rails, archived in a database or forwarded to superordinated systems [15].

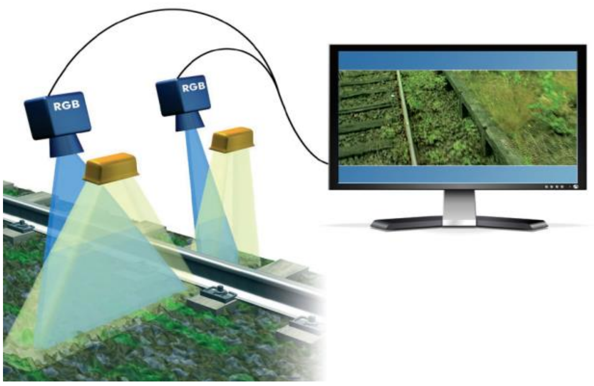

Fig.9. Vegetation inspection system

4. CONCLUSION

In this paper a brief review of visual monitoring systems used in cars and trains was given. This kind of monitoring is interested and challenging field in railway. While many new powerful and creative solutions already have been proposed, still many open issues exist. The future development on visual monitoring systems used in railway will have to deal with challenges like higher speeds of trains and longer distances at which these systems have to operate. In addition to technical breakthroughs, the phase of market introduction is critical for the success of this technology.

ACKNOWLEDGEMENT

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NIGHT VISION BASED SYSTEM FOR ATO OBSTACLE DETECTION

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***Abstract** – This paper presents an obstacle detection system for autonomous train operation (ATO) based on night vision. Experimental setup with ICCD (Intensified CCD) camera, as night vision system, was used for image acquisition at night conditions. For obstacle detection, advanced image processing algorithm was developed and used. In order to achieve reliable detection, rail tracks were detected to define Region of Interest (ROI). In ROI, detected rail tracks were analyzed with goal to find any interruption which is caused by existence of an obstacle. Detection of obstacle was done using of image segmentation method. The algorithm was tested on great set of images captured in six specific cases for obstacle detection, which are quite characteristic for the field of railway. The results showed that system can provide good obstacle detection at night conditions.*

Keywords – night vision, obstacle detection, autonomous train operation, railway.

1. INTRODUCTION

Railway represents one of the most important type of the transport. Modernization of the railway is a comprehensive process that includes increasing of safety, quality, effectiveness and capacity of all segments of the railway. One of the set of segments is the development of Autonomous Train Operation (ATO), which represents an important module for modernization of the railway. This module includes different systems with specific tasks, however, one of the important systems is an obstacle detection system. The task of this system is to detect objects on certain distances, in order to provide on-time braking and avoiding of the accident.

One of the key elements for correct detection of the obstacles are environmental conditions. That provides good or bad visibility of the obstacles that affects on quality of detection. In a day and good-light and good weather conditions, there are many vision sensors for quite good detection [1]. However, in low-light and bad weather conditions, visibility of objects can be reduced, and an obstacle detection can be unsatisfactory. In that conditions, thermal imaging systems with their operating range in the invisible infrared region of the spectrum, can be used [2-5]. Use of night vision system for an obstacle detection in those specific conditions enables detection in extremely low-light conditions and at night, because this system needs a very small amount of light for good operating. In [6] two-step method for detection and tracking of pedestrians with single night vision camera installed on vehicle, is proposed. The detection is performed using of support vector machine (SVM) and the tracking with a combination of Kalman filter prediction and mean shift tracking. Two new techniques for pedestrian detection using a stereo night-vision system installed on the vehicle is introduced in [7]. Two-stage method for stereo correspondence and motion detection without explicit ego-motion calculation use of characteristics of night-vision video data, in which humans appear.

In this paper, application of night vision system for detection of obstacle in autonomous train operation is presented. First, rail tracks were detected using of image segmentation method, in order to define a region of interest (ROI). Continuity of detected rail tracks was analyzed in ROI, for finding of interruption where obstacle can be. For obstacle detection, image segmentation method was used.

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2. NIGHT VISION SYSTEM

Night vision systems can use various types of technologies to allow users to see in no light and low-light conditions. Basic working principle of night vision system is to collect the tiny amounts of light, that are present in environment but may be imperceptible or is not enough for human eyes, and amplifying it to the point that user can easily observe the image. Night vision system, which was used in this research, is ICCD (Intensified CCD) camera consist of optical lens system, image intensifier tube and CMOS camera sensor coupled on image intensifier tube output screen (Fig.1.).

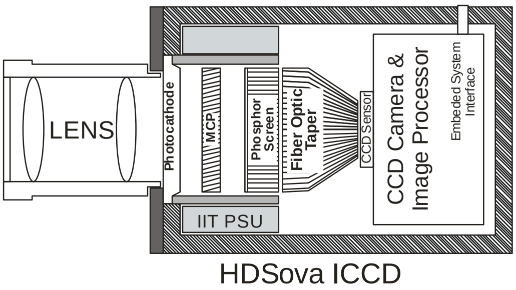

Fig.1. ICCD camera scheme

The task of optical lens system is to provide good magnification of object at certain distances. The main function of the image intensifier is the multiplication of the incoming photons, i.e. the amplification of the incoming light signal. This enables the ICCD camera to capture images at extremely low light condition and/or at extremely short exposure time down to 200ps, when the integral of the photon flux over the exposure time is very small. Image intensifier (Fig. 2) consists of three functional units:

- The photocathode, that converts the incoming photons to photo electrons,
- The micro channel plate (MCP) that strongly multiplies these photo electrons,
- The phosphor screen that converts the multiplied photo electrons back to photons.

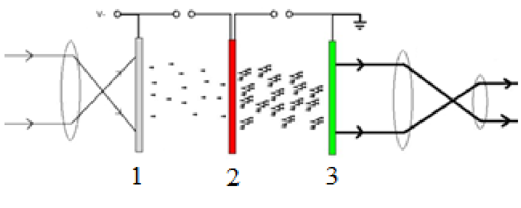

Fig.2. Three functional units of an image intensifier: the photocathode (1), the micro channel plate (2) and the phosphor screen (3)

Image intensifier provides the so-called gating capability of the ICCD camera, i.e. the shutter function. If the camera is gated "on", the shutter is open. In this case the incoming light is intensified, i.e. amplified, transmitted to the CCD chip and collected. If the camera is gated "off", the shutter is closed and no light is transmitted to the CCD sensor. This enables ICCD camera to be used for many purposes in no light or low-light operating conditions.

3. OBSTACLE DETECTION SYSTEM

The main goal was to detect obstacle on rail tracks and/or in their close vicinity in no light and low-light conditions. For that purpose, after image acquisition with night vision system, first, rail tracks were detected using of region based segmentation method. In this case, thresholding and region growing with optimal threshold range was used [8]. Region of interest (ROI) is determined as region where rail tracks are detected with a certain space next to them, because any object located farther from the rail is not object of interest. After that, continuity of detected rail tracks is analyzed, starting from the assumption that there is an obstacle at the place where rail tracks have discontinuity. i.e. where rail tracks are interrupted. For detection of obstacles, image segmentation with optimal threshold was used, and detected obstacles was marked with red rectangle. The image processing algorithm for obstacle detection is shown on Fig. 3.

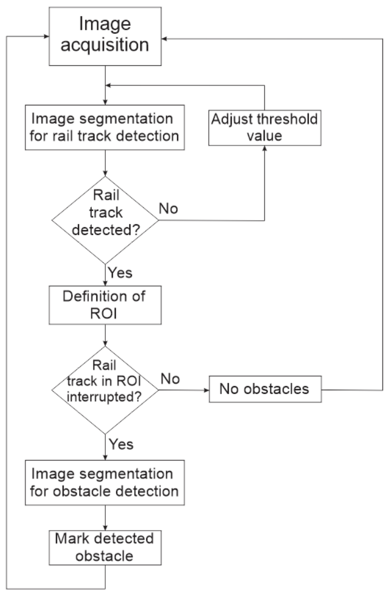

Fig.3. Obstacle detection algorithm

4. EXPERIMENTAL SETUP

Experimental setup consists of three monocular RGB cameras, one IR camera, one night vision system and one laser scanner. All cameras were mounted in metal housing, especially designed for this purpose (Fig.4). For an obstacle detection in no light and low-light conditions, IR camera and night vision system were used. This setup was tested on field tests performed on rail tracks in different times of the day and night. During tests, humans were imitating obstacles on the rail tracks and next to them on different distances from experimental setup.

Fig.4. Experimental setup on field

5. RESULTS AND DISCCUSION

In order to achieve greater reliability and robustness, image processing algorithm for an obstacle detection is implemented and tested on a great set of images. Those images were continuously captured by experimental setup with night vision system during night conditions. There were six specific cases for an obstacle detection, which are quite characteristic for the field of railway.

The first case was that there was no any obstacle on rail tracks and/or in their close vicinity (Fig. 5 left). Rail tracks were detected (Fig. 5 middle) and, based on that, ROI was defined. There were no interruptions of rail tracks so, in further analysis was confirmed that there were no obstacles in ROI (Fig. 5 right). The second case was that there was obstacle on right rail track (Fig. 6 left). First, rail tracks were detected (Fig. 6 middle) and ROI was defined. However, in this case, there was interruption on right rail track, and in further image processing, obstacle was detected in ROI and marked with red rectangle (Fig. 6 right). In the third case, obstacle was next to the right rail, but quite far from it (Fig. 7 left). Rail tracks were detected (Fig. 7 middle), ROI was defined, but there were no interruptions on rail tracks. In further analysis, it was confirmed that obstacle was far from rail tracks and out of ROI. (Fig. 7 right). The fourth case was with obstacle between rail tracks (Fig. 8 left). Rail tracks were detected (Fig. 8 middle), ROI was defined, but even obstacle was not directly on rail tracks, its position affected the occurrence of interruption on the rail tracks. In further image processing, obstacle was detected in ROI between rail tracks and marked with red rectangle. (Fig. 8 right). In the fifth case, obstacle was next to the left rail, but far from it (Fig. 9 left). Rail tracks were detected (Fig. 9 middle) and ROI was defined. However, there were no interruptions on rail tracks and obstacle was not detected because it was not in ROI. (Fig. 9 right). The sixth case was with obstacle on left rail track (Fig. 10 left). After rail tracks were detected (Fig. 10 middle) and ROI was defined, there were interruption on left rail track. That indicated that there was an obstacle there, so in further image processing, obstacle was detected in ROI on left rail track and marked with red rectangle. (Fig. 10 right).

Fig.5. The first case – no obstacles

Fig.6. The second case –obstacle on right rail track

Fig.7. The third case –obstacle next to the right rail track

Fig.8. The fourth case – obstacle between rail tracks

Fig.9. The fifth case –obstacle next to the left rail track

Fig.10. The sixth case –obstacles on left rail track

6. CONCLUSION

Development and modernization of railway includes implementation the novel and intelligent technical solutions, such as Autonomous Train Operation (ATO). However, one of the important parts of complex ATO module is obstacle detection system with task to operate in any weather and illumination conditions.

In this paper, an obstacle detection system based on night vision for ATO, is presented. Detection is performed by developed advanced image processing algorithm based on region based image segmentation method, that includes rail tracks detection and obstacle detection on rail tracks and in their close vicinity. System was tested on great set of images captured by night vision system at night, and showed good results for obstacle detection during night conditions with certain noise which can be solved with some artificial intelligent tools.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

ANALYSIS OF THE KINETICAL BEHAVIOUR OF THE AXLE ASSEMBLY IN THE RAILWAY VEHICLES

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Abstract –*A heat generated due to the wheel rolling on rails and wheel rolling in the stage of braking has the significant influence on the thermal behaviour of the bearing arrangement of wheel axle assembly. Kinetical behaviour of the wheel assembly directly affects the quantity of the generated heat in this assembly what represents the basic reason for researching the kinetical behaviour. This paper analyzes the kinetical behaviour of axle assembly in the railway vehicles whereat the velocities of characteristic points of wheel assembly are defined as well as the position of instantaneous velocity pole, wheel angular velocity and sliding velocity. Three cases of rolling were analized: rolling without sliding (when the instantaneous velocity pole is between wheel and rail), rolling with sliding in forward direction (when the wheel is rolling with braking) and rolling with sliding in backward direction (when the wheel is rolling with slippage). The considered speeds of train motion are in the range of 10 to50 km/h.*

Keywords – Towed railway vehicles, wheel axle assembly, kinematical behaviour.

1. INTRODUCTION

Rail transportation represents one of the oldest forms of transport and today it takes the second place for the transport of cargo after the sea transport and the second place after the road transport when it comes to passengers. Its most important function is the long distance transport of industrial and agricultural materials, wood construction materials, ores and semi-products of chemical industry.

Although in comparison with the other forms of transport, the railway transport has a range of advantages related to economic benefits (lower energy consumption and especially ecological sustainability, the ability to transport various goods), inefficiencies created by railway regulations have brought this type of transport into inferior position. The standstill in the innovations of railway technology and inadequate response to the significant increase in the quantity of smaller packages, alongside the reduction in goods suitable for railway transport (such as ore, coal, ...), are the primary explanation for the decrease in railway transport. The European Union treats the railway as transportation provider of the future and seeks to reaffirm the railway transport throughout Europe, with the demand of competitive, secure and quality transportation of all types of goods. The realization of all these goals requires, among other things, the construction of the modern wagons adapted to the market challenges, specific technological requirements and systems that allow for loading/ unloading operations to be carried out quickly [2].

Wheel axle assembly of the towing and towed vehicles represent one of the vital assemblies due to the fact that it carries and transfers the complete load onto the rail.

Wear of vital and functional parts of railway systems such as towing and towed vehicles has been accelerated in exploitation mainly because of inadequate maintenance, hidden manufacturing errors, overload in exploitation etc. For these reasons, the possibility of the system vital parts revitalization has been considered with respect to the replacement with the new ones, where technically feasible and reliable from the exploitation point of view. From the very

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existence of monoblock wheel, ER7 material quality, as one of the basic vital parts of the railway towed vehicle, very litte has been changed up to now in the technological process of maintenance in exploitation. The maintenance of monoblock wheel of ER7 quality in exploitation is most often performed by machining of rolling surface and forming of new profle. This technological procedure is relatively expensive and very often insufficiently economical manner of maintenance. By this way, an average of 50 kgs of the quality steel material turns into sawdust and it is only feasible for the limited number of times. It is estimated that of the total unwanted material wear of the monoblock wheel of ER7 quality in exploitation, 60% wear accounts for wheel-rail contact abrasion, 30% for wheel-brake shoe contact, 6% for high temperature, 1% for corrosion and about 3% for other forms of wear [11].

Mohan [9] upon applying finite element methods conducted a prediction of the thermal and static behaviour of the towed railway vehicles wheel. Based on this analysis the temperature value for the wheel flange amounts to 70 [°C]. By the static analysis Von Mises stress values were determined depending on the deformations caused by static load. The maximum deformation occurred on the wheel flange amounts to 0,2196 [mm], while the maximum stress on the wheel 46,34 [N/mm^2]. The analysis of the wheel static behaviour was made only for the wheel itself without other vital parts of this assembly (bearings and axle). By the integration of the thermal and static behaviour on one model the values of displacement and stress were determined. The maximum displacement on the wheel flange amounts to 1,084 [mm] and the maximum stress on the wheel 148,98 [N/mm^2].

Bearing arrangement and therewith the cylindrical roller bearings for railway are the key components of the towed vehicles wheel. The temperature of bearing is one of the most important parameters whose monitoring can determine its condition in exploitation. Roller bearings for axle assemblies are the most frequently lubricated by grease put into the closed box to secure the proper lubrication. During the bearing rotation this grease comes into the contact with the rollers and rings what after the certain period of time causes the mechanical degradation of grease. For this reason it is very important to change grease before it loses its mechanical properties. Based on the test results it may be concluded that lubricant has the important infuence on the temperature value of bearing in exploitation [8].

Heat generated due to wheel rolling on rails, heat generated due to braking as well as the effect of surrounding temperature make the significant impact onto the thermal behaviour of the bearing arrangement of axle assembly what was confirmed on the bases of a large number of experimental testings and computer modelling of axle assembly and presented in [1].

In order to develop the reliable computer model of generated heat impact due to rolling without braking, with braking and with slippage to the thermal behaviour of the bearing arrangement of axle assembly, it is necesary to make the reliable mathematical model for determination of kinetic behaviour of axle assembly.

2. WHEEL AXLE ASSEMBLY

Wheel axle assembly of the towed railway vehicles can be configured with various types of bearings (cylindrical roller bearing, barrel-shaped roller bearing and tapered roller bearing). Type of bearing, as well as its static, thermal and dynamic behaviour directly affect the lifetime of axle assembly.

Kinematic behaviour represents the important parameter affecting the behaviour of axle assembly in exploitation i.e its bearing configuration. Figure 1 shows the wheel axle assembly with bearing configuration.

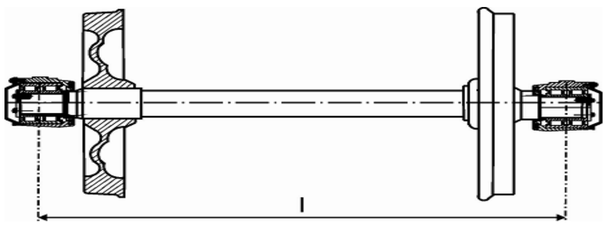

Fig.1. View of wheel axle assembly

3. KINEMATIC BEHAVIOUR OF AXLE ASSEMBLY

Any physical object in motion along the straight line, generally, and at any moment has, on its material or non-material part, only one point P, the velocity of which is equal to zero V_P=0. This point is called the instantaneous velocity pole.

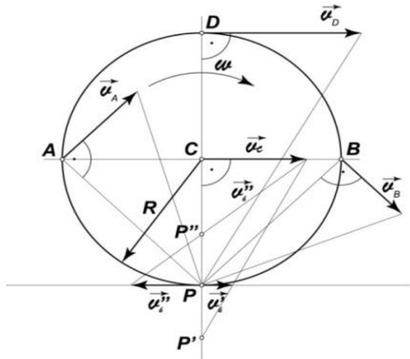

Fig.2. Position of instantaneous velocity pole

When the direction of the point velocity is known, the straight line pulled through this point and perpendicular to the velocity vector must pass through the instantaneous velocity pole P. The position of instantaneous velocity pole at wheel rolling on rails is shown in figure 2.

Three cases of instantaneous velocity pole position are shown as follows:

- rolling without sliding (P);
- rolling with sliding forward (P');
- rolling with sliding backwards (P'').

When the point at the wheel flange becomes wheel-rail contact point P it has no vertical velocity component:

$$V_{Py}=0 \tag{1}$$

i.e. it has the horizontal velocity component only:

$$V_P \equiv V_{PX} = V - R\,\omega \tag{2}$$

If at the wheel-rail contact point P there is instantaneous velocity pole, then, according to definition of instantaneous velocity pole, valid is

$$\overrightarrow{V_P} = \mathbf{0} \tag{3}$$

so getting

$$V_P = V - R\,\omega = \mathbf{0} \tag{4}$$

respectively

$$V_C = V = R\,\omega \tag{5}$$

or

$$\omega = \frac{V_C}{R} = \frac{V}{R}. \tag{6}$$

The expressions (4) and (5) represent the condition of rolling without wheel sliding on rails. Instantaneous velocity pole when rolling without sliding is in wheel-rail contact point. If there is no instantaneous velocity pole at wheel-rail contact point P, then it is

$$\overrightarrow{V_P} \neq \mathbf{0} \tag{7}$$

Based on previously exhibited situation it can be concluded that:

$$V_P = V - R\,\omega \neq \mathbf{0} \tag{8}$$

When the condition (8) is valid then at contact point P comes to sliding and

$$V_k = V - R\,\omega \equiv V_P \tag{9}$$

If

$$V_k = V - R\,\omega = V_k' > \mathbf{0} \tag{10}$$

then sliding appears at contact point, the velocity of which is directed to the wheel motion (forward direction) and instantaneous velocity pole P is under the contact point P.

If

$$V_k = V - R\,\omega = V_k'' < \mathbf{0} \tag{11}$$

then sliding appears at contact point, the velocity of which is directed opposite to the direction of wheel motion ($V_{\downarrow}k^{\uparrow}(,))$.

The equation of instantaneous velocity pole in case of no sliding is:

$$\omega = \frac{V_A}{PA} = \frac{V_B}{PB} = \frac{V_C}{PC} = \frac{V_D}{PD} \tag{12}$$

respectively

$$\omega = \frac{V_A}{P'A} = \frac{V_B}{P'B} = \frac{V_C}{P'C} = \frac{V_D}{P'D} \tag{13}$$

in case of wheel sliding forward, and

$$\omega = \frac{V_A}{P''A} = \frac{V_B}{P''B} = \frac{V_C}{P''C} = \frac{V_D}{P''D} \tag{14}$$

in case of wheel sliding backwards.

4. RESULTS AND ANALYSIS

The values of angular velocity in figure 3 are shown on the basis of practical values of train motion speed without sliding.

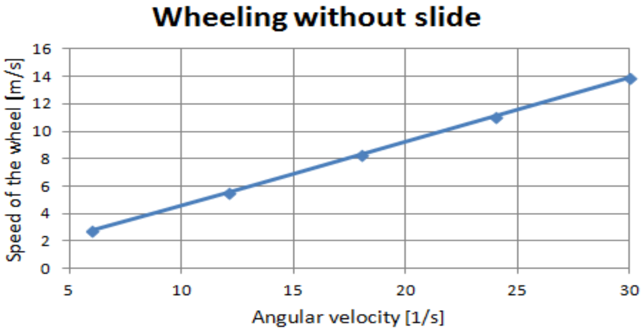

Fig.3. Effect of wheel motion speed on angular velocity

Effect of wheel rotation angular velocity on the speeds of characteristic wheel points are shown in figure 4.

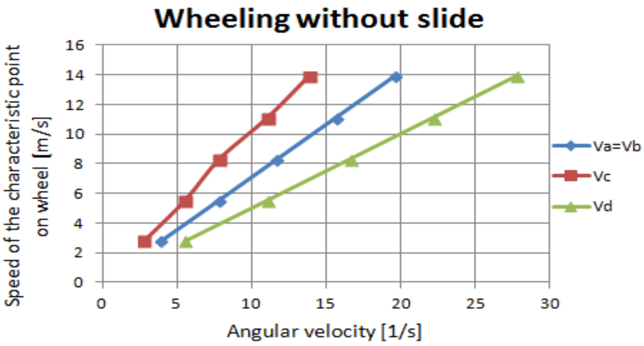

Fig.4. Effect of wheel rotation angular velocity on the speeds of characteristic wheel points

Wheel rolling on rails with sliding represents the second considered case of train motion and the sliding velocity is directed forward while instantaneous velocity pole is under the surface of the wheel-rail contact. The results of the wheel sliding velocity in dependence on angular velocity and the speed of wheel motion are shown in figure 5. With the increase of distance between the wheel-rail contact point and instantaneous velocity pole the numerical value of sliding velocity is getting closer to the value of train motion speed.

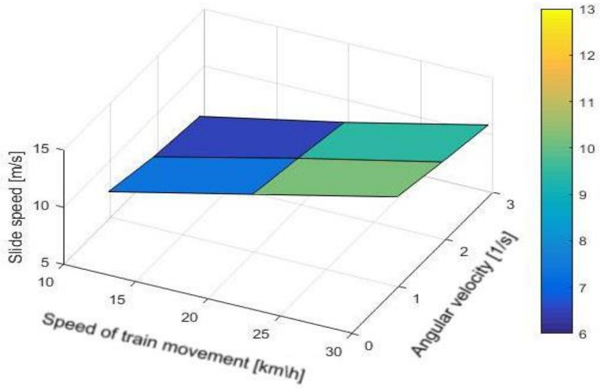

Fig.5. Effect of wheel rotation angular velocity and wheel motion speed on sliding velocity- sliding in forward direction

The last considered case of rolling is when the sliding velocity has an opposite direction to the direction of wheel motion, then it comes to wheel slippage. The sliding velocity is in the function of angular velocity and wheel motion speed as shown in figure 6.

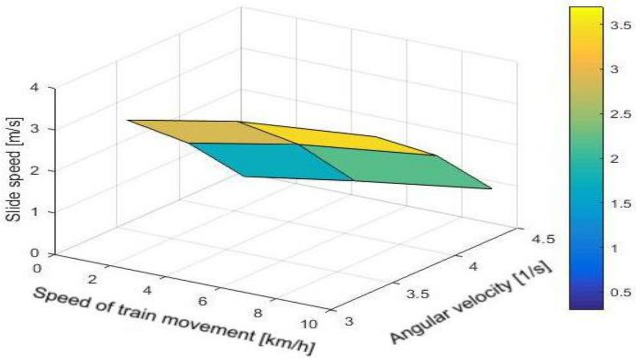

Fig.6. Effect of wheel rotation angular velocity and wheel motion speed on sliding velocity-sliding in backward direction

5. CONCLUSION

The paper analyzes kinematic behaviour of axle assembly in the towed railway vehicles representing the basic pre-condition for the development of mathematical and computer models of the thermal behaviour due to wheel rolling with and without sliding. The numerical values of the motion speeds and sliding velocities are to be one of the input parameters in the computer model for prediction of the generated heat due to wheel rolling and braking. Based on previously exhibited material it can be concluded that the sliding velocity has the significant impact on wearing and heat generation in wheel-rail contact and this heat affects the heat of bearings used in assembly having the limitations in respect of permissible working temperature.

ACKNOWLEDGEMENT

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ANALYSIS OF METHODS FOR DETERMINING OF IMPACT FORCES AT CROSSING OF WHEEL OVER RAIL IRREGULARITIES

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Dragan PETROVIĆ [3]

Abstract *– During the exploitation, the rail is exposed to intensive forces caused by the trains passing. These forces lead to the wear and non-uniform damages of the rail head. When the wheels pass over these places, sudden change of rail geometry causes very intensive impact forces which are transmitted to the track and railway vehicle. The consequences of action of these dynamic forces are very often fatigue and failure of elements of vehicles and tracks which in many cases cause derailments with enormous consequences. From this reason, these problem is very actual in the field of research of dynamic behavior of railway vehicles. Hence, the aim of this paper is to analyze some of the existing methods for determination of impact forces at crossing of railway wheel over the rail irregularities. This initial research of authors should draw attention of wide scientific and professional auditorium on this problem and to give base for further research and improvements in this area.*

Keywords – Impact forces, wheel-rail contact, track irregularities.

1. INTRODUCTION

During the running of railway vehicles there are intensive impact forces due to the various irregularities of the track. When the wheels pass over these places, sudden change of rail geometry causes very intensive impact forces which are transmitted to the track and railway vehicle. Due to the significant influence on the safety on railway, this problem is very actual in the field of dynamic of railway vehicles [1, 2]. The subject of the state of the art papers in this field is usually concerned to the determination of impact forces at dipped rail joints and modeling of discontinuities in the wheel-rail contact [3, 4]. The very actual issue is also research of the damages of the rails under fatigue of material, improper maintenance, etc [5]. The intensity of impact forces is proportional to the increase of geometric abnormalities of the track, the stiffness of the rails, the running speed, uneven distribution of the cargo on the vehicle, etc. The next chapters show analysis of some existing ways for determination of mentioned impact forces and for studying of this phenomena in general.

2. MODELING OF WHEEL-RAIL CONTACT

The dynamic model of moving the wheel along the rail is shown in Fig. 1. This model is usually used for describing the single point wheel-rail contact. The differential equation which describes this motion has the following form [3]:

$$m_w \dot{u}(t) + k_h \cdot u(t) = k_h \cdot z(t) \quad (1)$$

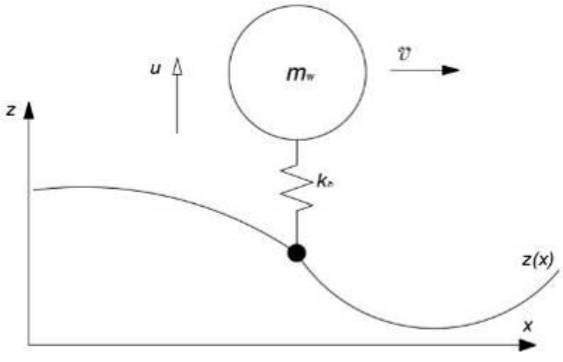

Fig.1. The modelling of continuous single point wheel-rail contact [3]

In equation (1) are: m_w – mass per wheel, u – the

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degree of freedom in the vertical direction, k_h – Hertz's rigidity on contact, z – vertical movement along the apripriate axis.

However, given model is not applicable in the analysis of crossing of wheel over rail irregularities. For these analysis, the wheel-rail contact in two points must be used. In this aim, we will observe the rail and the wheel as two rigid bodies. The wheel of radius *R* is moving with certain velocity ϑ and crossing over the step with height u_0 (Fig. 2). The distance *a* represents the minimum length at which the wheel is in contact with the rail at two points. Also, we assume that $u_0 << R$.

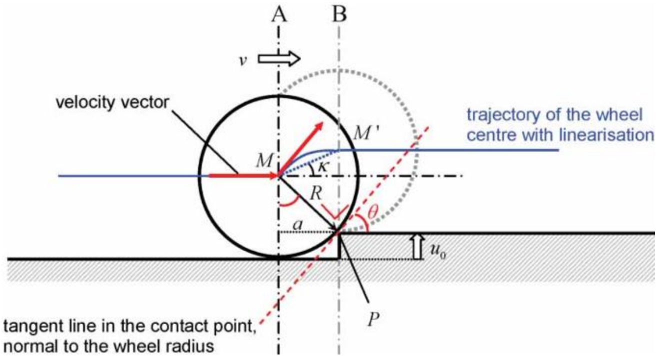

Fig.2. The kinematical wheel displacement for a vertical step in the rail surface [3]

The intensity of vertical velocity at wheel moves from point A to point B is [3]:

$$\dot{u}(0) = \vartheta \cdot \sin\theta = \vartheta \cdot \sqrt{\frac{2u_0}{R}} \quad (2)$$

The time required for the wheel transition from position A to position B is:

$$t_B = \frac{\sqrt{2Ru_0}}{\vartheta} \quad (3)$$

The equation which represents the movement of the wheel in vertical direction is [3]:

$$z(t) = \sqrt{\frac{u_0}{2R}}\vartheta t \cdot H(t_B - t) + u_0 \cdot H(t - t_B) \quad (4)$$

The previous equation (where *H* is Heaviside function) establishes the relation between the height of the step, radius of the wheel and running speed.

3. DETERMINATION OF IMPACT FORCES

3.1. Standard approach

For analysis and analytical determination of impact forces, we will consider situation when the wheel with a high velocity passes over the damaged rail (Fig. 3). In the moment of transition of the wheel from the rail 1 to the rail 2, intensive shock and high frequency vibrations occur. This situation can be modeled with the system with two degrees of freedom, as shown in Fig. 4. The wheel with mass m_w moves at a constant speed ϑ as it passes on the rail at an angle 2α. Here k_t represents rail stiffness which is in range 50÷200 MN/m, while k_h is Hertz's contact stiffness which is usually increasing and amounts about 1000 MN/m [1]. The impact force P_1 occurs at the moment when the wheel hits the bottom of the irregularity. This force has very short duration and it is caused by existing of some elasticity in the wheel-rail contact, which is taken into account with the Hertz's contact stiffness.

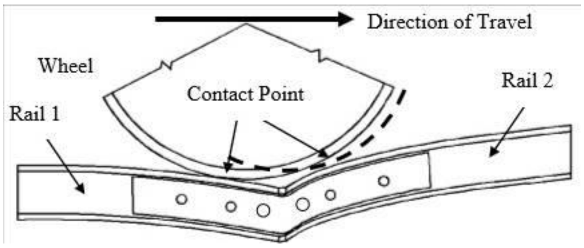

Fig.3. The wheel that passes over damaged rail [3]

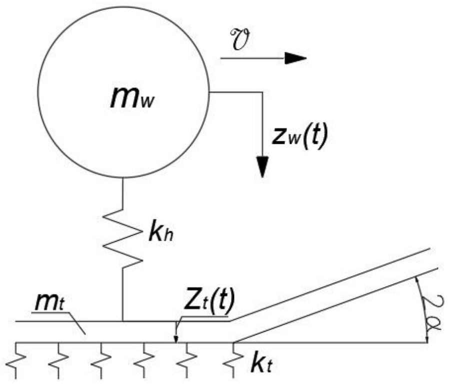

Fig.4. The model of wheel that passes over damaged rail [1]

The impact force P_2 occurs at the moment when the wheel come across to the curve with an sudden change of the rail geometry. Its duration is for a few milliseconds longer regard to P_1 (Fig. 5).

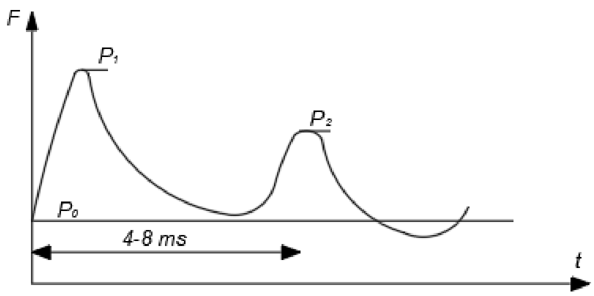

Fig.5. The impact forces P_1 and P_2

It should be noted that the force P_1 is caused by inertia of the rail and connection elements, while the force P_2 is caused by the rejection from the rail (P_0

is static load which wheel generates on the rail). The force P_1 cause a frequency in range 200÷1000 Hz, while the force P_2 cause a somewhat lower frequency in range 50÷200 Hz [3].

With assumption that $k_t << k_h$, the eigenfrequency of the rail and the wheel is [1]:

$$\omega_{P1} = \sqrt{\frac{k_h(m_w + m_t)}{m_w \cdot m_t}} \tag{5}$$

The impact force is calculated with equation [1]:

$$\Delta P_1 = k_h(z_w + z_t) \approx k_h z_w \tag{6}$$

If the initial vertical movement is equal to zero, then we can calculate the vertical velocity with the following formula:

$$\dot{z}_w(t = t_1) = \vartheta \cdot tg(2\alpha) \approx 2\alpha\vartheta \tag{7}$$

By using equations (5) and (7) we can write equation for vertical movement of the wheel [1]:

$$z_w(t) = \frac{\dot{z}_w(t_1)}{\omega_{P1}} \sin(\omega_{P1} t) \tag{8}$$

The change of equation (8) in equation (6) gives the equation for maximum impact force P_1:

$$P_1 = P_0 + k_h z_{w,\max} = P_0 + 2\alpha\vartheta \sqrt{\frac{k_h m_t}{1 + \frac{m_w}{m_t}}} \tag{9}$$

With assumption that $k_h = \infty$, the expression for eigenfrequency is:

$$\omega_{P1} = \sqrt{\frac{k_t}{m_w + m_t}} \tag{10}$$

The equation for the second force is [1]:

$$\Delta P_2 = -m_w \cdot \ddot{z}_w(t) \tag{11}$$

The impact force P_2 is:

$$P_2 = P_0 + 2\alpha\vartheta \sqrt{\frac{k_t m_w}{1 + \frac{m_t}{m_w}}} \tag{12}$$

The equations (9) and (12) are very significant for further considerations and research of influences of stiffness, mass, velocity, etc.

Despite the simplicity, this model gives clear identification of key problems in crossing of the wheel over rail irregularities.

3.2. Steenbergen's approach

This approach implies that during the wheel crossing over the rail irregularity the change of the speed and the resulted impact are happening only in some finite interval. Also, plasticity plays an important role.

For the case from Fig. 2, with the assumption of vertical linear movement and the wheel-rail contact in two points, the differential equation of system is [4]:

$$m_w \ddot{u}(t) + k_h \cdot u(t) = m_w \vartheta_0 \delta(t) \tag{13}$$

In the equation (13), δ represents the Dirac delta function while ϑ_0 can be calculated from formula (2). From equation (13), expression for calculation the amplitude can be obtained [4]:

$$\hat{u} = \vartheta \sqrt{\frac{2 m_w u_0}{k_h R}} \tag{14}$$

The equation for determination of impact force is [4]:

$$\hat{F} = \vartheta \sqrt{\frac{2 u_0 k_h m_w}{R}} \tag{15}$$

3.3. Simplified approach

Lately there are methods with a new simplified equations for determination of impact forces at crossing of wheel over the rail irregularities. One of the most important is method of Mandals et al. The dynamic of cargo semi-wagons that passes over the track irregularities of different depths with different speeds is analyzed (Fig. 6) [3].

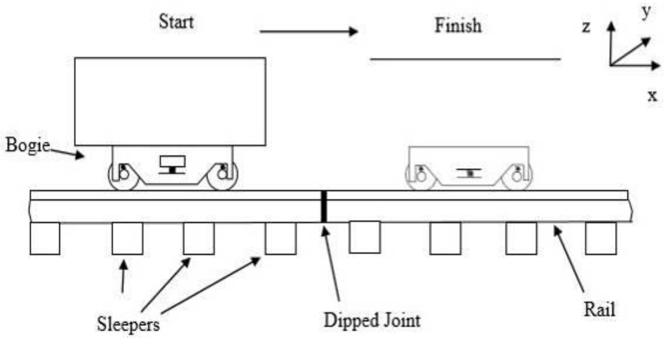

Fig.6. The dynamic wheel-rail interaction of a half-wagon model on the symmetrical dipped joint [3]

For this analysis, 1719 degrees of freedom is used. Research is conducted for speeds of 25 km/h, 50 km/h, 75 km/h and 100 km/h, as well as for irregularities with deep of 0.4 mm, 0.8 mm and 1.2 mm. The approach is based on the fact that forces P_1 and P_2 have linear relation which depends from the coeficient of corelation *X*.

The equations for determination of impact forces are [3]:

$$P_1 = 13X + 1,05 \quad (16)$$

$$P_2 = 6X + 1,05 \quad (17)$$

The correlation between the dynamic impact forces and non-dimensional coefficient X is shown in diagram in Fig. 7.

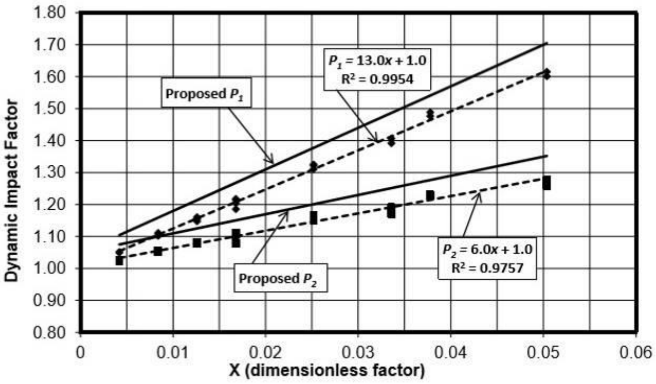

Fig.7. The non-dimensional expresions for P_1 and P_2 [3]

4. IMPORTANCE OF FATIGUE OF RAIL JOINTS

A lot of railway disasters in the period between 1996 and 2002 are caused necessity for research of influence of fatigue of rail joints. These research are usually concerned to analyzing of phisical influences of the railway wheels on the rail joints during the train passing. The estimation of bending stresses on the place of rail joints under the wheel load is usually based on the FEM (finite element method) analysis.

For rail type 132RE, bending moment can be calculated from following formula [5]:

$$M_R(x) = \frac{P}{4\lambda}\left[\exp(-\lambda x)(\cos(\lambda x) - \sin(\lambda x)\right] \quad (18)$$

In the previous expression, P represents the dynamic load of the wheel, while λ (constant) is defined with the following relation:

$$\lambda = \sqrt[4]{\frac{k_v}{4EI_R}} \quad (19)$$

In the expression (19) are: k_v – rail stiffness, E– modulus of elasticity, I_R – moment of inertia.

Accordingly, the maximum bending moment on the rail joints can be calculated with the following formula [5]:

$$M_J = \beta \frac{P_2}{4\lambda} \quad (20)$$

It can be noticed that in this expression the factor of joint efficiency β plays important role. The laboratory and field tests indicate that this factor depends on the condition of the joint. For a good joint it needs to be in the interval 0.6÷0.8 [5].

The factor β can be calculated from the following expression:

$$\beta_{\max} = \left(\frac{M_J}{M_0}\right)_{\max} = \sqrt[4]{\frac{I_J}{I_R}} \quad (21)$$

In the previous expression, I_J and I_R are the moments of inertia of the rail joint and rail.

The maximum bending stress of the upper part of the rail in case when wheel passes directly over the rail joint and when it is at a certain distance, can be determined by using the following equations [5]:

$$S_{J-} = \frac{M_J c_J}{I_J} \quad (22)$$

$$S_{J+} = \frac{\beta M_R(x_{rb}) c_J}{I_J} \quad (23)$$

5. CONCLUSION

This paper analyzes some of the existing methods for determination of impact forces at crossing of railway wheel over the rail irregularities. The impact forces which occur when wheel passes over the rail irregularities can be even 3 times larger than static load. In many cases these forces are caused catastrophic scenarios and derailments on the railway.

This initial research of authors in this field should draw attention of wide scientific and professional auditorium on this problem. Besides, it should provide the proper base and motivation for further research and improvements in this area with the main aim of enhancing of safety on the railway.

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METHODOLOGY FOR STATISTICAL ANALYSIS OF SQUAT RAIL DEFECTS

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Abstract *– This paper proposes a methodology for statistical analysis of data obtained by visual inspection of squat defects on the rail head. Rail inspection by visual observation, including measurement of the squat defect position and depth was performed in Pančevo Varoš railway station in 2017. The obtained data about the squat rail defect (defect type 227 according to the UIC 712) on the main tracks was analysed in this paper. The rail defect position was determined regarding the position of the nearest sleeper in the track. Statistical analysis of the occurrence of squat rail defect was conducted according to the performed visual inspection in the field. Statistical data processing was performed for tracks zones according to the vertical stiffness of rail support. Furthermore, the impact of traffic load, the type and the arrangement of sleepers on the appearance of the squat rail defect was considered.*

Keywords – railway, rolling contact fatigue, squat, visual inspection, statistics.

1. INTRODUCTION

During May, June and July 2017, detailed visual inspection of squat rail defects (rail defect due to rolling contact fatigue type 227 according to [1]) was performed on main tracks in Pančevo Varoš railway station (track number 2 and 3 as shown in Figure 1). In order to point out the importance of an effective methodology for inspection, classification and treatment of squat rail defects occurring during exploitation, the set of relevant data was collected. The main purpose of this research is to improve the rail maintenance, thus reducing the risk of fracture due to rolling contact fatigue (RCF). The research results are expected to be applied in the technical regulations for railway infrastructure maintenance in the Republic of Serbia.

On modern railways, rail defects due to RCF are the dominant problem in the wheel - rail system and they are subjected to the intense research. RCF rail defects require an adequate maintenance strategy to avoid the risk of sudden rail breaks. Unfortunately, these defects are largely visible on the track rails in Serbia, without proper maintenance strategy.

There is a common occurrence of squat rail defects on straight tracks or in large radius curves $R \geq 3000$ m (Figure 2). Since the squat defect occurs in the areas with braking and acceleration of the railway vehicles, the visual inspection of rail defects was performed on the tracks in station and straight railway sections in the front of pre-signal and signal. Furthermore, it was necessary to inspect the zones around the sleepers with the change of vertical track stiffness, zones with corrugated rail head and welded rail joints [2, 3, 4].

Fig.1. Pančevo Varoš railway station

Before the visual inspection in Pančevo Varoš station was performed, main tracks were divided into the zones:

- zone I - from switch No. 1 to switch No. 5 (km 17+854.61 - km 18+027.89),
- zone II - from switch No. 5 to station building (km 18+027.89 – km 18+210.00),
- zone III – from station building to switch No. 14 (km 18+210.00 – km 18+719.06),
- zone IV – from switch No. 14 to switch No. 16

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(km 18+719.06 – km 18+774.26).

The track No. 2 was divided into I, II, III and IV zones, and the third track into II and III zones.

Fig.2. Successive occurrence of squats (left rail, track No. 2, Pančevo Varoš station, 2017)

The squat rail defects observed by visual inspection are separated from other existing defects, photographed, measured, positioned and systematically arranged. Afterwards, statistical processing of the obtained data was performed using the created squat defect database for the main tracks No. 2 and No. 3.

2. SQUATS IN PANČEVO VAROŠ STATION - RESULTS OF THE STATISTICAL ANALYSIS

Database was created for the left and right rail of main tracks No. 2 and No. 3 (extension of the Belgrade-Vršac railway line through the Pančevo Varoš station) in accordance with the above-mentioned track zones for visual inspection. Squat rail defects observed by visual inspections were classified according to the position along the track. The distribution of defects according to their location (above the sleeper or between two sleepers) was analysed for both rails. The average depth was measured for each defect. The distance between the sleepers was measured at each position of squat defect occurrence. Each squat defect was photographed and assigned with the appropriate symbol ($SQ_1, \ldots, SQ_n$) in the database. Furthermore, zones with wooden and concrete sleepers were marked in the database.

Table 1 shows the statistics of the total number of squat defects observed on the tracks No. 2 and No. 3. Accordingly, 87% of detected defects occur on the track No. 2 and 13 % on the track No. 3. Since the inspected length of track No. 2 is 270 m greater than the inspected length of track No. 3, and considering that traffic load on track No. 2 is two times higher than load on the track No. 3, one could conclude the severity of number of squat rail defects observed on the track No. 2. The traffic load was estimated according to available official data.

Tab.1. Statistics of squat defects

Information about track and squat defects	Track No. 2	Track No. 3
Inspected track length [m]	920	650
Average sleeper distance [cm]	55	54
Number of electric-powered vehicles [number / year]	6570	0
Number of diesel-powered vehicles [number / year]	9855	6205
Estimated total traffic load per track [MT / year]	6.25	3.16
Total number of squats	155	23
Percentage [%]	87	13

Figure 4 shows the distribution of squat rail defects in zones I-IV. The greatest number of squats was observed in zones II and III on both tracks, in the area where trains break and accelerate (in front of the station building).

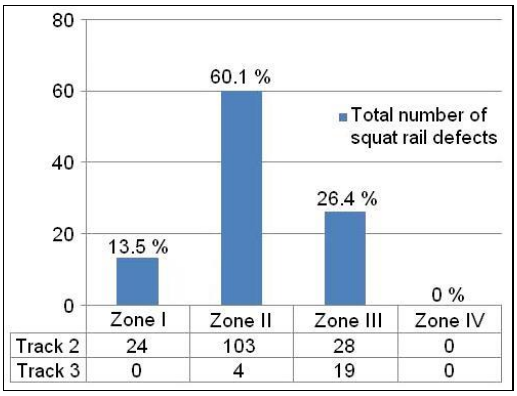

Fig.4. Distribution of squat rail defects per zones

The total number of squat rail defects on the left and right rails in the second and third tracks is shown in Figure 5. It was observed that the left rail of the second track is significantly more damaged than the right rail.

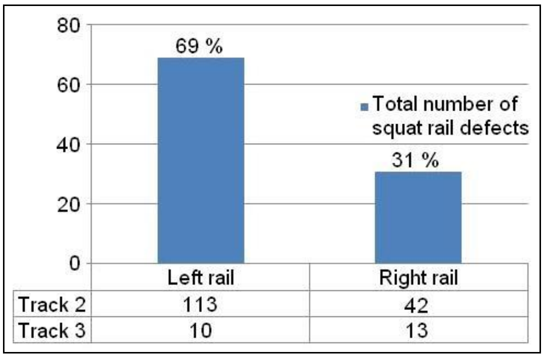

Fig.5. Distribution of squats on rails

The following statistics refers to the total number of squats that occur above the sleeper and between two sleepers (Figure 6). The zones above and between sleepers are defined in accordance with [3] (Figure 7).

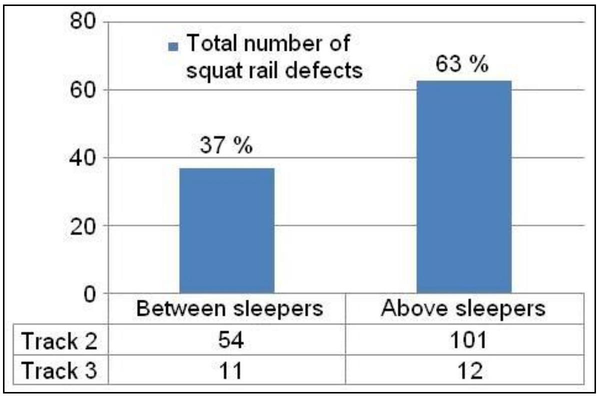

Fig.6. Distribution of squats between and above sleepers

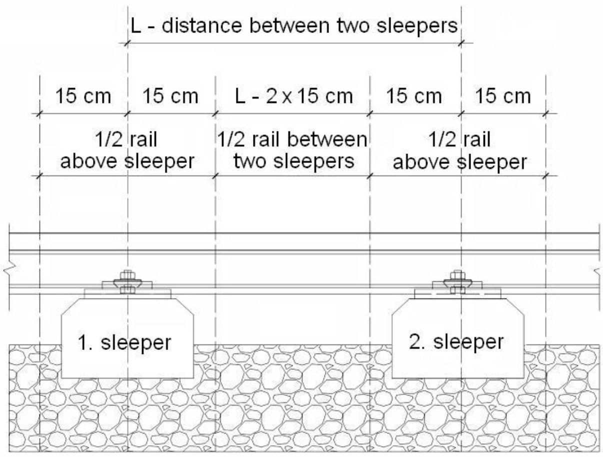

Fig.7. Zones of squat occurrence above and between sleepers

Furthermore, two cases were considered: one with the sleeper distance less than 60 cm and another with distance greater than 60 cm (Figure 8).

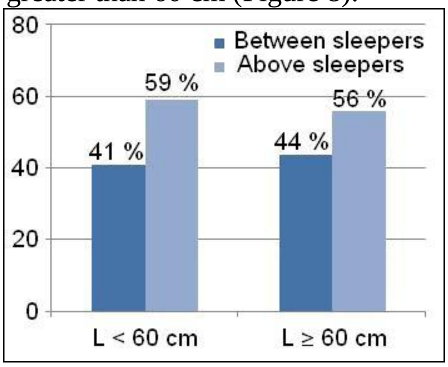

Fig.8. Distribution of squats depending on the sleeper distance

Figure 9 shows statistical data on the total number of squats observed on the tracks No. 2 and No. 3 in zones with wooden and concrete sleepers (zones II and III). According to the total number of detected defects, a significantly greater number of squat defects was observed in zones with concrete sleepers.

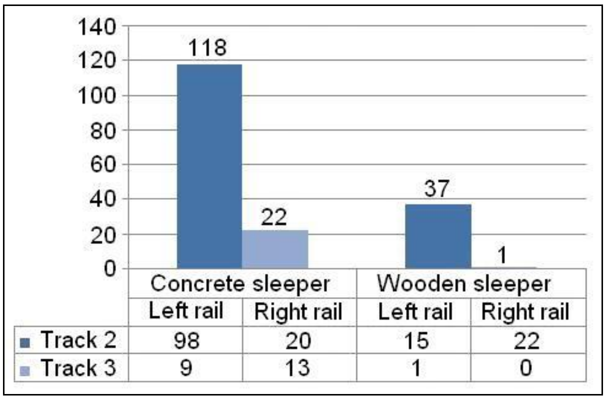

Fig.9. Distribution *of squat rail defects in zones with concrete and wooden sleepers*

The visual inspection showed a higher percentage of squat occurrences in the zones above the concrete sleepers for both tracks (Figure 10).

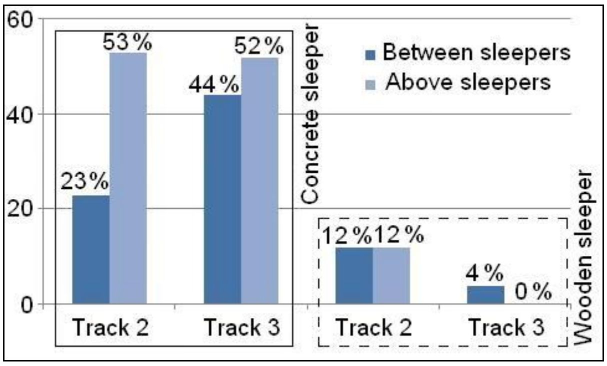

Fig.10. Distribution of squat rail defects occurring between and above concrete and wooden sleepers

The depth of squat rail defects is divided into three classes: 0.5 mm, 1 mm and 2 mm. Figure 11 shows the average depth of squat defects per tracks in zones with concrete and wooden sleepers.

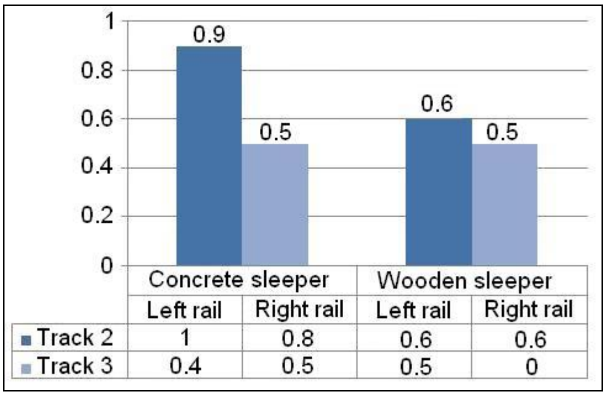

Fig.11. Average depth of squat rail defects [mm]

3. DISCUSSION AND CONCLUSION

Rail defects due to rolling contact fatigue (RCF) in the areas of high wheel/rail contact stresses are a serious danger for railway traffic worldwide [2, 5]. RCF rail defects are coded, described and illustrated in the Handbook of Rail Defects according to UIC Code 712 [1]. Furthermore, UIC Code 725 [6] provides recommendations of methods for inspection, monitoring and processing of these defects. After conducting a detailed visual inspection of the rails, information about squat rail defects is entered in the form in accordance with [1] and saved into the database. Photos of defects and other necessary details are attached to the main form according to [3].

Significant difference in traffic loads on inspected main tracks in Pančevo Varoš station confirmed that the occurrence of squat rail defects is directly related to the traffic load. This was proved by the obtained results, which showed that the appearance of squat rail defects is more frequent on the rails in track with higher traffic load.

Due to inadequate railway infrastructure maintenance in Pančevo Varoš station, especially in the inspected zones II and III, where the trains break and accelerate, a successive squat occurrence was observed. Therefore, the statistics of squat rail defects in the station proved that these defects occur in places with higher friction, i.e. on the track sections where greater traction and greater braking are required.

It is interesting to note that the left rail is significantly more damaged than the right rail on both tracks. Wooden sleepers are located in the zones of switches at the beginning and at the end of railway station, while the zones II and III contain concrete sleepers. By comparing zones with wooden and concrete sleepers, it can be concluded that the percentage of squat rail defects is significantly higher (more than 3 times) on the rails above the concrete sleepers. This is closely related to the rail support stiffness.

Based on the defined zones of defect occurrence (Figure 7), around 63% of all squat rail defects were detected in the zone above the sleeper, while 37% of squat defects were detected in the zone between two sleepers. Thus, the correlation of the defect location and the rail support stiffness was confirmed. In addition, larger number of defects above the sleepers was detected in the case of decreased distance between sleepers (L<60 cm). Therefore, it could be concluded that the distance between sleepers affects the occurrence of squat rail defects. The continuous occurrence of squat rail defects is observed in the zones with smallest sleeper distance (higher vertical stiffness of rail support).

The results of the squat depth analysis for the second track show a greater average depth value in the zones with concrete sleepers (0.9 mm) comparing to the zones with wooden sleepers (0.6 mm). However, the maximum measured depth of squat rail defect was 2 mm (the rails were laid in the track in Pančevo Varoš station in 1992). This could be considered as an alarming situation, since squat depth between 3 and 5 mm leads to the crack propagation downward and transversely, thus causing the rail break [3].

The data collected in the field investigation that is presented in this paper will be considered in future research, which is aimed at monitoring the development of observed squat rail defects, detecting new defects, as well as their mutual comparison.

Visual inspection represents a significant and reliable inspection method for detecting rail surface defects. However, such type of inspection is slow and subjective. Nowadays, different automatic visual inspection systems are developed. Therefore, certain phases of visual inspection should be replaced with automatic visual inspection whenever possible, and only disputable track sections should be inspected visually. In order to make the rail inspection faster and more accurate, visual and automatic visual inspection should be combined.

ACKNOWLEDGEMENT

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Strategy and Policy

REPLACEMENT OF SHORT-HAUL FLIGHTS BY TRAINS - REQUIREMENTS FOR AIRPORT TRAINS

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***Abstract** – Because of ecological and economical reasons there are numerous co-operations between airlines and railways, especially in replacing short-distance feeder flights by trains. However, these co-operations are not by far in a position to tap the full passenger potential because they are in many cases not sufficiently attractive. For example, currently there is no possibility to check in and drop off luggage during the time of rail journeys to the airport. For 80% of passenger luggage transport is the main criteria not to choose the train. Missing service features related to luggage transport lead to the situation that a big proportion of the air passengers travel to the airport by car or prefer inland feeder flights. For approx. 75% of air passengers an interesting and important aspect would be the possibility to check in luggage in the airport transfer train. The realization of this luggage deposit system would exert its influence on the modal-split-behaviour of and be an important attraction to accept train in long-distance traffic as an airport transfer. The objective of the project Terminal On Rail is to develop an overall airport transfer system for railway long-distance traffic, under the consideration of all technical-logistical challenges with regard to the possible luggage drop off in train and interfaces to the airport. This facilitates an efficient use of the travel time and ensures obtaining definitely attractive airport transfer trains. As outcome of the project the paper will focus on passenger requirements for airport feeder trains and will give an overview of options for baggage drop off inside the train during the train ride.*

Keywords – intermodal transportation, airport trains, baggage handling.

1. INTRODUCTION

In order to reach the EU international community of nations demand for a limitation in temperature rise by 2050 in the EU, greenhouse gas emissions in the transport sector must be lowered by at least 60% compared with 1990 and around 70% compared with 2008. By 2030 a reduction of about 20% below the level of 2008 is required.1 Taking into account the assumption that mobility will continue to increase and as a result the volume of traffic will increase, a reduction in greenhouse gases can only be achieved by an increased use of environmental- and resource-conserving modes of transport. For this purpose, the European Commission has defined ten objectives for the transport sector in a White Paper titled "Roadmap to a Single European Transport Area - Towards a Competitively Oriented and Resource-Conserving Transport System". One of these objectives targets long-haul passenger traffic and proposes the following measures:

- Completion of a European high-speed railway network by 2050;
- Tripling the length of the existing network by 2030 and maintenance of a dense rail network in all member states;
- By 2050 the majority of passenger transport over middle distances should be allotted to the railway.

In order to be able to meet these objectives as much as possible, one feasible approach is to shift to the train (ultra) short-haul flights, which usually have a feeder function to medium- and long-haul flights. In this regard, there are a variety of cooperation possibilities between the aviation and railway sectors.

Parallel to this, the political objectives in the field of air traffic are formulated in “FlightPath 2050” published by the European Commission in 2011.3 In this strategy paper, in addition to societal objectives (for 90% of EU citizens a door-to-door four hour connection should be possible by 2050), environmental protection measures are also formulated (reduction of emissions despite projected growth in the aviation

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industry). This is a subject of discussion by European industrial leadership who also demand preservation of the already very high safety level in Europe despite the increase in air traffic. These objectives are currently being processed and implemented within the framework of European research programmes (such as JTI CleanSky - fuel efficiency and noise reduction and SESAR - "common" European airspace).

2. INTERMODAL COOPERATION CONCEPTS BETWEEN TRAIN AND AIRCRAFT

A good transport connection is an important attractive feature for airports. At present, around 130 of all airports worldwide have rail connections, with further railway connections being planned. Originally, rail connection played only a limited role, which mostly involved only local transport and primarily connected city centres and the surrounding areas with airports. It has only been in the past few years that concepts have been implemented to connect city centres to airports, which have made rapid connections possible (e.g. Heathrow Express in London), and in some cases also connections providing service functions such as check-in or luggage check-in (e.g. the CAT in Vienna).

With the advent of high-speed rail transport, new opportunities for trains were created with regard to their competitive relationship to aircraft. The shorter travel times allowed the train to compete directly with aircraft at distances between 350 km and 750 km. From this competition situation, cooperation comprised of a combined offer between train and aircraft also developed to some extent. A distinction is made in the literature between the following forms of the relationship between train and aircraft:

2.1 Competition, Cooperation and Integration

The two points "cooperation" and "integration" are the forms of intermodal traffic between train and aircraft which are relevant for airport connections. Different forms of cooperation between railway companies (RCs) and airlines are being developed, which are intended to provide passenger-aligned services. This can include, for example, the area of luggage transport, check-in, ticketing, information and security services. Depending on the degree of cooperation, the offers may be classified as follows:

low: This type of cooperation is intended to provide travellers with a fast and congestion-free arrival to or departure from the airport. This includes, for example, the sale of train tickets by the airline (e.g. Rail&Fly - Germany).

moderate: This form of integration usually involves codeshare agreements between the RC and the airline. In addition to the train number, the respective train is assigned its own flight number and is distributed by both parties. The advantage for the traveller is that in case of late arrivals, the necessary measures such as rebooking are carried out by the airline or the RC (e.g. tgvair - France).

high: A higher form of integration in addition to the aforementioned points also includes luggage transport or separate areas in the train for business- and first-class passengers (e.g. AIRail - Germany, up to 2007)

Tab.1. A comparison of the included service features of the described models

Intermodal offer	**Rail& Fly (DB)**	**Check-in at train station (SBB)**	**tgvair (SNCF)**	**AIRail (DB)**
Train ticket sales by airlines	X			
Codeshare - agreement (own flight number for train)			X	X
Check-in at departure train station		X	X[1]	X
Luggage check-in at departure train station		X		(X)[2]
Guarantee in case of late arrival			X	X
Separate area in the train and catering				X

3. INFLUENCE OF LUGGAGE ON THE CHOICE OF TRANSPORT MODE

The transport of luggage is an essential decision-making criterion for the choice of transport mode. Despite increasing costs in the area of motor vehicle traffic or increasing traffic problems, the auto still enjoys unwavering popularity, with feeder traffic to the airport as well, above all due to luggage transport when travelling. The reason is that compared to all other elasticities, elasticity with luggage is highly valued.

Tab.2. Travel elasticity in Austrian holiday travel traffic – comparison (Rüger, 2005)

Luggage	0.685
Mobility to destination	0.655
Travel cost	0.630
Transfer	0.469
Travel time	0.386

The thereto by comparison lower cost and travel

[1] just for a view airlines.

[2] Service was offered till 2007.

time elasticity presupposes that changes in travel cost whether these are: cost increases for passenger-car traffic, cost reductions for train traffic as well as alterations in travel time, prolongation with passenger-car traffic or expediting measures with public transport; in all cases of travel in which luggage is transported, these have a correspondingly lower effect than measures relating to luggage transport.

Thus, for example, for 82% of winter holidaymakers travelling by auto in Austria, travel luggage is a major reason for the choice of the auto during holiday travel, whereas for only 55% the cost and for 40% the travel time have a decisive influence. These findings apply analogously in feeder traffic to airports.

In the case of air travel, the luggage for example, strongly influences the choice of transport mode for arrival at the airport. Above all in the case of transport of larger and heavier pieces of luggage, airport taxi services or private autos are chosen depending on the distance to the airport. The train is then preferred if little or no luggage is taken. Conversely, travellers in intermodal traffic (rail- air-traffic) are prepared to pay the most for luggage transport services compared to all other services.

4. WISHES FOR AIRPORT FEEDER TRAINS

In the research projects “Gepäcklos” and "TerminalAufSchiene", among other things, the wishes and needs of AlRail passengers for appropriate feeder trains were compiled separately.

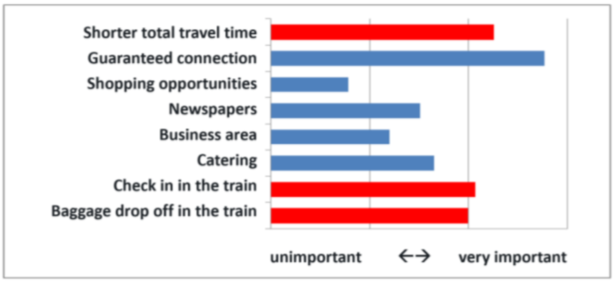

Fig.1. Importance of diverse product features for airport feeder trains (Albl, 2015)

In addition to the connection guarantee in the sense of assurance of connections or travel alternatives, which are offered in the above-mentioned cooperation and integration systems, above all the factors: "short travel time", "check-in on the train" and "luggage check-in on the train" play an important role in regard to the attractiveness and increased choice of the train in feeder traffic to airports. All three criteria are evaluated on average as "rather important", with an average score of 2.9 to 3.3 on a scale from 1 (not important) to 4 (very important) (see Figure 1).

For approx. 70% of travellers arriving at the airport, the possibilities for handing over luggage and at the same time checking in on the train are important (for 40% of them even "very" important) and would therefore be a significant reason for the decision to choose the train as a mode of transport to the airport. For over 80% of travellers the shorter travel time is correspondingly important (see Figure 2).

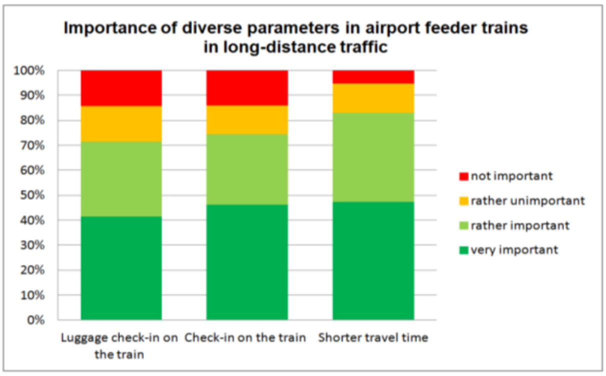

Fig.2. Importance of luggage drop off and check-in on the train (Albl, 2015)

For a short travel time, in addition to high travel speed and short stop-over time, an efficiently used travel time is also important. This can be achieved by relocating activities at the airport (e.g. check-in and luggage check-in) to the train. For this, an appropriate interior design in an airport feeder train is necessary. With regard to check-in service, it must be taken into account that through the use of new media, the classic check-in at the counter is being increasingly replaced by web check-in or mobile check-in. It is to be assumed that check-in at the counter is predominantly used in connection with luggage check-in. However, the possibility of check-in on the train is rated as similarly important to the possibility of luggage check-in on the train.

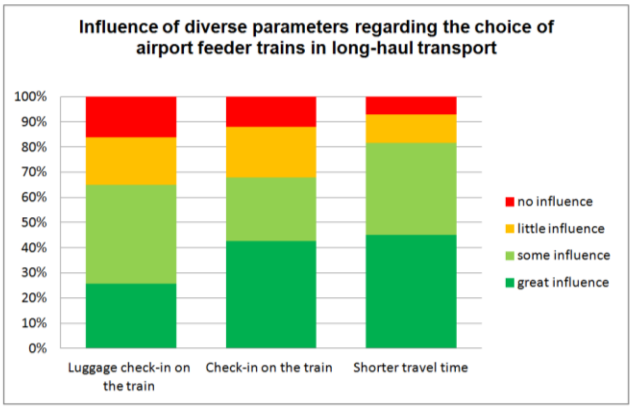

Fig.3. Influence of diverse criteria on the choice of transport mode for airport feeder traffic (Albl, 2015)

Regarding the influencing criteria: whether in the future appropriate airport feeder trains in long-haul transport will be chosen, 65% of travellers indicate that the possibility of luggage check-in on the train would have an influence on behaviour in the choice of transport mode. For more than 25% this possibility would have a great influence. In terms of travel time, over 80% of travellers say that a shorter travel time would have an influence on the future choice of the transport mode for arrival to flights and for 45% travel time for arrival would have a large influence (see Figure 3). It is important to take into account that travel time for arrival is not the only travel time to the airport, but is to be considered as a whole-time requirement for door-to-door mobility.

5. CONCLUSION

The studies show that there is a great interest among air travellers in using the train for arrival to the airport. Attractive service features tailored to air travellers are essential for the acceptance of the train. These include: on the one hand, already known services and in many cases services that have already been implemented by many providers in the area of "connection guarantees". On the other hand, it is clear that above all luggage transport has a major influence on the choice of the transport mode, also in terms of airport arrival behaviour. In this area, there are to date few or no suitable service concepts that ensure the attractiveness of the train to a sufficient degree. At the same time, it is clear that from today's point of view, effective innovative concepts such as luggage check-in during train travel to the airport would create corresponding interest and acceptance by air travellers and would have a deciding influence on the choice of transport mode.

If the aim is to transfer a large part of intra-European short-haul air-feeder traffic as well as the airport-feeder traffic overall to the train, it is essential to develop innovative service concepts that are from the traveller's point of view, highly attractive and go beyond what is offered today.

ACKNOWLEDGEMENT

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RISK ANALYSIS OF INVESTMENT PROJECTS IN SERBIA RAILWAY TRANSPORT

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Predrag JOVANOVIĆ[2]

Abstract – *The aim of this paper is to present major risks in realization of investment projects in railways of Serbia. Risk in the context of investment activity is defined as the probability of an event occurring, which may have a negative impact on the realization of the project. The identification of risks is based on the activities on the critical path of the project. The significance of the identified risks for the projects examined has been assessed by taking a numerical expression of the probability and severity of the damage. As a result of the study, the level of risk has been determined, such as the combination of probabilities and severity, and the impact of mitigation measures on the investment project. At the end, the model was tested at projects for Serbian Railways Infrastructure Manager.*

Keywords – Risk Analysis, Railway Investment Project.

1. INTRODUCTION

The risk is defined as the probability of occurrence of an event, which may have a negative impact on the realization of the project. Factors influencing the project can be divided into two main groups:

- External factors, which are the main prerequisites for the implementation of the project, namely: political, economic, legal, ecological.
- Internal factors that directly affect the implementation of the project: beneficiary's management, investment area, activity characteristics, type of infrastructure.

Part of the internal factors are very important for the concrete implementation of the objectives and tasks of the projects. They are: managerial style; organizational structure; participants in the project; management team; communications.

2. PROJECT RISK ANALYSIS

The complexity and multiplicity of project impacts usually lead to a high level of uncertainty, so it is good to choose a simplified method for identifying project-specific risks. Identification is based on the activities of the critical path.

Very often, in the management of projects, it is not possible to apply methods of physical identification of risk and therefore the risk assessment is carried out by methods of expert assessment based on risks described by the Assignor. Pre-identified risks are controlled using critical variables. Changing the "critical" variables individually or together would cause a change in the core features of the project. In the preliminary risk analysis, it is appropriate to work with two critical variables: the period for completion of the project and the scope of the envisaged activities. These variables can most accurately reflect unwanted events during the implementation of the project.

For the purposes of our study, we identified the following undesirable events and risks:

1. Risk related to the lack of coordination and interaction between the participants in the project. This risk has a strong impact on the completion period.
2. Risk associated with insufficient organization and project management. This risk also has a strong impact on the completion period.
3. Risk related to the agreed and authorized by external institutions. Unlike the previous two risks, this may affect both the completion time and the scope of the activities envisaged.
4. Ownership risk. This risk, most often occurs in the implementation of transport infrastructure projects.

The significance of the identified risks is assessed on the basis of a perceived numerical expression of probability grading (P), given in percents, and the severity / significance (S) of the injury. The risk level

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is the combination of probabilities and weight

$$R = P \cdot S \quad (1)$$

The four levels of risk can be defined as follows with the associated colors:

Tab. 1. Defined leves of risk

Low	
Moderate	
High	
Unacceptable	

Weight/ Probability	I	II	III	IV	V
A	Low	Low	Low	Low	Moderate
B	Low	Low	Moderate	Moderate	High
C	Low	Moderate	Moderate	High	High
D	Low	Moderate	High	Unacceptable	Unacceptable
E	Moderate	High	Unacceptable	Unacceptable	Unacceptable

The likelihood of harm is judged by: significance; the probability of occurrence of an event; technical possibilities to limit or avoid damage; human abilities to avoid or limit injury (qualifications, experience, practical experience and skills, etc.). The numerical values in the next two tables are expertly defined by us, using analogy with similar projects, as well as interviews with contractors and project promoters.

*Tab.2. Classification of probabilities **(P)***

		Probability	Numerical measure
A	Very unlikely	0-10%	0,1
B	Unlikely	10-33%	1,0
C	Probably not	33-66%	3,0
D	Probably	66-90%	6,0
E	Very likely	90-100%	10,0

The severity of the damage is assessed according to the severity of the possible consequences for the scope and the results.

The end result of the risk assessment determines the eligibility of the identified risk and the need to apply measures to prevent or limit it, also taking into account the effectiveness of the risk mitigation measures already in place.

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Also taking into account the effectiveness of the risk mitigation measures already in place.

From the table is noticeable that small risk are in range up to 10, while risk rating grater then 300 is considered catastrophic, and drasticals steps must be taken. Such situation would probably lead to termination of the project.

*Tab.3. Weight classification **(S)***

Rating	Description	Num. measure
I	No significant effect, without corrective action	1
II	A minor effect, but corrective action is needed	3
III	A modest effect - leads to financial damages. Corrective actions can solve the problem.	7
IV	Critical effect. The emergence of this risk leads to a change in the scope of the project. Corrective actions cannot eliminate it completely.	15
V	A catastrophic effect - it can lead to a serious change in the scope or suspension.	40

*Tab.4. Eligibility **(R)** of Risk to achieve the project results in the foreseen time and scope*

Risk rating	Deg.	Risk (R)	
Up to 10	**0**	Unimportant	Acceptable
From 10 to 40	**1**	Small	Attention is needed
From 40 to 100	**2**	Moderate	Reduction measures are needed
From 100 to 300	**3**	Critical	Reduction measures are needed
>300	**4**	Catastrophic	Termination of work until removal

3. CASE STUDY

Scope of the study was tested on the example of two investment projects for Serbian Railways Infrastructure Manager (SR IM):

A. Procurement of construction works for the reconstruction of the infrastructure capacity in the Belgrade station area in order to construct the container terminal.
B. Low order public procurement for delivery of section insulator for speeds of up to 200 km / h from the contact network of the single phase system 25kv, 50Hz.

The selected projects allow the risk difference to be examined for projects with different characteristics. This is important for the preliminary planning of activities and the determination of the severity of key events.

3.1 Project A. (Infrastructure investment)

For the chosen project and identified risks, assessment was made to rank the risks according to the probability of occurrence. For this purpose, we use a scale according to the "R" calculations based on the methodology described above.

Tab.5. Risk ranking for Project A. (Infrastructure investment)

	Description	Probability		Effects	Eligibility
4	Ownership risk	90%	10	15	150
3	Risk related to the agreed and authorized by external institutions	45%	3	15	45
1	Risk of lack of coordination and interaction between project participants	40%	3	7	21
2	Risk related to underdeveloped and project management	30%	1	3	3

From the above table, it is evident that the risk is most likely to arise from risk 4 - Property related, followed immediately by No 3 - related to the agreed and authorized by external institutions. Risk reduction measures are needed.

3.2 Project B. (Equipment delivery)

Similarly, for Project B risk ranking was conducted, using the same scale according to the "R" calculations based on the methodology described above.

Tab.6. Risk ranking for Project B. (Equipment delivery)

	Description	Probability		Effects	Eligibility
3	Risk related to the external institutions' compliance	45%	3	15	45
2	Risk related to underdeveloped and project management	10%	1	3	3
1	Risk of lack of coordination and interaction between project participants	20%	1	3	3
4	Ownership risk	10%	0,1	1	0,1

It is apparent from the above table that the highest probability of occurrence of a project for the supply of equipment is risk № 3 - related to the external institutions' agreement, followed immediately by risks № 2 and № 3 - related to the organization of the project and the coordination of activities that have a comparable influence.

The risks identified so require to develop an appropriate management system. Three management strategies are used in developing the system:

- risk avoidance - a strategy that reduces the likelihood of risk occurring;
- minimizing the risk-taking effect - a strategy that mitigates the consequences of the risk;
- extraordinary actions - a strategy where the organization accepts the risk and is ready to deal with it if it comes to fruition.

The strategies chosen lead to the following risk mitigation measures:

- Avoiding the relevant risk by terminating the activity that causes it or replacing it with an alternative;
- Reducing the possibility of occurrence of the relevant risk, by introducing control processes, improving the supervision of the activity, training;
- Reducing the effect of risk exposure through further action;
- Transferring the relevant risk to third parties that are essentially subject to the same type of risk;

- Preliminary identification and acceptance of part of the effect of the relevant risk as inherent in the respective activity;
- Provide additional resources to compensate for the time lag;
- Providing assistance from state institutions.

The previous table shows the potential additional risks for the implementation of the project as well as the relevant measures that will be taken to reduce it and manage it.

Based on the experience of such projects, other risks that could arise during the implementation of projects and which could jeopardize implementation are identified. The prerequisites for the occurrence of these risks are:

- Insufficient information
- Limited access to additional information
- Insufficient institutional support
- Non-compliance with contracts.

Tab. 7 Additional risks

Types of risks	**Mitigation measures**
Narrow time horizon	Continuous monitoring
Changes in scope as a result of the implementation of the initial activities	Changes to the execution schedule
Gaps in the application of legal provisions, rules, procedures by third parties	Collaboration with the assignor
Need for further analyzes and developments	Changes in resources and time

4. CONCLUSION

The importance of the process of risk identification and management is that by incorporating it in all phases, everyone involved in the project implementation has the necessary level of awareness of the possible risks and their associated consequences associated with the need for additional time and financial resources. This prior awareness is crucial to contributing benefits to the project.

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DEVELOPMENT OF COTIF´S TECHNICAL UNIFORM RULES FOR THE INTERNATIONAL OPERATION OF RAILWAY VEHICLES

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Abstract – *Before their introduction into COTIF´s Uniform Rules, the conditions for accepting railway vehicles in international traffic were organised among rail companies in the form of the RIV and RIC agreements, which were coordinated by the non-governmental International Union of Railways (UIC). COTIF 1999 and its APTU and ATMF Appendices, which entered into force in 2006, moved responsibility for the admission of railway vehicles in international traffic from railway companies to government authorities. In 2015, OTIF started drafting a new Appendix H to COTIF with the aim of harmonising the principles for the cross-border operation of both vehicles and complete trains in order to help make international railway operations more efficient. This paper reviews the development and substance of the existing Appendices F (APTU UR) and G (ATMF UR) and the rationale underpinning the development of the new Appendix H (EST UR) to COTIF.*

Keywords – COTIF, admission of railway vehicles, railway system, interoperability, safe operation of trains.

1. INTRODUCTION TO APTU AND ATMF APPENDICES

Before APTU and ATMF, the conditions for accepting railway freight wagons and passenger vehicles into international traffic, including the technical specifications, were organised among rail companies in the form of the RIC [1] and RIV [2] agreements, which were coordinated by UIC.

With the adoption in 1999 of APTU [3] and ATMF [4] and their entry into force in 2006, the international acceptance of railway vehicles became a competence of state authorities rather than railway companies. The provisions included the mutual recognition of technical approvals between national authorities. APTU and ATMF set out the general principles and responsibilities, but the content and how to implement the rules in practice still had to be developed in detail.

During the time that elapsed between the adoption of APTU and ATMF in 1999 and their entry into force in 2006, the European Community developed its railway legislation to a considerable extent, leading to inconsistencies between European law and APTU and ATMF. As a result of these inconsistencies, and since full compatibility between the OTIF and EU legal systems had not yet been achieved, in 2006 the Member States of the European Community submitted declarations in accordance with Article 42 of COTIF [5] not to apply the APTU and ATMF Appendices[1]. To resolve the situation, modifications to APTU and ATMF were required and developed in a series of amendments explained in more detail below.

2. THE FIRST SET OF AMENDMENTS (2004-2010)

2.1. First "Schweinsberg group", 2004-2006

A specific working group, the so-called "Schweinsberg group"[2], was set up in 2004 to analyse the problems resulting from the inconsistencies between European railway law and APTU/ATMF and to find possible solutions. By June 2006, the group had analysed the approval procedure for vehicles in the European Community and the admission procedure in accordance with ATMF and concluded that there was a

[1] The EU Member States started lifting their reservations against the APTU and ATMF Appendices in July 2011 and this process was completed by July 2016. Since then, all EU Member States have applied APTU and ATMF

[2] Named after Mr Ralf Schweinsberg, Vice-President of the German Eisenbahn-Bundesamt, who chaired the subgroup

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lack of compatibility between these two approaches. It drafted proposals for amendments to APTU and ATMF and proposed transitional solutions for rolling stock marked in accordance with RIV and RIC. The group concluded that mutual acceptance would require equivalence between the technical requirements of the Technical Specifications for Interoperability (TSIs) and the corresponding APTU Annexes, which later became the Uniform Technical Prescriptions (UTPs).

The proposals to amend APTU and ATMF were submitted to the Committee of Technical Experts (CTE) in June 2007, which decided that the APTU and ATMF needed to be revised in order to be simplified, to take into account developments in European law and to include entities in charge of vehicle maintenance (ECMs). At the same session, the CTE also set up a working group to deal with legal questions (referred to in this paper as WG LEGAL) in connection with the amendments to APTU and ATMF.

2.2. The ad hoc working group for legal questions, 2007

WG LEGAL started its work by discussing the conditions under which the OTIF admission and authorisation of vehicles according to European law could be deemed to be equivalent (current Article 3a of ATMF). Furthermore, WG LEGAL also discussed the broader link between the European Interoperability Directive and the APTU and ATMF Appendices.

One of the conclusions was that UTPs, which were to be developed under APTU, should be equivalent to the European TSIs.

With regard to the further revision of APTU and ATMF, WG LEGAL suggested that the Schweinsberg group should be reactivated and given the task of looking at whether further amendments to APTU and ATMF were necessary.

2.3. The second Schweinsberg group, 2008-2009

The second Schweinsberg group analysed developments in the European legislation, especially the new Interoperability Directive (2008/57/EC) [6], and the preparation of the new elements in the Safety Directive (2004/49/EC) [7] and suggested amendments, including:

– for vehicles fully in conformity with the provisions of the UTPs, the full mutual acceptance of vehicles under both European legislation and COTIF would be ensured, provided a number of precise conditions were met (Article 3a § 1 and 2 and Article 6 § 3 of ATMF).
– For vehicles not fully in conformity with these provisions, checks that had already been carried out should not be repeated, but should be mutually accepted. In addition, it would be possible to admit vehicle types (Article 6 § 5 of ATMF).
– Introduction of the concept of Entity in Charge of Maintenance (ECM - Article 15 of ATMF) and the requirement that before being admitted to operation, each vehicle would be required to have an ECM assigned to it (Articles 2 and 15 of ATMF). ECMs for freight wagons had to be independently certified.
– Transitional provisions were also suggested, including grandfather rights for RIV, RIC and other vehicles admitted and marked according to bilateral or multilateral agreements between the Contracting States and notified to the Organisation (Article 19 of ATMF).
– A two-column layout in UTPs (Article 8 § 9 of APTU) showing, for information only, the corresponding TSI provisions in the right-hand column.

The proposals to amend APTU and ATMF were reviewed by the CTE and submitted to the Revision Committee for adoption in 2009. These modifications to APTU and ATMF entered into force on 1 December 2010.

3. THE SECOND SET OF AMENDMENTS (2012 – 2015)

Unlike COTIF, the European regulations contained overarching safety management principles in the Safety Directive 2004/49/EC and its amendments. These provide that Railway Undertakings (RUs) and Infrastructure Managers (IMs) have shared responsibility for the safe operation of the railway system. This was increasingly important with the introduction of new TSIs, which assumed systematic safety management and, in return, permitted a degree of technical freedom. A new question was raised as to whether COTIF was sufficiently compatible with this technical freedom. In 2012 the CTE concluded that it was necessary to develop COTIF further with respect to safety responsibilities and safety management in a way that would continue to allow UTPs to be fully equivalent to TSIs.

3.1. The ad-hoc subgroup for safety, 2012-2013

In order to analyse the above subjects in detail the ad-hoc subgroup for safety was established in 2012. The aim of the subgroup was to analyse what was needed and the possibilities in terms of developing certain safety management principles in OTIF’s regulations. The ad-hoc subgroup recommended a step by step approach, where the first step would be to revise the UTP WAG by including provisions relating to train composition and responsibilities concerning the safe use of wagons. As a second step, it advised including the safety management principles in ATMF. In 2013 the CTE endorsed the ad-hoc safety subgroup’s conclusions and implemented the first step by adopting a revised UTP WAG.

3.2. The ad-hoc subgroup for ATMF, 2013-2014

In 2013, the CTE also initiated the next step, which aimed at revising ATMF in relation to safety aspects. In order to facilitate the work an ad-hoc subgroup was established to revise ATMF. The work was based on the results and recommendations of the ad-hoc subgroup for safety. The new group recommended several amendments, including a new Article 15a concerning the responsibilities for train composition and operation and modifications to bring ATMF into line with the latest developments in European law.

In 2014 the CTE endorsed the proposed changes to ATMF and submitted them for adoption to the 25th Revision Committee, which convened in the same year. Following their adoption the modified APTU and ATMF entered into force on 1 July 2015.

4. THE THIRD SET OF AMENDMENTS (2015 -2019)

After the adoption of the fourth railway package in the European Union in 2016, and in particular the recast Interoperability Directive (EU) 2016/797 [8] and the recast Safety Directive (EU) 2016/798 [9], the European Union changed several provisions which had previously been harmonised with APTU and ATMF. On the basis of an analysis carried out by the European Commission and the OTIF Secretariat, the WG TECH prepared modifications to APTU and ATMF to ensure continued harmonisation with European law.

The modification of ATMF was necessary in order to harmonise some terminology with new European law and to take into account some procedural changes within the European Union, particularly the fact that the EU Agency for Railways (ERA) would have the competence to issue vehicle authorisations. This would make ERA, de facto, the competent authority (in the meaning of Article 5 of the ATMF UR) for OTIF Contracting States that are also members of the European Union.

Another modification was required to introduce, the concept of “area of use” of a vehicle, which was also introduced in European law, indicating the network or networks where a vehicle can be used.

Further modifications were required such as to allow joint vehicle registers to be set up by a group of states, i.e. a single European Vehicle Register in the European Union.

The modification of APTU would require future UTPs to define requirements that apply when existing subsystems (e.g. rolling stock) are renewed or upgraded and the parameters to be checked by the RU to ensure compatibility between vehicles and the routes on which they are to be operated.

In 2017 the CTE endorsed the proposals and subsequently submitted them to the Revision Committee which adopted them at the 26th session in 2018. Subject to the conditions set out in Article 35 § 3 of COTIF, these amendments will enter into force on 1 March 2019.

5. NEW APPENDIX H – THE SAFE OPERATION OF TRAINS IN INTERNATIONAL TRAFFIC

Although the *transport* of goods and passengers by rail had been international for a long time, as evidenced by the 125th anniversary of COTIF, rail transport *operations* are often not international. Therefore, in order to facilitate not only the exchange of vehicles, as covered by ATMF today, but also cross-border operation of complete trains in international traffic, the new Appendix H has been prepared.

5.1. The concept behind the new Appendix H

The aim of Appendix H is to contribute to making it possible for trains to be operated across borders under the responsibility of one railway undertaking. To this end, Appendix H harmonises the criteria on the basis of which states issue Safety Certificates to railway undertakings, so that one railway undertaking can obtain safety certificates for multiple states. Each state would remain responsible for issuing safety certificates for its territory, so there would not be automatic mutual recognition of safety certificates. However, states should mutually recognise the results of assessments made by the authorities of other states. Each state would be required to supervise the Safety Management System (SMS) of RUs for which they have issued Safety Certificates. All RUs should develop their SMS based on Common Safety Methods (CSM) [10], which will need to be developed for this purpose.

The new Appendix H is intended to be applied by states which already apply APTU and ATMF. States that declare that they will not apply the new Appendix H may continue to apply ATMF.

5.2. Next steps

The new Appendix H was reviewed and endorsed by OTIF´s 26th Revision Committee in March 2018 and subsequently submitted to the General Assembly for decision in September 2018.

After adoption by the General Assembly, the new Appendix H would enter into force twelve months after subsequent approval by two-thirds of the Member States. This may take several years.

6. COORDINATION BETWEEN THE OTIF SECRETARIAT AND THE EU

The aims and objectives of EU law and COTIF are not identical; however, compatibility between the two is essential so that railway vehicles can be freely used in all Contracting States, irrespective of whether or not they are also members of the EU. Since the adoption of the APTU and ATMF Uniform Rules in 1999, establishing and maintaining such compatibility has been one of the priorities of all parties involved.

With a view to establishing and maintaining such equivalence, the OTIF Secretariat, the European Commission's DG MOVE and ERA signed a cooperation agreement, the so-called Administrative Arrangements, in 2013 [11]. These arrangements enable effective coordination between the three parties and, for example, make it possible to represent the interests of non-EU OTIF Contracting States (CS) at ERA meetings. On the basis of the agreement, the three parties cooperate to ensure that developments in European law or COTIF do not compromise compatibility between the two.

At OTIF´s WG TECH meetings, ERA presents and discusses on-going projects on draft ERA recommendations, advice and opinions which may be of relevance in terms of equivalence. This also allows non-EU OTIF CS to be aware of these developments and to take part in the discussion.

Before ERA´s work to draft provisions reaches its final stage, ERA invites the OTIF Secretariat to consult the non-EU OTIF CS on the draft EU rules, e.g. TSI revisions. This allows the non-EU OTIF CS to analyse and comment on the text proposals of ERA. After such consultations, ERA also explains to WG TECH how it has considered the feedback received during the consultation.

This coordination is challenging and requires synergy between the parties to the arrangements. At the same time, this work is very important, as it contributes to ensuring that EU railway legislation develops in a way that is compatible with COTIF.

7. CONCLUSION

Since 2010, equivalence has been established between the OTIF and EU rules concerning vehicle admission, facilitating the exchange of freight or passenger vehicles across the borders of OTIF Member States.

Maintaining the established equivalence between EU law and COTIF is a challenging task which requires that the OTIF Secretariat and the EU work closely together.

As a next step, introducing the new Appendix H would further harmonise safety principles for the cross-border operation of trains and would help to improve the efficiency of international rail traffic.

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COMPETITION OF CORRIDOR X AND CORRIDOR IV – GAME THEORY APPROACH

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Abstract *– Game Theory is a tool and mathematical method which is used to solve conflict situations and cooperation in many areas. The subject of this paper is the researching opportunities for application of model based on Game Theory to generated competitiveness between Pan-European railway Corridor X and Corridor IV, which are largely overlapping within the European transport market. Modeling the best strategies for each of the corridors is in the function of achieving as much competitiveness as possible for these corridors.*

Keywords – game theory, competition, rail corridors.

1. INTRODUCTION

With the opening of the transport market in Europe and the creation of the Single European Railway Area, the competitiveness of transport corridors has been imposed as a new area for research. By establishing a unique network of transport corridors on the territory of Europe, some corridors have created a real market competition for attracting as many goods as possible. This particularly applies to situations where transport corridors represent alternative routes for service users and there is a possibility of choice.

Such a situation is with Corridor X and Corridor IV. The competitiveness of these corridors is very pronounced. Especially in relation to the flow of goods. This can be seen in the map (Figure 1). It is obvious that they are parallel (alternative to each other) and in on one (most significant) part have the same initial (Port of Pireus) and the final point (Budapest).

Port of Piraeus increased its work by switching to the majority ownership of the Chinese company COSCO. This led to the flow of goods to Central and Western Europe via the Mediterranean rather than through the ARA port. This event even more encouraged the already generated competition of these two corridors.

The newly created situation prompted the authors to explore the possibility of applying mathematical tool - Game theory to examine the competition of the this corridors in the context of strategic management.

This paper discusses the application of the Game theory to inter-corridor competition in order to provide the basis for the analysis and selection of the best strategies by corridor authority.

The basic purpose of this paper is to set the basis for applying the Game theory in examining strategies for increasing the competitiveness of corridors. Therefore the paper gives a random numerical example for a logical check of the presented analytical approach for making a decision on investing in corridors.

The work is structured as follows. Chapter 2 presents a description of the problem. Chapter 3 includes the postulates of Game theory and basic concepts. In Chapter 4, a model of inter-corridor competition based on strategies Invested/Not-invest with numerical example is presented. Chapter 6 gives the conclusion and scope of future research.

2. PROBLEM DESCRIPTION

Competition is a contest between at least two entities in a particular market. It occurs if there is a demand for something for which there are substitutes or alternatives. If we observe a certain transport market, competition can occur both between different shippers and operators and between alternative transport infrastructure capacity - corridors. Inter-corridor competition is reflected above all in the competition to attract as much flow of goods as possible.

In the conditions of expansion of global flows of goods, and thus the possibilities of attracting new flows of goods through Corridor X and Corridor IV, the governments of the countries of Southeast Europe are facing the decision to raise the competitiveness of

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the corridor they are located.

In general, all possible strategies include two categories of measures so-called. "Soft" and "hard" measures. "Soft" measures include those measures that do not require high investment but require a high level of organization and consent of actors on the corridor, for example, introducing integrated border crosings and OSS, reducing the cost of infrastructure charges, introducing various ITS systems, etc. The "hard" measures include a primary investment in the form of capital investments in order to increase the quality of the corridor infrastructure. The strategies and actions of a corridor will have an impact on the demand and profit of the corridor.

Consequently, taking into account the competitive environment and the great interdependence of these corridors, the governance of the corridor must now also consider decisions on competing corridors if they want to win in this market game.

Fig.1. View of Corridors X and IV from Port Piraeus to Budapest

In other words, the governments of countries must decide to choose one of these two options to increase the competitiveness of the corridor or to combine these two options, or to decide for one of the strategies based on these possibilities.

3. GAME THEORY APPROACH

In everyday life, individuals and groups of people perform a range of activities in which sometimes unconsciously, influence each other. By making various decisions related to one's own activities, people influence on decisions of other individuals and thus interact with each other. Impacts that individuals achive at each other may be based on the common interest and good will, but they can also be based on conflicting interests or hostility. Such uncertainty in decision-making is called a game, and a science whose task is to study such problems is Game theory [1]. Game theory represents a mathematical formalization and analysis of the process of rational decision-making in the conditions of common interests of participants in the game or conflicts, as well as in circumstances of risk and uncertainty [2].

The beginnings of the Game theory are usually linked to the Hungarian-American mathematician and scientist John von Neumann and the American economist of the German origin Oscar Morgenstern and their jointly written book *Theory of Games and Economic Behavior* from 1944, which first included the systematization of matter from the Game theory. The basic terms that define the game are:

• game rules - pre-defined instructions that each player must strictly adhere to;

• assumptions - player rationality and common knowledge about the rules of the game

• players - participants in the game between which there is interaction and who make decisions in order to achieve the best possible results;

• strategy - a set of moves that the player will perform in the observed game;

• information - represent the knowledge that the players possess and on the basis of which they carry out their moves;

• payoff - numerical data on the player's gain (loss);

• equilibrium - a set of optimal strategies that players have to choose to maximize their payoff.

The concept of solutions developed by John Nash in 1950 under the name of Nash equilibrium is the basis of non-cooperative games to date. This concept of the solution can be defined as a pair of strategies that represent the Nash equilibrium if and only if each of these strategies is the best response to others [3].

There are different types of games (Figure 2). The number of players, the number of possible strategies, types of payments, information, etc., are most often used as the criteria for division. These criteria allow modeling of different conflict situations.

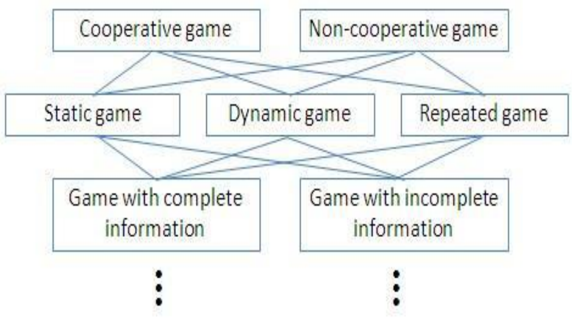

Fig.2. Game Classification [4]

In the last 50 years game theory has become a crucial tool for the analysis of strategic behaviors of individuals and competition among companies in oligopoly markets [5]. Concepts from this theory first appeared in transportation models in the form of a behavioral hypothesis for route choice, Wardrop's first principle being identical to the statement characterizing a Nash noncooperative game, with each traveller corresponding to a player [6]. Non-cooperative games provides powerful tools for analysing transport systems, because it deals with situations involving multiple decision makers, whose objectives fully or partially clash with each other; many transport problems fit into this area [7].

Game theory provides an approach that can simulate the behavior of different stakeholders in the transport market in order to achieve a competitive edge.

4. NUMERICAL EXAMPLE

This section shows the application of game that illustrates the effect of reducing the travel time on the corridor to the number of trains using the numerical examples in order to find a Nash equilibrium.

4.1. Game model

The game is modeled for two players - Corridor X and Corridor IV, in which a set of possible strategies for each player are two strategies to "Invest" and "Non-Invest". In addition, the payment of a player depends on the decision of the player's reaction to the decision of the other. Nash equilibrium is the optimal choice for both players (Figure 3).

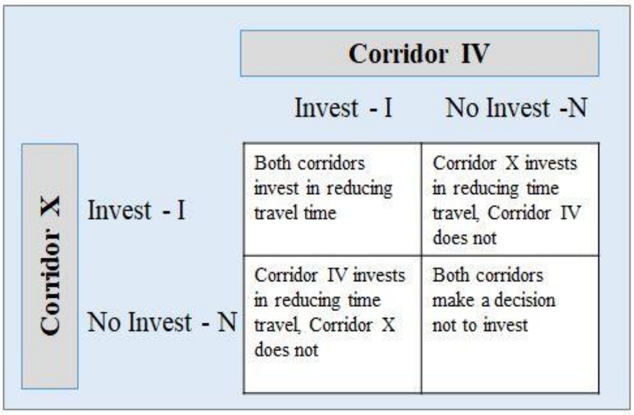

Fig.3. Possible Nash equilibriums

The model is based on the following assumptions:

- Both corridors can invest in reducing travel time. With invest, Corridor 10 can reduce travel time for eight hours and Corridor 4 for four hours;
- The corridor authority allocate funds for investment purposes from their own additional income;
- The number of trains depends on travel time and their sensitivity to changing travel time is estimated by the author.
- The number of trains on the corridor represents dependent variable of profit functions.
- The cost of the one train kilometre is equal to both corridors and is 2 € / km.

4.2. Profit function of corridor

The goal of the corridor authority is to maximize profit:

$$max_{T_i \in \{T_i^0, T_i^1\}} \Pi_i(T_i, T_j) = T_i \times L_i \times C_i - I_i \qquad (1)$$

where Π_i represent the profit of the corridor and depends of the number of trains on that corridor - T_i. If any of the corridor authority decides to invest and reduce travel time, a new number of trains will appear on the corridors T_i^1. Constants L_i and C_i are relating to the length of the corridors and the cost of one train kilometre respectively. Profit functions are given in Table 2.

Tab.1. Profit functions

		Corridor 4	
		I	N
Corridor 10	I	T_{10}^1; $\Pi_{10}(I,I) - I_{10}$ T_4^1; $\Pi_4(I,I) - I_4$	T_{10}^1; $\Pi_{10}(I,N) - I_{10}$ T_4^1; $\Pi_4(I,N)$
	N	T_{10}^0; $\Pi_{10}(N,I)$ T_4^1; $\Pi_4(N,I) - I_4$	T_{10}^0; $\Pi_{10}(N,N)$ T_4^0; $\Pi_4(N,N)$

As status quo (case (N, N)), the authors chose that there were 120 trains on Corridor X and 150 trains on Corridor IV. The lengths of Corridors X and IV are about 1700 km and 2000 km respectively, and with the price of one train kilometre of 2 € / km, is obtained that Π_{10}= 408,000 and Π_4=600,000. Changing the number of trains and profits, depending taken decisions, is given in Table 2.

Tab.2. The value of profits for different investment decisions

		Corridor IV	
		I	N
Corridor X	I	140; 476.000-I_{10} 130; 520.000-I_4	155; 527.000-I_{10} 115 ; 460.000
	N	100; 340.000 170; 680.000-I_4	120; 408.000 150; 600.000

4.3. Possible decisions of the corridor authority

Perspective of Corridor X: Corridor X can consider investing if Corridor 4 does not invest, and in that case it will increase profit function by (119 thousand) in relation to the status quo. Also, in that case, it will also have higher profit from Corridor 4 for (67 thousand). In this case, if the I_{10} is less than (67 thousand), then for the Corridor X to invest is the best decision that can be made regardless of the decision of Corridor 4. If I_{10} is greater than (119 thousand) then the best decision of Corridor 10 is not to invest regardless of the decision of Corridor 4.

If both corridors invest, Corridor X will increase its profit for (68 thousand). If I_{10} is between (67 and 68 thousand), then Corridor X will invest only in case if Corridor 4 does not invest.

Perspective of Corridor IV: If Corridor IV is investing and Corridor X does not invest, profit function of Corridor IV profit will increase by (80 thousand). Corridor IV can decide to invest only if I_4 is less than (80 thousand) in case when Corridor X does not invest because it will have higher income in relation to the status quo and from Corridor X. If I_4 is greater than (80 thousand) then Corridor IV is the best decision not to invest.

4.4 Nash equilibrium

When deciding whether to invest, any corridor authority can use Nash Equilibrium to make the best decision. Assume that I_{10} and I_4 are different values. Below is a discussion given for several scenarios:

Scenario 1. $I_{10} < 67.000$ and $I_4 < 80.000$.

For Corridor X, the best decision is to invest regardless of the decision of Corridor IV. Corridor IV can make a decision to invest only if Corridor X does not invest, otherwise it will have more profit when it does not invest. The Nash equilibrium for this scenario is (I, N).

Scenario 2. $67.000 < I_{10} < 68.000$ and $I_4 < 80.000$

In this case, if Corridor X invests, it will have greater profit only if Corridor IV does not invest. While for Corridor IV is better to invest only when Corridor X decide to not invest. Depending on the aspect, from aspect of Corridor X, Nash's equilibrium is (I, N) and from the aspect of Corridor IV is (N, I).

Scenario 3. $I_{10} > 119.000$ i $I_4 > 80.000$

In this case, the best decision for both corridors is that they do not invest and Nash's equilibrium is (N, N).

5. CONCLUSION AND FUTURE RESEARCH

This paper introduces the problem of competition in the transport market between Corridor X and Corridor IV. Also, a simple model with a numerical example based on Game theory has been developed.

The game is based on making decisions about investing in order to reduce the travel time on the subject corridors. Also, within the numerical example was identified a pure strategy of the Nash equilibriums for different scenarios that are characterizied by possible increase in profit and investment costs.

However, in order to be able to make a real decision based on the model of Game theory, it is necessary to develop a more complex and more practical model of competition. It requires additional or complete information that will enter in profit function or other objective functions of each of the corridors.

Also, it is necessary to conduct research and analysis of the port of Piraeus and transit flows through Corridor X and Corridor IV. Likewise, it is necessary to carry out an analysis of individual parameters (travel time, capacity, bottlenecks) that aff0ect the competitive edge. In addition, it is necessary to define and describe all the strategies that can be modeled within the game with the aim of creating a model with wich will be able to create a corridor management policy.

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HOW TO RECONCILE ENERGY REGULATION AND TRACTION CURRENT SETTLEMENT SYSTEM IN SERBIAN RAILWAY SECTOR

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***Abstract** – Similar to railway sector, electricity sector also went through the process of restructuring with the main goal of enabling a concept of „Third party access" (TPA) or final customer's right to choose the supplier of electricity on his own behalf. Today, energy regulation defines a final customer as a person who buys electricity for its own use and it does not foresee the concept of mobile consumers, neither the existence of one single contract for several measuring units. In the railway sector, from the perspective of railway regulation, infrastructure manager (IM) is a de facto final customer. This ambient caused many institutional, regulatory, organizational and technical issues to the railway market because final customers are in fact - operators. In this paper will be shed light on this problem using comprehensive analysis of energy and railway regulatory framework and best international practice. Finally, authors will propose possible guidelines for implementation of energy regulation in the Serbian railway sector.*

Keywords – traction current, energy regulation, railway access charge, the settlement system.

1. INTRODUCTION

Since the year 1996, the idea of a single European electricity market has found its way to EU regulation. The idea of „Third Party Access" (TPA) has passed a certain path and all household and non-household users now have the right to freely choose their own electricity supplier. Directive 2009/72/EC[1] has, among other, introduced terms such as generation, transmission, distribution, and supply of electricity.

These two novelties, the TPA and internal market segmentation („separation") have caused „a lot of troubles" to the railway sector of EU. Like many others, this problem also had its depth and width, which can be expressed through these two questions: 1) *How to organize the traction current supply system in line with energy regulation,* and 2) *How to calculate charges for consumption of traction current,* but bearing in mind the requirements of both, energy and railway regulation.

In the beginning, the majority of EU countries simply claimed their railway system as an exception from the energy regulation for being „specific, historical" systems. That approach lasted for a while until railway operators filed first lawsuits on the court and complains to the European Commision court[2]. After this, court decisions definitely put railway system (regarding traction current) under the jurisdiction of energy regulation[3].

Until then, EU countries are trying to adjust their railway systems to new demands and to establish their traction current supply systems and charge calculation, in a legal and efficient but still „railway" manner.

As a consequence, this situation had a demotivational influence on operators to make them energy efficient, it limited the possibility of use of regenerative braking and it used to make railway transport less competitive in general due to high costs of traction current.

In this paper will be shed light on this problem, the current legal framework in this field will be investigated, and possible guidelines for implementation of energy regulation in the Serbian railway sector will be proposed.

[1] EU Directive 2009/72/EC *concerning common rules for the internal market in electricity*

[2] *Case AT.39678/AT.39731 — Deutsche Bahn I/II*

[3] *Summary of Commission Decision of 18 December 2013 relating to a proceeding under Article 102 of the Treaty on the Functioning of the European Union*

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2. ENERGY REGULATION

EU regulation

Directive 2009/72/EC foresees four main segments in electricity market since its adoption in 2009:

1) *Generation* of electricity and the existence of a *producer* as person or company performing the activity of generation of electricity;
2) *Transmission* of electricity via extra high-voltage and high-voltage grid with goal of its delivery to end-users or distributors (without supply - sell) and *transmission system operator* as a person or company in charge for managing, maintenance, and development of the transmission network;
3) *Distribution* of electricity via high-voltage, medium-voltage and low-voltage grid with goal of its delivery to end-users (without supply - sell) and *distribution system operator* as a person or company in charge for managing, maintenance, and development of the distribution network;
4) *Supply*, which is in fact sale, including re-sale, of electricity to end-users.

As already mentioned, in the sense of this directive, the final customer is the person „buying electricity for its own use” and it should have the right of TPA, which means the possibility to assign contract with supplier (or suppliers) based on the principle of consumption data and price transparency [1].

This provision represents the root of the problem for railway sector from the perspective of energy regulation because de facto final customer (consumer) of electricity on railways is railway operator (his traction units).

In practice, Infrastructure Manager (IM) is the one buying electricity from a public network (distribution system), and also, it plays the role of the distribution system operator and the supplier, even if it is not certified for such activities according to energy market rules. Also, many railway operators do not enjoy the right of TPA, but rather the IM is their exclusive „supplier.”

As the problem unfolds, it can be seen that certification of IM for activities on electricity market is not an easy task if it is known that this requires additional investments and costs due to quality standards and other technical requirements.

Additionally, it is not practically possible to enable TPA to operators as long as their traction units are not equipped with on-board measuring devices in line with TSI[4] Regulation (EU) 1302/2014[5] and standard EN 50463, because it is impossible to charge railway operator with 100% accuracy without these devices.

Energy regulation leaves the possibility to classify particular system that distributes electricity on the geographically limited area and which does not supply households, as a „closed distribution system”, as stated in the directive. These systems are excluded from some administrative burdens and, precisely, the provisions of Article 25 (5) regarding the coverage of loses in the network and Article 32 (1) regarding the procedure of tariff and methodology approval. However, even if these represent some reliefs, being a closed distribution system does not mean the possibility to limit its users’ right of TPA.

Serbian regulation

In the Republic of Serbia (RS), all non-household users have the right to freely choose (and change) their own supplier of electricity since 2008. But, since the regulated prices were lower than market ones, such changes did not take place [2]. All users of the distribution system (except households) from January 2014 have lost their right to buy electricity on regulated prices.

Systematic law, which regulates this field in RS, is the Law on energy („Official Gazette of RS,” no. 145/2014). It was adopted in 2014 and was brought into force at the beginning of 2016. It is classified as „mostly harmonized” with its EU „twin” - Directive 2009/72/EC.

This law also foresees four segments of the electricity market and their financial and organizational independence. Generation and supply of electricity are being organized according to market principles, while the transmission and distribution have the legal status of activity of public interest [3]. Same as in EU, all subjects on electricity market have to be licensed according to Law, for the specific action they wish to perform, which is not the case with the Serbian IM.

General impression for mostly both, Serbian and EU regulation, is that they does not foresee the specific characteristics of the railway system: mobile consumers, possibility to „attach” several measuring points to one contract, technical specifications and standards for on-board measuring units, etc.

3. RAILWAY REGULATION

EU regulation

So-called 4th Railway Package (Directive 2012/34/EU[6]) brought some changes in terms of allocation of railway services inside packages of access charges. Using of traction equipment is now being considered as a minimal package service, while used traction itself remains an additional service. Reason for this change lies in the fact that wear and

[4] Technical specifications of interoperability

[5] Concerning a technical specification for interoperability relating to the ‘rolling stock — locomotives and passenger rolling stock’ subsystem of the rail system in the European Union

[6] Directive 2012/34/EU *establishing a single European railway area*

tear of the catenary overhead lines and equipment depend on the volume of traffic, while the consumption itself depends on other factors such as speed, acceleration, the weight of the train, the category of train, type of locomotive, etc.

Directive 2012/34/EU repeats the earlier-established principle of direct costs, or fact that all charges for the minimal package and additional services package have to be based on costs directly incurred as the result of operating the train [4]. This means, simply put, that railway operators must be only charged for what was actually consumed.

This is the root of the problem caused by the Directive to the traction current settlement system. The question that arises is how to charge operator for consumed electricity based on direct costs, if his traction units are not equipped with on-board measuring devices. Formulas which are in some cases used by the IM's, can only provide as the result an approximative value of electricity consumption.

To try to make it at least a bit clearer, EC has adopted Implementing Regulation 2015/909[7], where is given an explanation what direct costs are: „costs for which can be objectively and precisely proven that they were incurred as the result of operating the train service" [5]. Article 23 re-claims that costs of traction energy supply cannot exceed the actual costs of providing the service.

Serbian regulation

Starting on June 8th, 2018 the new Law on Railways („Official Gazette of RS", no. 41/2018) was brought into force, and its Article 15 states that „securing electric traction current supply is not considered as an energy activity in sense of the law regulating energy" and that „IM is the final customer in terms of law regulating energy" [6]. This means that traction current supply system is made as an exception from, and it does not fall for provisions, of the Law on Energy, which is not in line with mentioned EC/court decisions in EU on this matter.

Similar to Directive 2012/34/EU, the use of energy supply equipment is being considered as a part of a minimal package of services, while the consumed traction current is considered an additional service [6].

Traction current consumption on Serbian railways is being calculated according to the approximate formula given in Network statement by the IM, based on the price of electricity for one gross-ton kilometer of train traffic [7].

4. INTERANTIONAL PRACTICE

In this chapter, the traction current settlement system of six EU countries will be briefly described, and presented in table 1. For comparison, three of them are neighboring countries of RS, and three of them are central European well-developed countries.

5. INSTED OF CONCLUSION –POSSIBLE GUIDELINES

In years to come, during the process of further harmonization of Serbian regulatory framework with the EU legislative, problems of traction current settlement system and consumption calculation will become much more important. Therefore, it is necessary to pay extra attention to this problem and to find an optimal solution in line with both, railway and energy regulation.

The fist step should be adequate correction and adaptation of energy regulation, in the manner of incorporating the specifics of the railway system in it. This means that Law on Energy and other by-laws should recognize railways as a special technical system. Further, technical specifications for on-board measuring devices should be adopted, the term of mobile consumers and mobile measuring point should be recognized and the possibility to „attach" several measuring points to one contract should be enabled. Paralel to this, on-board measuring devices should become mandatory for all vehicles new on network.

In the second step, Serbian IM should license itself as a distribution network operator according to provisions of the Law on Energy. Possible solution might also be to declare energy infrastructure as a closed distribution system in order to gain, already mentioned, certain regulatory reliefs.

Eventually, IM or preferably its subsidiary, needs to obtain a license for the supply of electricity and, finally, to enable the access to its network to all interested suppliers in order to achieve full implementation of Directive 2009/72/EC and Law on Energy. Recommendation is that this step should be done by establishing the subsidiary of the IM for the activity of supply. In case IM becomes the supplier, it will also remain as distribution network operator.

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Table 1: International practice of the traction current settlement system

Country	TPA	Segments	Charging
Croatia	Not legally possible.	„HZ Infrastructure"[8] offers the service of traction current energy supply to all railway operators. Traction current is bought from public distribution network operated by HOPS[9].	The approximate formula is well developed, and it takes into consideration the tariffs of national energy supplier (day and night tariff) and specific consumption of several types of trains (4 categories).
Romania	Legally possible, but in practice only one company offers the service.	„SC Electrificare CFR SA", subsidiary of the national IM is licensed distributor, generator and supplier of electricity on the electricity market administrated by OPCOM[10].	Law recognizes the concept of mobile comsumers, possibility to attach several measuring units to one contract etc. There is existing legal framefork for on-board measuring devices. For vehicles not equipped with measuring device, well developed approximate formula is in use.
Bulgaria	Legally possible, but in practice only one company offers the service.	Traction current energy supply is being organized according to provisions of Law on Energy and Directive 2009/72/EC, and railway operators are allowed to buy electricity from licensed electricity suppliers since 2018. „NKZI"[11] is a licensed distributor of electricity and it performs all the activities according to the special rulebook.	According to the Decision of Regulatory body for energy and waters, railway operators are paying to „NKZI" a fixed price of electricity based on gross-tons kilometers.
France	Legally possible and being implemented in practice.	„SNCF Reseau"[12] is responsible for maintenance of traction current equipment, and it covers losses in the network. Railway operators are buying electricity from licensed suppliers under the French Law on Energy. „SNCF Reseau" is also one of the licensed suppliers, but operators are allowed to change their supplier at any time according to law.	Since 2006, every new vehicle on the French network has to be equipped with on-board measuring device and consumption is billed according to actual use of electricity. There is also an approximate formula based on train-km for vehicles which are not yet equipped with on-board measuring device.
Germany	Legally possible and being implemented in practice.	„DB Netze" is the company responsible for the operation of energy infrastructure (licensed distributor), while „DB Energie GmbH" is one of the licensed suppliers of electricity.	Since 2003, on-board measuring devices are mandatory on all new traction units and consumption is billed based on actual use.
Austria	Legally possible and being implemented in practice.	„ÖBB"[13] is the owner of the energy infrastructure, but it is also the licensed generator, distributor and supplier of electricity. It also performs an action of measuring. Since 2016, „ÖBB" has opened its network to other suppliers of electricity, which are now able to offer their services to railway operators. Also, „ÖBB" has 10 hydro-electric power plants in its possession, which covers 45% of traction current demands.	Since 2003, on-board measuring devices are mandatory on all new traction units and consumption is billed based on actual use.

[8] National IM in Croatia
[9]Croatian operator of distribution network
[10] Romaninan gas and electricity market operator
[11] National IM in Bulgaria
[12] National IM in France
[13] National IM in Austria

DO TECHNOLOGICAL ADVANCES AND RAILWAY MARKET COMPETITIVENESS GO HAND BY HAND – DISCUSSION OF SERBIAN RAILWAYS

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Abstract – *In 2011, the European Commission passed the White Paper on Transport which, among all, introduced future aims for railway transport. Some of the principal goals are: shifting 30% of road freight to rail or waterborne transport, doubling ton-kms in rail freight and establishing of European multimodal transport information, management and payment system by the year 2030. For such targets to be achieved, general competitiveness of railway sector needs to be improved, which can be done by improving product attractiveness to customers, reducing life-cycle costs (LCC) and also by introducing modern technologies in rolling stock, maintenance procedures, ticketing, infrastructure and operations.*

Keywords – technological advances, railway competitiveness, non-EU country railway.

1. INTRODUCTION

General transport policy of the European Union is pointed towards creating a sustainable, low-emission, European transport system based on principles of free market. It is no easy task to achieve because it requires careful and thorough long-term planning.

In EU long-term plans, railway plays a significant role – as can be seen in White Paper on Transport from 2011. In the paper, it is stated that the general plan is to shift 30 % of road freight towards railway or waterborne, and also to double rail freight ton-kms while establishing multimodal transport information, management, and payment system by 2030 [1].

If these plans are to be fulfilled, it will put a significant strain on mostly loaded railway networks, working on the edge of their capacities. To make matters worse, investments in new infrastructure are seen as the last resort [1]. Thus a solution should be found in a way to utilize the existing capacities better. In light of that fact, probably the best way to achieve such a thing is to introduce some new technologies in infrastructure, rolling stock, operations, maintenance and customer service.

Because of that, significant investments are actually made in the segment of research and development (R&D), and many new technologies are being developed or even implemented [2]. Of course, this raises the question in which manner will the use of new technologies affect the general competitiveness of railways.

When it comes to Serbian Railways, the same question could be asked, but perhaps from a (slightly) different angle. Serbia is still a neighboring EU country, and as such, it is not considered evenly in EU planning, but it is nevertheless considerably affected by EU long-term plans. Because of such a position, the key question for Serbian Railways is, perhaps, not how to increase general competitiveness by using new technologies, but how to still remain competitive.

This paper analytically addresses that question, having in mind the key issues of Serbian Railways in order to identify which of the new technologies could be of help, with regard to their implementation costs. To simplify matters, an overview of technologies of interest is given, along with a brief analysis.

2. COMPETITIVENESS

In today's world, it is all about being able to produce/provide a quality service at the right time and place – in other words, being competitive. To be able to provide such a service, a company must be active on the market, keeping track of the customer's needs, ongoing changes and introducing innovations. Besides being active, to be competitive also means to provide your service with lower cost. It is a widespread situation that the market leader is the company which provides its service with lowest costs, and using state

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of the art technologies often guarantees that.

Independent railway companies of today’s world are, of course, no exception. They also have to be active on the market and to fight for their share with other competitors by capitalizing on their advantages and competitors’ weaknesses.

The general level of railway competitiveness, perceived by the EU is usually marked as non-satisfactory, especially towards the road traffic [1]. Tremendous efforts are made by the EU to increase it, but time has shown that it presents a considerable challenge. This is mainly because of the railway’s two major hindrances – poor service flexibility and substantial investment costs (life-cycle costs, to be more precise). With its ubiquitous presence, road traffic is able to provide the exact service which railway cannot do on its own – a door-to-door service most of today’s customers prefer.

As can be seen from the previously stated, the increase in the railway’s competitiveness poses a great challenge. Because of that, the EU focused on what can be done, and that is of course not to make the railway’s presence also ubiquitous, but rather focused on these lines which could bear the burden of increased traffic. As a consequence of such thinking, something which is identified as Trans-European Transport Network (TEN-T) and Core Network Corridors (CNC) has emerged.

With the introduction of TEN-T and CNC railway starts to play a vital (if not even central) role in future transport plans. It is stated that global railway competitiveness should be increased primarily on the lines identified as part of these networks in order to shift traffic from road to rail [1]. Although large investments to increase network capacity are planned, they are still not enough to make the desired effect because of the network’s magnitude and a long time-span of these investments. Because of that, a quicker solution is being sought elsewhere, and that is in use of the new technologies.

New technologies which are implemented or planned in the future should increase general railway competitiveness because they provide [2]:

- Increased capacity;
- Improved operations;
- Improved maintenance which increases the availability of infrastructure and rolling stock;
- Increased interoperability;
- Added value to railway service;
- Higher commercial speed in some cases;
- Reduced life-cycle costs.

3. CORE NETWORK CORRIDORS

The first step towards creating a European transport network was to define its extent, both in terms of its configuration and of transport modes which will be present. Thus TEN-T network was born encompassing many trans-European, regional and local transport lines and all modes of transport.

On this TEN-T network, all the major lines of traffic were soon identified and were marked as Core Network Corridors (CNC) – nine of them in total (Figure 1). These corridors present lines with the biggest flow of goods and passengers. Defining these corridors was very important for railways because on these exact lines most of the modal shift from road to railway should happen [1].

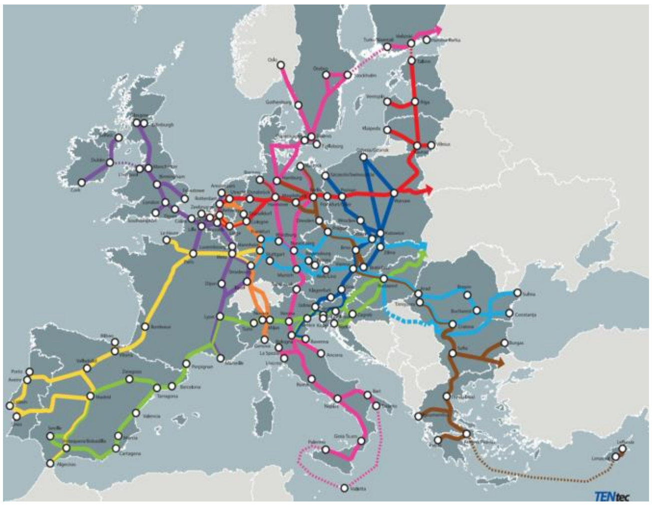

Fig.1. European Core Network Corridors (CNC)

It is important to note that with the introduction of CNC, major European transport corridors have been in some extent reshuffled, and also renamed. Some of them were altered (shortened or extended), whilst some of them have been excluded. Unfortunately, Serbia’s main transport route, the Corridor X, has been for most part excluded from the CNC network, as it can be seen on Figure 1. This is rather worrisome, because it seriously affects the competitiveness of Serbian Railways and threatens to affect it even more in the coming years, especially with the full implementation of new technologies on the CNC.

Then it will not only be the question of the level of investment in the infrastructure needed to remain competitive but also if there will be enough flow of passengers and goods running on an ‘’obsolete’’ network to keep the business going. It is therefore clear that in the near future, big investments in infrastructure could be a blank shot if they are not followed by technological advances. This can simply lead to the situation that a hefty part of passengers and goods avoids our network because a competitive corridor has better service quality.

Of all the European corridors, the one that should be carefully observed is Corridor IV (now named Orient/East-Med Transport Corridor), because it presents direct competition to Corridor X. For a large part, lines on these two corridors run parallel to each other, and they also share some of the transport nodes and have some common starting and end points for flow of goods and passengers. If the implementation of new technologies on this parallel corridor comes to life, it could seriously affect the competitiveness of Serbian railways in international traffic.

4. NEW TECHNOLOGIES – AN OVERVIEW

Given that the EU policy is such as it is, the primary purpose of technological advances (TA) to be implemented on railways would be to increase competitiveness with as low costs as possible [1]. Because of that, the focus of these TA is on new technologies in rolling stock, operations and maintenance rather than infrastructure. Railway businesses can be basically improved in three ways: use of automated processes (automation), use of IT technologies (digitalization) and use of new materials. Following this rule, the most significant TA in these three segments is presented in table 1, and they could be marked as priorities for Serbian Railways.

Tab.1. Most significant technologies advance for the railway competitiveness

TA	Type	Implementation	Effects	Description
European Rail Traffic Management System – ERTMS	Automation	Infrastructure, Rolling Stock & Operations	Increased capacity. Higher level of interoperability. Improved operations. Higher train speeds.	European train guidance system
Condition-based maintenance (CBM)	Digitalization & Maintenance	Infrastructure & Rolling Stock	Increased capacity. The decrease in LCC. Improved operations.	Predictive maintenance using on-board sensors to discover failures.
Light-weight cars	Use of new materials	Rolling stock	Increased capacity. Higher train speeds.	A new type of rail car which is lighter and able to carry heavier loads.
Innovative train braking systems	Use of new materials	Rolling stock	Improved safety. Increased capacity.	Use of disk and electro-pneumatic brakes
Mobility as a Service, E-Ticketing (MaaS)	Digitalization	Operations and management	Added value to the service	Offering a seemless travel to customers using a unified ticket
Shipment tracking	Digitalization	Operations	Added value to the service	Informing the customers of shipment whereabouts via the internet
On-board Wi-Fi	Digitalization	Rolling stock	Added value to the service	Installing of wireless internet in vehicles

5. DISCUSSION IN THE CONTEXT OF SERBIAN RAILWAYS

Of all the TA selected in Table 1, none of them is currently in use on Serbian railways. In sense of implementation of these TA, Serbian Railways start from point zero. Having that in mind, the authors of this paper suggest the implementation according to two simple criteria: is the given technology a priority and whether the benefits of potential implementation could beat the costs. The following analysis is based on these two criteria, having in mind the current state of infrastructure and rolling stock, which could be deemed as poor.

First on the list would be ERTMS, even besides its huge implementation costs and LCC which are currently slowing down its implementation across Europe [3]. This automated train guidance system has immense potential to enable ease of operations and maximum utilization of capacities, and by that to increase competitiveness as well as interoperability. However, cost issues make its current use limited to several lines and also make its future use to be justified only on lines with heavy traffic – mostly on corridors [3]. Because of that, future implementation of ERTMS on Corridor X as our main transport route should be considered. Especially since Bulgaria and Romania had already introduced ERTMS pilot lines several years ago, plus that (ex) Corridor IV is included in the general implementation plan.

with this guidance system by 2023, and Romania by 2025. Also, Croatia will equip route Vinkovci – Tovarnik, part of the Corridor X with ERTMS. These should be reasons enough why the implementation of ERTMS in Serbia should be seriously considered.

One of the presumably most interesting TA is predictive maintenance or condition-based maintenance (CBM). By using on-board sensors, infrastructure and rolling stock are continuously monitored, and maintenance is done before failures occur. This significantly reduces operational costs and increases capacity through better use of assets [2]. Also, it prolongs the life cycles of both the infrastructure and the rolling stock, which is an interesting feature for countries like ours, where infrastructure and rolling stock investments are scarce and hard to obtain. But, what might be the best news, is that implementation costs may not be so high not to consider introducing CBM on Serbian Railways, especially since it would contribute to big savings in operational costs and thus justify the investment.

Of all the innovations, perhaps the easiest to implement are those in the sphere of IT technologies (digitalization). Though easiest to implement, they certainly are not of least importance, since IT technologies are already a huge part of everyday use and they also present the future. It is needless to say just how important is the use of IT in order to remain competitive, and also that it would be irresponsible to avoid their use since costs of their implementation are quite low compared to what they offer [2].

In today's mobile world, customers have a much greater need for transportation. They want their service to be reliable, comfortable and easily accessible. To make the service more accessible, the introduction of IT is crucial, because it needs to be online, where it can be accessed via desktop, laptop, tablet or smart-phone. In that manner, E-tickets were introduced in passenger traffic, which enable customers to buy their tickets online. The invention of E-ticket opened up a door to something called MaaS – which means that now the whole trip using different operators (and transport modes) can be arranged at one place by just using the application or website [2]. But, to provide such a service, the transporter must also be online, so that he can be able to be a potential part of the ''travel chain'' a customer would prefer. It is evident that not being online seriously affects competitiveness, and we believe that introducing MaaS should be seriously considered by the Serbian Railways.

How much MaaS means to passenger traffic service, shipment tracking has similar importance in freight traffic. It also adds a lot of value to the service and fulfils customer's need to be aware of the status of their shipment. Since many of the freight traffic operators have this service in their offer, Serbia Cargo as a freight traffic operator should really consider adding value to their service by introducing shipment tracking.

Another not too expensive add-on in the passenger traffic service is introducing wireless internet onboard trains. This significantly adds value to the service and offers passengers no longer to perceive travel time as ''lost time'', because thanks to Wi-Fi, many of them can do their businesses while traveling [2]. Since this service provides many benefits with low implementation costs, we think that the implementation is really a must for Serbian Railways.

The last topic of this discussion is the use of new materials on railways. It is left for the end, not because of its least importance, but rather because it is hard to see the implementation of new light-weight cars and braking systems any time soon. These new technologies require either large investments or they might be challenging to implement so that for the time being they could not be seriously considered. Perhaps only a hint could be given, that future procurement of new rolling stock can be in the direction of buying these new light-weight cars, in a step-by-step manner.

6. CONCLUSION

Introduction of TA presents one of the ways to make railways more competitive. Their introduction is intensive for years now, and has begun at a various moments in different countries. Which TA will be introduced depends from (1) condition of railway system at that given moment, and (2) choice how to make railways more competitive.

In this paper, it is indirectly shown Serbian Railways percieve the use of TA in accordance to EU transport policy. Given the country's position on European railway map, Serbian Railways need to direct their policy towards making even the smallest steps towards introduction of TA, because in near future it will no longer be the question of ''to be or not to be'' competitive, but of sheer existance and becoming a part of European railway market.

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PERFORMANCE ASSESSMENT OF THE ŽRS ROLLING STOCK STRUCTURE IN CHANGED CONDITIONS OF TRANSPORT MARKET

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Abstract *– Analysis of commodity flows, as well as relevant flows (which need to be followed in purpose of formulating measures of rational reallocation) for implementers and transport organizers, is very important. It is very important to look at, and to exhaust all the resources, ie. goods that are interesting and suitable for the railway transport, as well as to see the capabilities of rolling stock belonging to Railways of Republic of Srpska (ŽRS) for transporting these goods. Looking at the flows of goods being transported on the network of Railways of Bosnia and Herzegovina (BiH), a focus is given on the flows of interest to the ŽRS. Current economy needs have changed significantly in relation to the capacities of the rolling stock owned by the ŽRS from the previous period. In the paper, the capacities of the rolling stock will be considered in relation to the flows and needs of the economy, as well as the rating of it's structure advantage, brightning the way of acquisition of new, and the modification of the existing wagons.*

Key words – wagona, rolling stock, transport market, competitiveness, sustainability.

1. INTRODUCTION

Opening up the market is an unstoppable process that takes place, no matter how much some railways are ready for it. The needs of the economy have changed considerably, and goods and its flow have become a resource for which there is need to compete in the market conditions of business. It is important to note that competition in such unpredictable conditions has become very large and strong.

Cargo transportation capacities are the most important assets of each operator, since their business success depends on management and usage of these capacites. This paper, based on the needs of the economy and good's flows, take into account the capacities of the rolling stock owned by the ŽRS from the previous period, and show the direction for making future decisions on procurement and adjustment of the rolling stock in conditions of an open market and the emergence of competition.

Dealing with development of rolling stock structure is, due to the very nature of the problem, separated into two parts:

- solving the problem of choosing a series and a subseries of wagons and
- determining the required number of wagons and procurement's dynamics.

2. POSITION OF ŽRS IN THE TRANSPORT MARKET

2.1. Participation of ŽRS in transport of goods

ŽRS and Railways of the Federation of BiH constitute an integrated system of rail freight transport in BiH, which, looking at the network of railways in Bosnia and Herzegovina, carries out transportation in most of the mass goods (flows), gravitating along this network and constituting important resources of the economic system.

However, the research concluded that many mass goods are being transported by road carriers (trucks), regardless of the fact that there is a possibility of transport by rail. Reasons for this are numerous, some of them being: transport prices, transport speed, diversity in service offered and commercial offer, operational results and productivity of labor resources, etc. Current market structure is, to a large extent,

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oriented and relying on the operation of national railways within national railway networks, while transport flows have largely became transboundary in their nature.

The railway network of BiH consists of two main strategic lines, which are also the main railway lines for the carriage of goods:

1. Line North - South: Šamac – Doboj – Zenica – Sarajevo – Mostar - Čapljina, is on Corridor Vc and
2. Line West - East: Dobrljin – Novi Grad - Banja Luka – Doboj – Tuzla - Zvornik, railroad parallel with Corridor X.

The main customers of the ŽRS, who also make the main flows of goods, are:

1. Elektroprivreda BiH with transport of coal from mines to coal processing stations, located mainly in Tuzla and Kakanj;
2. Mittal Prijedor with the export of iron ore;
3. GIKIL Lukavac with import and export of coke;
4. Alumina Zvornik with alumina, sodium hydroxide, bauxite and zeolite;
5. Mittal Zenica with waste and metallurgical products;
6. Aluminij Mostar;
7. Bimal i Sugar Factory Brčko with import and export of sugar and oil;
8. Seaports and riverports (Ploče, Rijeka, Brčko, Šamac) etc.

2.2. Structure of the ŽRS's cargo rolling stock

Optimizing the size and structure of the freight rolling stock in relation to transport requirements is one of the prerequisites for the efficiency of any railway carrier.

In a situation where the ŽRS is becoming capable for appearance on market and harmonization of laws in the technical, administrative and security area, and when the economy indicates the need for increased capacity for transport (due to the construction of important corridors - the need for transporting large quantities of bulk cargo, increasing the exploitation of iron ore from the mine Ljubija, increased volume of container traffic, etc.), it is necessary to carry out an analysis of the existing situation in order to look at the structure of the cargo rolling stock owned by ŽRS [5]. Table 1. represents numerical state of the working and non-working ŽRS's rolling stock, presented in the wagons series, for the year 2017.

It is noticeable that more than a half of the inventory rolling stock (IRS) owned by ŽRS is made up of an unused rolling stock, ie. wagons not carrying goods. Reasons for this state of the rolling stock are multiple, some of them being: reduced demand, deadlines for regular and periodical inspections and repairs, long-term standing and non-usage of wagons, damage on wagons caused by war activities or theft of certain parts, old wagons, etc. Poor condition of rolling stock influences available capacities, affects the restriction of transport capacity of the ŽRS, and furthermore causes the failure to meet the needs of the transport user.

Tab.1. Structure of the rolling stock of ŽRS

SERIES	NUMBER	
	Rolling stock	Out of service
G	0	89
H	18	61
I	0	1
T	11	25
E	921	615
F	0	1
K	1	1
R	54	143
L	0	8
S	1	18
O	0	0
Z	0	51
U	21	34
Total:	1027	1047

From Table 1, ie. the structure of the freight rolling stock owned by ŽRS, it can be concluded that half of wagons are an open ones. Based on this fact, it can be said that the majority of IRSs have the capacity to transport bulk cargo, ores and other goods suitable for transportation in open freight wagons. Since the structure of the freight rolling stock in the national ex-SFRJ railways was formed mainly on the base of the needs of the economy of each former member states, therefore, in view of the needs of mass transport of goods (iron ore, coal, coke, bauxite, etc.) structure of rolling stock on BiH railroad network was developed in that direction. With the collapse of the SFRJ, each of the countries retained the structure of the freight rolling stock within its railways. Table 2. presents the age structure of the series of wagons having the largest share in the current transport of goods.

Tab.2. Age structure of ŽRS rolling stock

Age	Dominant wagon series						
	H	T	E	R	U	Σ	%
to 5 god.	0	0	0	0	0	0	**0%**
5 – 10	0	0	37	0	0	37	**4%**
10 – 20		11	0	17		28	**3%**
20 - 30			21			21	**2%**
30 - 40	13	0	402	30	0	445	**43%**
over 40	5	0	463	7	21	496	**48%**
TOTAL	18	11	923	54	21	1027	**100%**

Based on the age analysis of the individual wagon series and the total, it can be concluded that the cargo rolling stock is outdated and that modification, reconstruction and procurement of the wagons will soon be necessary.

It should be noted that in the period of 2010/2011, 200 new Eans wagons were purchased (they are currently in a non-working stock due to the impossibility of brakes test, which can not be performed in the ŽRS workshops). Also, in 2013, 37 new Eaos / Eanos wagons were purchased. Attention was not given to other series and no procurement was made. However, based on the next analysis of commodity flows, it is noted that such approach was not justified.

As justification for an approach mentioned in previous text, non purchasing of wagons can be given a difficult current financial situation of the ŽRS. In spite of everything, ŽRS nevertheless tries to solve the problem with wagons whose exploitation life has expired, and wagon is no longer profitable to repair (through cassation).

3. ADMISSIBILITY OF THE ROLLING STOCK TO EXISTING MARKET NEEDS

As part of research of the optimal development of the freight rolling stock's structure, a survey of the correlation between the requirements structure for certain types of goods and the structure of the freight rolling stock must be started. In other words, as a first step it is necessary to determine the types of goods that appear in the carriage and the type of wagons we can use to carry out the transport of the goods.

Based on such a matrix of correspondences and actual quantities of particular types of goods appearing in transport, it is possible to evaluate the advantage of the existing structure of the freight rolling stock and the need for harmonization. Out of the entire assortment of goods transported on the railroads of Republic of Srpska, for the purpose of simplifying the assessment and assessment of the adaptation of the rolling park to the existing market needs, 9 groups of goods were identified which can be characterized as dominant (Table 3).

Tab.3. Dominant goods on ŽRS railroads

	TYPE OF GOODS	Wagons
1.	Sugar and sugar products	T, H, R
2.	Salt, stone, earth, gipsum, lime	E
3.	Rude, snap, ashes	E
4.	Coal	E
5.	Mineral fuels and oils	U, Z
6.	Non-organic chemical products	Z,U,E,H
7.	Wood and wood products	E
8.	Basic metals and their products (iron)	E
9.	Containers	R

It is very important to determine the trend of transport of the dominant commodities characterized, because on this basis we can predict and forecast the future flows and needs of the wagons.

Based on the records from the ŽRS's Sector for Tariffs, the Control and Distribution of Transport Revenues, the Sector for Exploitation and the effects of trains operations, Table 4. shows volume of transport of dominant goods by type for the period 2013-2017.

On the basis of the quantities of goods transported given, Table 5, presents the difference in the state of the employed wagons.

Tab.4. Trend of transport of dominant commodities on the ŽRS lines for the period 2013-2017

		Dominant goods transported on ŽRS lines					Wagons	**Trend**
		2013	2014	2015	2016	2017		
1.	Sugar and sugar products	190.443	87.941	116.357	129.735	121.934	T, H, R	↘
2.	Salt, stone, earth, gypsum, lime	86.827	64.049	70.940	76.071	69.262	E	↘
3.	Ores, snap, ashes	2.442.714	2.221.868	2.263.354	1.827.493	1.690.969	E	↘
4.	Coal	1.095.547	1.341.314	1.181.126	1.184.241	1.240.015	E	↗
5.	Mineral fuels and oils	118.323	120.267	102.575	100.636	121.214	U, Z	↗
6.	Non-organic chemical products	383.035	435.636	501.724	430.039	504.199	Z,U,E, H	↗
7.	Wood and wood products	74.388	74.663	37.655	45.493	34.422	E	↘
8.	Basic metals and their products (iron)	246.591	210.410	190.362	165.554	167.253	E	↘
9.	Large containers	25.852	43.330	50.733	102.156	193.899	R	↗

Market research has led to the observation that certain quantities of goods (oil, sugar, alumina, zeolite, containers, concrete elements, wheat, corn) were transported by other wagons owners. According to the nature of the thing (RIV 2000), all goods that are being loaded in the territory and in the area of the ŽRS should be transported by the ŽRS owned wagons. Based on this, the following conclusions can be drawn for the characteristic chosen series of wagons (Table 5):

- E wagons – The ŽRS have a sufficient number of these wagons for the current economy needs, ie. ŽRS has 361 wagons that are not engaged (these wagons can be leased or given to the assistance to other railways).
- H wagons – ŽRS **does not** have enough of these wagons for current economy needs. All currently available wagons are engaged (they were given as help for transport of "soda" in Lukavac and one during time for transport of "zeolite" in Alumina Zvornik). They could also be engaged to transport sugar from Brčko.
- T wagons – ŽRS **does not** have enough of these wagons for the current economy needs. Currently, all available wagons are not in use, although they can be used for the transport of sugar from the Port of Ploče, as well as seasonaly for the transport of cereals. (Private operator PPD Zagreb is using wagons owned by other owners and that company took over the transport of sugar from the port of Ploče). Also, the transport of cereals on the ŽRS network is carried out by other wagons owners (the alleged reason why the ŽRS car is not transported is small number of wagons - for one route it takes about 26 Tad wagons).
- R wagons – ŽRS **does not** have enough of these wagons for the current economy needs. All currently available wagons are in use (used for the transport of "biomass" and containers from Banja Luka to the port in Rijeka and for the transport of "soda" from Lukavac. They can be used for the transport of oil from Brčko, as well as for the transportation of concrete elements, as needed. Since container transport is on a steady pace, the economy needs are higher, the ŽRS could use these wagons.
- U wagons – ŽRS **does not** have enough of these wagons for the current economy needs. Total of 21 wagons owned by ŽRS are Udž wagons used for carriage of stone, and they are not engaged, because there is little economy need for this type of wagons. If ŽRS owned wagons of different type, they could be used for alumina transport from Zvornik, where mainly wagons owned by other owners operate.
- Z wagons - ŽRS **does not** have enough of these wagons for the current economy needs. ŽRS have these types of wagons, they could be used for the oil transport from Brčko, as well as for the base transport from Zvornik, where mainly wagons owned by other owners operate.

Tab.5. Trend of needs for selected wagons series on ŽRS

Wagon series	State	Needed for transport - engaged	Difference
E	921	560	361
H	18	18	0
T	11	0	11
R	54	54	0
Z	0	0	0
U	21	0	21

Situation described in previous text should be followed by a good ŽRS commercial policy ŽRS to enable itself to use its wagons in the conditions of market competition, because it should, according to the nature of the things and the demands of its economy, belong to it.

4. CONCLUSIVE CONSIDERATIONS

This paper is written to indicate the complexity of matching the rolling stock with the economy needs, and to give some guidance for deeper analysis and research about the possible need for the procurement of certain series and types of wagons, or the modification of its own (defective ones and ones in good working order).

On the basis of a shorter analysis of the needs for wagons, it can be pointed out that there is a "space" for the rolling stock extension, but with wagons series no attention has been given so far (R, H, T, Z, U).

It is also possible to reconstruct certain series of cars, which, with minimal investments, can be equiped and used to provide transport services on the market.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

ERTMS DEPLOYMENT ACROSS EUROPE: STATE OF PLAY, MAIN CHALLENGES AND FUTURE PLANS

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Abstract *– Though there is no doubt that introduction of ERTMS (European Rail Traffic Management System) brings various benefits for the railway systems, the practice shows that numerous issues have arisen during its deployment in the previous years. This is evidenced by the fact that only 40% of TEN-T funding available for ERTMS deployment for the period 2007 - 2013 was absorbed. With ERTMS now in a deployment phase across Europe, much work is still required to establish an interoperable system. Accordingly, this paper aims to give an overview of ERTMS benefits and implementation progress achieved with the EU support for ERTMS deployment and to provide insight into main challenges facing the introduction of ERTMS, as well as to present planned actions for its further implementation.*

Keywords – ERTMS, deployment, infrastructure, rolling stock, interoperability.

1. INTRODUCTION

To overcome the fact that there are around 30 different signalling systems across the EU and in order to contribute towards the creation of a single European railway, in the late 1980s and early 1990s the European rail industry, supported by the European Commission, started developing European control - command, signalling and communication system – European Railway Traffic Management System (ERTMS), a single system designed to foster interoperability among national rail networks and cross - border rail transport.

Despite the existence of the common agreement on necessity of unique, standardized signaling system across the EU, last decade showed that rollout of ERTMS in Europe has fallen far behind the deployment targets set by the EU, jeopardising achievement of the deployment targets set for 2030 and investments made so far, as well as longer-term interoperability objective and finally, it may also adversely affect the competitiveness of rail transport as compared with road transport.

The aim of this paper is to give overview of current state of the ERTMS deployment, to explain major challenges that ERTMS is facing in its implementation and to present plans for future development.

2. CURRENT STATE OF ERTMS DEPLOYMENT

2.1 Political and strategic background

Between 2005 and 2016, the Commission (and ERA since 2008) signed four Memorandums of Understanding with the rail stakeholders, aiming at strengthening cooperation and speeding up ERTMS deployment.

In 2009, the Commission adopted an ERTMS European Deployment Plan (EDP) setting out the detailed rules for ERTMS deployment and identifying six ERTMS corridors as well as a number of main European ports, marshalling yards, freight terminals and freight transport areas to be covered by ERTMS connections, together with their respective timetables, between 2015 and 2020.

Another important step was the adoption of the TEN-T guidelines in December 2013, which envisaged that the core network and the comprehensive network should be equipped with ERTMS by 2030 and 2050 respectively.

On 30 January 2013, the Commission adopted its proposal for the Fourth Railway Package to complete the single European railway area. The technical pillar, which entered into force in June 2016, covers elements directly linked to ERTMS such as rail

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governance issues and the reinforcement of the role of the European Union Agency for Railways (ERA), which will become the system authority for ERTMS as from mid - 2019 in order to maintain, monitor and manage the corresponding subsystem requirements, including the technical specifications for the European Train Control System (ETCS) and the Global System of Mobile Communications – Railway (GSM-R). It also transfers tasks that today are carried out by the National Safety Authorities to ERA regarding authorisation of rolling stock (including ERTMS on-board subsystems) and safety certificates for Railway Undertakings. Finally, the Fourth Railway Package has introduced a new process concerning the pre-approval of trackside implementations by ERA. [1]

Finally, on 5 January 2017 the European Commission adopted new ERTMS EDP, which sets target dates until 2023 by which time about 30 - 40% of the Core Network Corridors should be equipped.

2.2 EU financial support for ERTMS

To help the Member States deploy ERTMS, approximately 1.2 billion euros were allocated from the EU budget between 2007 and 2013, out of which 645 million euros from the Trans - European Network for Transport Programme (TEN-T) and 570 million euros from the European Regional Development Fund and the Cohesion Fund. [2]

The EU budget mostly co-finances two types of project in relation to ERTMS: trackside (equipping rail tracks with the necessary equipment) and on-board (equipping locomotives with ERTMS units). Other co-financed projects are related to contribution to the fulfilment of the MoU’s provisions, such as test campaigns, assistance to ERA regarding development and maintenance of ERTMS specifications, etc.

At the time of closing the 2007 - 2013 financial framework, 52 ERTMS actions received an EU contribution from the TEN-T program. The final TEN-T funding absorbed by this ERTMS portfolio is 248,6 million euros, out of which the largest part i.e. 55% was allocated to trackside deployment, 31% to onboard deployment and remaining 14% to the MoU related activities. [3]

Estimated budget for the period 2014 - 2020 is 2.7 billion euros, out of which 850 million euros coming from the Connecting Europe Facility, which has replaced the TEN-T Programme, and approximately 1.9 billion euros from the European Structural and Investments Funds. [2]

In addition to the sources previously mentioned, additional funding can be provided by the Shift2Rail Joint Undertaking which was established in 2014 and aims to invest almost one billion euro in research and innovation in 2014-2020 or by the European Investment Bank (EIB) which provides loans and guarantee schemes for ERTMS trackside deployment and purchase of new rolling stock equipped with ERTMS.

2.3 Current progress

The first official deadlines for ERTMS deployment are set out in the 2009 EDP, which was limited to six ERTMS corridors, indicating that 10 000 km of trackside should be equipped with ERTMS by 31 December 2015 and 25 000 km by 31 December 2020. [2]

Since it was estimated that by the end of 2017 less than 4.500 kilometers of Core Network Corridors lines will be operational with ERTMS and almost 7.000 vehicles equipped or contracted with ETCS in the EU, a substantial part of which has been supported by EU funding [4], the Commission revised targets in the new EDP and postponed the deadlines up to 2023.

In general, level of ERTMS deployment varies between the Member States and in some cases there is even lack of coordination between trackside and on-board ERTMS deployment within one state.

Currently ERTMS is deployed in a patchy way, with many stretches not connected to each other. There are cases of single lines outside the core network with no connection to the rest of the respective network or the cross-border section. Although the Commission is the initiator of the ERTMS concept, it has no precise overview of the overall deployment on the European level, as its monitoring is limited to the core network.

3. MAIN CHALLENGES

Despite the progress made so far much work is still required to achieve an EU - wide deployment of an interoperable system. Some of the main challenges ERTMS is facing with are:

1. No deadline is set for decommissioning of current national signalling systems. For ERTMS to be a single signalling system in the EU, national signalling systems must be decommissioned. Neither 2009 EDP nor the new EDP include any strategy for decommissioning of national signalling systems. The EU Member States have adopted different strategies for the deployment of ERTMS on their rail network. Denmark, for example, has chosen to dismantle its national system and roll-out ERTMS as a single signalling system on the majority of its national rail network, taking into account shortcomings and obsolescence of its current national signalling system. Other Member States have mainly opted for ERTMS as an add-on software based-system for their national signalling systems, in particular where their remaining lifetime is 15-20 years, such as in Germany, for example.

2. ERTMS investments are costly. It was only in 2015 and 2016 that the Commission started to assess the cost of ERTMS deployment in two studies. This assessment was limited to the cost of ERTMS equipment and installation and restricted to the core network corridors. Based on this cost category, the trackside deployment cost could range between 100000 and 350000 euros per kilometer i.e. 5 - 18 billion euros respectively. [2] In order to put ERTMS fully into operation on trackside, the total cost to be borne by the infrastructure managers is not however limited to the cost of equipment and installation, but also includes other associated works required to migrate from a fully-functional national signalling system to a fully-functional ERTMS system. According to the Commission, these works are a pre-requisite for deployment, even though they are not formally a part of ERTMS.

   Moreover, ERTMS deployed trackside as an additional system may entail further maintenance costs until the national system is not needed any more and is decommissioned.

   In addition to the cost of ERTMS deployment on trackside, which is borne by the infrastructure managers, ERTMS must also be installed on the locomotives, at the expense of railway undertakings. The situation differs for existing locomotives, which have to be retrofitted to be able to run on ERTMS equipped lines, and new locomotives, which are purchased with the ERTMS already installed on-board. In the case of existing locomotives, two Commission studies refer to a cost per locomotive between 375000 euros and 550000 euros, including ERTMS equipment and installation, testing and authorisation and unavailability of the vehicle. In addition, associated training costs are estimated at 20000 euros per locomotive. [2] Moreover, the additional ERTMS on-board equipment may result in further maintenance cost per locomotive until the national signalling system is decommissioned.

   New locomotives or trainsets have to be equipped with ERTMS irrespective whether they run on ERTMS equipped lines or not. The average cost of an on-board unit is estimated by railway undertakings in the Member States at approximately 300000 euros (around 15 % of the cost of the whole locomotive). Hence, ERTMS, together with the required associated works, entails costly investments which have to be covered by infrastructure managers and railway undertakings. The overall cost of ERTMS deployment, both trackside and on-board, could be up to 80 billion euro for the core network corridors or 190 billion euros for the comprehensive network. [2]
3. Problems of compatibility between different versions of ERTMS which may arise mainly as a result of two major factors: the integration of ERTMS with the existing national signalling system in each Member State and the deferred deployment of ERTMS across the borders. In the EU, ERTMS is embedded in the national rail networks and their signalling systems. Due to tailor-made ERTMS solutions in the national rail networks there is currently no ERTMS on-board unit in the EU able to run on all rail sections equipped with different versions of ERTMS. In addition, so far, ERTMS deployment has been limited to lines whereas train stations and hubs have not yet been equipped with ERTMS. The technical specifications for interoperability have evolved at a very rapid pace hampering the overall stability of the system (on average they have been changed every two years) and resulting in the need for subsequent upgrades.
4. Lengthy certification procedures to ensure compatibility. The certification of ERTMS involves notified bodies, which are responsible for testing and certification, and national safety authorities, which issue authorisations. In order to obtain a certificate for a line or an on-board unit the infrastructure managers and railway undertakings usually cooperate closely with the national safety agency from the very beginning of the project, before a formal application is submitted. The practice has shown that the certification and authorization processes arerelatively lengthy and require on average one to two years. In the case of cross-border operations the certification of on-board units was particularly complex and costly due to national variations which also hindered the cross-acceptance of work performed by the national safety authorities in other Member States

4. PLANS FOR FUTURE DEPLOYMENT

The new EDP, which is supported by the Member States, is a step towards more realistic deployment, but major challenges remain. Firstly, as in the past, it does not include any overall cost assessment for ERTMS deployment. Secondly, it is in no way linked to any dedicated funding nor is the source of this funding defined; hence, other incentives have to be found for the sector to meet its targets. In addition, there is still no legally binding deadline for decommissioning the current national systems with a view to making ERTMS a sole (and not additional) signalling system. The new EDP only refers to specific trackside deployment targets between 2017 and 2023, whereas the remaining sections to be equipped are only shown as "beyond 2023", with no fixed deadline (except for the general deadline of 2030). This affects the coordination of deployment among Member States and discourages railway undertakings from planning their on-board investments accordingly. Moreover, the planned deployment is affected by a lack of time alignment between Member States on cross-border sections. This shows that Member States plan their deployment according to their national needs, regardless of any commitment made in relation to EU priorities.

Still, Deployment Action Plan has set a number of recommendations concerning the assessment of ERTMS deployment costs, decommissioning of national signalling systems**,** individual business case for infrastructure managers and railway undertakings**,** compatibility and stability of the system; role and resources of ERA**,** alignment of national deployment plans, monitoring and enforcement; absorption of EU funds for ERTMS projects and better targeting of EU funding, which should enable better progress of ERTMS deployment in future**.** [1]

5. CONCLUSION

Despite the strategic political decision to deploy a single signalling system in the whole EU, there has been little coordination between obligations, priorities and deadlines and this has hindered a coherent deployment of ERTMS. Practice shows that there is still number of huge and complex legal, financial and technical obstacles that need to be overcome before the idea of seamless international rail transport across Europe's borders can be realised.

In the course of the last 20 years, numerous legal documents have set obligations related to the deployment of ERTMS. There have also been attempts to prioritise specific lines and set differentiated deadlines. However, no overall cost estimate was performed to establish the necessary funding and its sources. EU financial support is available for ERTMS investments both trackside and on-board, but it can only cover a limited amount of the overall cost of deployment. It leaves most of the investment to individual infrastructure managers and railway undertakings which do not always benefit, at least immediately, from the deployment of ERTMS. In addition, not all EU funding available for ERTMS was finally allocated to ERTMS projects and it was not always well targeted.

Furthermore, there is a number of technical problems with compatibility of the different versions installed as well as the lengthy certification procedures that also adversely affect the individual business case for infrastructure managers and railway undertakings.

Despite the complexities of EU deployment, ERTMS is already a global standard for train control and communication. The development of ERTMS has provided excellent opportunities for developing high value business and expertise within Europe and for export around the world. Ultimately all involved parties need to work constructively to achieve in a business-relevant time horizon the desired goal of interoperability.

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DIGITALISATION OF THE RAILWAYS, WHERE ARE WE NOW?

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Abstract *– Digitalisation is present in all aspects of our lives, and offers enormous opportunities and challenges in everyday life of the people. For rail and other transportation industries, the fourth industrial revolution promises continuing acceleration of innovation on both the supply and demand side. The common objective of all rail stakeholders is to offer highly efficient and attractive transport service to their customers, and digitalisation is one of the key tools to achieve this in a fast-moving technology environment. Digital traffic management systems, digital energy management solutions, e-ticketing, digital tracking and tracing applications, Big Data applications, are just a few examples of how the rail sector is implementing the latest technologies for telematics applications for passenger and freight services in the interest of the customers and contributing to the Digital Single Market. In order to become an integral part of the European Railway, in addition to investing in reconstruction of infrastructure, overhaul or purchase of new locomotives and wagons, the railway system in Serbia should emphasize the development of new digital services or to start using existing ones already used by other European railways.*

Keywords – digitalization, railways, improvement.

1. INTRODUCTION

During the last decades, IT developments and the increased use of digital technology have transformed the way railways are working today and now have a big influence on our economy and the expectations of our customers.

Digitalisation in transport and logistics is an important driver for efficiency, simplification, lowering costs, and a better use of resources and existing infrastructures. It also creates new opportunities for business and has the potential to change the way cargo and traffic flows can be organised and managed in the future.

The objective for the rail sector is to offer highly efficient and attractive transport options to their customers and to make the most of the opportunities offered by digital transformation and digitalisation should be one of the top priorities for the rail sector and its future.

1.1. Industry 4.0

Industry 4.0 is a term that describes the fourth generation of industrial activity that is enabled by smart systems and Internet-based solutions.

Industry 4.0 takes digitisation a step further, using cyber-physical systems, the Internet of Things and Cloud computing to collate data, turn this into big data, then smart data and finally business data.

There is no reason why the same approach cannot be applied to rail infrastructure. Currently, rail systems such as signalling, rolling stock and passenger or cargo traffic control are separated, with one system unable to talk to another. This makes the introduction of collaborative platforms hard to apply.

If all the data from every system was brought together, the whole network could communicate seamlessly and instantaneously. The key is interoperability of systems while retaining a critical approach to data security.

2. DIGITALISATION ON THE RAILWAYS

Digitalisation provides a huge opportunity to reduce costs by streamlining processes and improving efficiency and reliability. It can provide real-time information on train movements, which for too long has been rail's Achilles heel, while predictive maintenance for both rolling stock and fixed assets can finally become a reality. Digitalisation will allow

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railways to analyze overall performance and subsystems to identify weaknesses, which need to be addressed.

The technology is also encouraging new companies, often in the form of start-ups, to enter the rail industry and inject fresh ideas and new ways of working.

In order to take advantage of the full benefits of digitization, it is vital to educate people on how to make the best use of it and to ensure they understand how they will benefit. People must not come to fear digitalisation but embrace it. This applies to both employees and customers.

2.1 Institutional activities

In past several years, railway companies in different countries have developed their digitalisation programs. On European level, solutions and guidelines are given through initiatives like Shift2Rail and UIC Digital Platform, which promotes digital transformation of railways on European level.

A Roadmap for Digital Railways [1] published in March 2016 in collaboration between CER, CIT, EIM and UIC specifies that the main areas of deployment of digital technologies in rail transport are:

- offering connected railways by providing reliable connectivity for safe, efficient and attractive railways;
- enhancing customer experience by offering better and added value for customers;
- increasing capacity by enhancing reliability, efficiency and performance of railways;
- boosting rail competitiveness by making the most of transport data.

In November 2017, CER together with EIM, ERFA, UIP, UITP and UNIFE signed the Joint Rail Sector Declaration on Digitalisation of Railways [2] that reaffirms the continued provision of products and services using digital technologies for the benefit of people and to make contributions to the Digital Single Market. They have called on the European Commission to uphold digitalisation as one of its key priorities and to ensure that the political importance of the topic is reflected in the funding commitments in the next Multi-Annual Financial Framework.

2.2 Technology and solutions

The main technologies and solutions which have accelerated digital transformation in the railway sector in recent years are:

- Internet of Things (IoT);
- Cloud Computing;
- Big Data Analytics (BDA);
- Automation and Robotics.

Mobile applications, e-ticketing, digital train control, signalling and traffic management, digital platforms for predictive maintenance are the key areas of digitalisation in the rail sector.

The Internet of Things (IoT) represent the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect and exchange data, creating opportunities for more direct integration of the physical world into computer-based systems, resulting in efficiency improvements, economic benefits, and reduced human exertions. Connections and communications in side of the network can be defined as: people-to-people (P2P), people-to-machine (P2M), as well as fully automated data exchange between machines (M2M)

The combined Information Technologies (IT), operational technologies (OT) and IoT have enabled the emergence of the Concept Industry 4.0 and Industrial internet of things (IIoT), which assume that automated production based on real-time data exchange with the use of a range of technologies, will render a reduction of overall operational costs, improve performance and the capacity to offer advanced products and services, while still observing the behavior and preferences of their consumers.

2.3 Digitalisation of the Railways in practice

In past several years, some of the European railways made significant improvements in communication with passengers. These improvements can be seen through:

- More informative and user friendly web sites;
- Mobile applications offering real time information about vehicles in motion, and allowing ticket purchasing;
- Onboard infotainment services;
- Dynamic passenger and timetable information implemented at stations and stops.

For example, in Germany, passengers can access the internet on significant number of stations, in DB Lounges and on board ICE trains. The entire ICE fleet of DB Long Distance is equipped with fast, multi-provider WiFi technology. Passengers can use WiFi free of charge in both first-class and second-class coaches. It is also available on all ICE international trains to France, within the Netherlands and to Austria. The free ICE Portal offers an overview of up-to-date information on journey and connecting trains, as well as a wide variety of audiobooks and games, books, films, the news section, daily newspapers. Similar examples exist in other countries with other railway operators.

Solutions which are based on electronic platforms and applications, enabling real-time journey information, making of reservation and purchase of tickets are called Mobility as a Service. It analyses a number of possible journey scenarios, using different modes and means of transport (public and private), it offers booking and ticketing services at the same time monitoring the traffic, road works, incidents and accidents on line. DB Navigator, developed by DB is one of the applications which can provide mobile booking, real-time information with current departure and arrival times. During 2017, about 17mil. tickets were booked with this application, and about 4 mil travel queries are served daily in average.

The use of digital data processing is revolutionizing maintenance of infrastructure and rolling stock. Based on millions of data points captured from sensors on critical train components, analytics can detect impending part defects, ensuring maintenance is only done when required, but before a defect occurs. By consolidating volumes of maintenance data with business processes and IT systems and using cloud computing, manufacturers of rolling stock are now able to offer a number of new digital services, such as:

- Fault Detection as a Service;
- Predictive Maintenance as a Service (PMaaS);
- Simulation as a Service.

DB Cargo AG has commissioned Siemens to equip its locomotive fleet with a system for condition based, predictive maintenance with a view to improve the availability and energy efficiency. The upgrade applies to Siemens locomotives of the 152 Series Eurosprinter ES64F and locomotives of the 170 and 191 Series, both Vectron types. For the 152 Series locomotives, Siemens will retrofit the necessary telemetric systems and network all locomotives with the TechLOK system used by DB Cargo. The telemetric systems continually collect data on the condition of the locomotives. With these data, experts at Siemens' Mobility Data Services Center will work with DB Cargo to develop applications and data analytics models. The system TechLOK is being implemented by DB Cargo's subsidiaries in four countries: Poland, Great Britain, France, and Germany. About 2,000 locomotives of 16 types will be interlinked by 2019 drive significant efficiency improvement.

In rail transport, the development of autonomous systems has been mainly connected with area of public transport services, such as: driverless metro lines, light rail transit (LRT), people movers, and automated guided transit (AGT). In these systems, automation refers to the process by which responsibility for operation management of trains is transferred from the driver to the train control system.

Apart from implementing autonomous train service on metro lines, i.e. in closed systems with short intervals between services and high frequencies, another challenge will be the introduction of Automated Train Operations (ATO) in urbanised areas for regional and cross-country trains. A combination ETCS with ATO is a promising solution for future fully automated operation for mainline services. ETCS monitors the train's movement to ensure it adheres to the local speed limit and its own permitted top speed. The system can be scaled up to different levels. For example, at Level 2, the required GSM-Railway radio channel enables both the train-track communication for the ETCS itself and the communication between the trackside Automatic Train Supervision (ATS) and ATO. Technically, this means that ETCS is a train control and protection system that acts as an intermediary between the vehicle and the track to ensure railway safety and that conveys driving instructions from the track to the vehicle. The advantages when ETCS is combined with ATO are particularly through improved energy efficiency and greater line capacity.

DB aims to use digital technologies to increase the rail network's capacity, making room for thousands of additional trains each day. First highly automated S-Bahn to start operating in Hamburg in 2021. The core components of the Digital Rail for Germany program for the future are the European Train Control System (ETCS) and digital signal towers. These sophisticated digital technologies are creating brand new opportunities for increasing railway reliability and rail network capacity by up to 20 percent.

Internet of Trains is concept, which should create value for multiple stakeholders. This concept is true example how Internet of Things (IoT) is implemented in rail transport. It implies that train's smart sub-systems communicate data via cloud computing to the central data platform. In order to take advantage of the functionality of the Internet of trains, reliable and uninterrupted communication is necessary between three different networks: one providing the connection between the train components and the on-board controls, one used by the crew on-board and one broadband mobile internet connection service offered to passengers. The prerequisite for implementing IoT is the operation of the GSM-R standard.

The advantages of the implementation of IoT solutions for particular stakeholders can be:

- For the Manufacturer (real-time access to information about train components helping prevent defects);
- For the train operator (a better understanding of passenger needs; possibility to offer additional services in cooperation with partners; real time maintenance data updating allowing for predictive maintenance);
- For Infrastructure managers (real-time access to data about the location and movement of trains, helping to reduce safety hazards and for planning of infrastructure maintenance);
- For IT platform Operators (the possibility to

offer embedded service in cooperation with partners; added value services created by digital business models);
- For Passengers (access to on line services, even when not onboard trains; automatic ticketing and payement processing; fast and flexible journey planning).

In order to have constant progress in development of digital solutions as well as the ability to monitor new digital technologies and techniques through time, railway companies have developed their Digital business strategies.

Deutche Bahn has developed program under the name DB 4.0 which covers the whole holding and it involves initiatives in all areas of DB's business activity.

The three currently prioritized areas of digital transformation in DB are:

- The development of the customer interface;
- Supporting operations, including the maintenance of infrastructure and rolling stock;
- Designing new business models that reach beyond the basic business activity (Qixxit platform).

2.4 Digitalisation of Railways sistem in Serbia

The rail system in Serbia does not have a significantly developed digital service for stakeholders. The systems for tracking of wagons and trains on the rail network have been developed in the past and it is based on manual data entry by operators in stations. The state passenger train operator (Srbija Voz), started trial period for issuing of electronic tickets on one railway line in Serbia (Pančevo-Vršac). After purchasing of new train sets, Srbija Voz has decided to install IT equipment for providing WiFi internet in some of the new train sets.

In general, information systems that have all three state-owned railway companies are outdated and some of them are even out of order.

Systems used for monitoring of electricity and signaling equipment are very old and without possibility to collect more different data at the same time from the railways line as well as for the quality processing of collecetd data for purpose of prevention measures or making investment decisions.

During next 5 or 10 years, some of the railway line in Serbia will be upgraded and modernized, what would be a good chance for the installation of modern equipment and systems capable for collecting different types of data which can be used further for development different aplications conneceted to needs of all stakeholders.

3. CONCLUSION

Digital technologies will create groundbreaking new opportunities to take rail operations into the future, along with all of rail's unique characteristics – its ability to move significant volumes of people and goods at the same time, to handle high-capacity transport, to be climate-friendly and energy-efficient, and to offer sophisticated electro mobility while requiring little space. One of the intentions is to increase the existing network's capacity without building additional routes. Availability of data to all interested parties in railway sector will be very important. Digitalisation of railways in Serbia is mandatory to happened in order to have proper railway system which will become integral part of the European railway network in one moment of time. This will enable full interoperability of railway system concerning of exchange of railway vehicles and exchange of data with all other railway users on that network.

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ANALYSIS OF THE FACTORS INFLUENCING THE EFFICIENCY OF PASSENGER RAILWAY TRANSPORT IN BULGARIA

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Abstract – *An analysis of the factors influencing the efficiency of passenger transport is presented. The analysis is part of a task set to researchers from three universities and is aimed at improving railway transport service in the Republic of Bulgaria by purchasing new passenger rolling stock. The factors influencing the efficiency of passenger transport are analysed and the most important of them are identified. An analysis of passenger flow has been made and on the basis of it five options are proposed for renewal of passenger rolling stock. The most efficient option is that of upgrading the rolling stock of fast trains with high cost-effectiveness on major railways.*

Keywords - rail transport, efficiency, passenger transport.

1. INTRODUCTION

In 2017, a team of researchers from three higher education institutions in the Republic of Bulgaria was commissioned to justify the number and the main parameters of new rolling stock, which is to be purchased for the needs of "BDZ Passenger Services" Ltd. [1, 2, 3].

The transport service of passenger transportation of provided by "BDZ Passenger Services" Ltd., is of great social and economic importance for the Republic of Bulgaria. Unfortunately, over the last few years in our country there has been outflow of passengers from railway transport. The reasons for this are diverse the main being: increasing use of automobiles by the population, bad quality of the transport service, demographic factors, etc.

In order to clarify the reasons for that state of affairs a thorough analysis of the quality of the transport service, presented below, was conducted. Important advantages of railway transport were formulated in terms of their importance for the development of the country and the emphasis they have been given in various documents of the EU and in policies concerning the development of transport.

2. ANALYSIS OF PASSENGER FLOW

2.1. Evaluation of train efficiency

Evaluation of the efficiency has been carried out on all nine main railway lines.

Statistical data about passenger transportation for a period of a year and a half (for the year 2017 throughout May 2018) have been used for this purpose. Several indicators have been analyzed: revenue, costs, cost-effectiveness, transportation work (passenger kilometers), occupancy, distance covered.

For the purposes of the analysis we have calculated the **coefficient of efficiency of transportation**, which is the correlation between the relative share of the different types of trains (fast, suburban, regional and trains on railway lines with low passenger flow) in the passenger kilometers and train kilometers covered:

$$CE_{TR} = \frac{P_i}{T_i} \tag{1}$$

CE_{TR} – coefficient of efficiency of transportation,
P_i – the relative share of the different types of trains (i) – the passenger kilometers
T_i – the relative share of the different types of trains (i) – the train kilometers

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i – types trains F – fast trains, S – suburban trains, R – regional trains and L – trains on railway lines with low passenger flow

The values of the coefficient are presented graphically in Figures 1 to 9.

- **Railway line № 1**
  Kalotina-Sofia-Plovdiv-Svilengrad

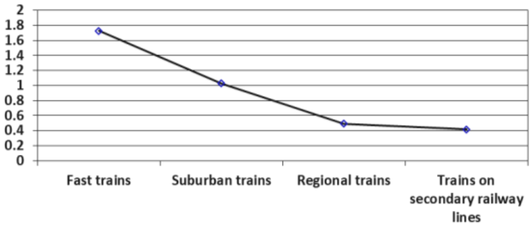

Fig.1. Transportation efficiency of the different types of trains on RWLs 1, 13, 16, 18 and 19

- **Railway line № 2**
  Sofia-Mezdra-Gorna Oriahovitsa-Varna

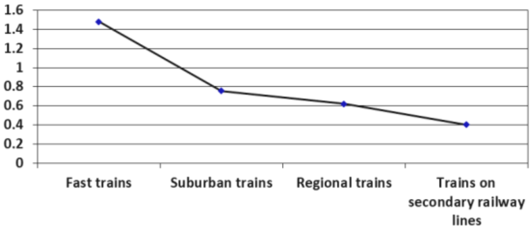

Fig.2. Transportation efficiency of the different types of trains on RWLs 2, 23, 24 and 28

- **Railway line № 3**
  Sofia-Karlovo-Karnobat-Varna

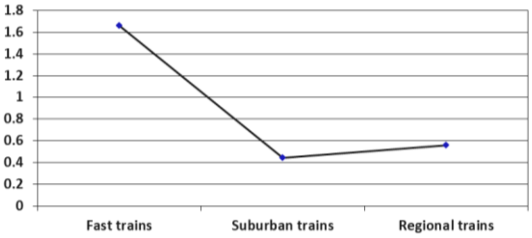

Fig.3. Transportation efficiency of the different types of trains on RWL 3

- **Railway line № 4**
  Russe-G.Oriahovitsa-Dimitrovgrad-Podkova

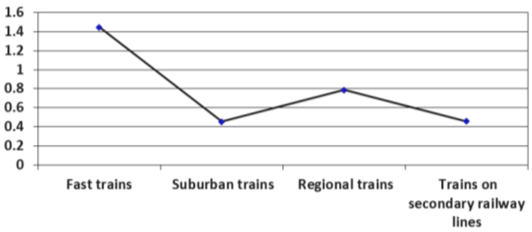

Fig.4. Transportation efficiency of the different types of trains on RWLs 4 and 42

- **Railway line № 5**
  Sofia-Vladaya-Pernik-Kulata

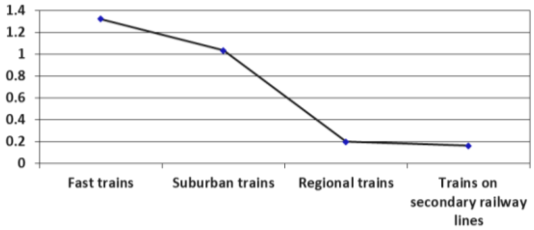

Fig. 5. Transportation efficiency of the different types of trains on RWL 5

- **Railway line № 6**
  Sofia-Voluyak-Pernik-Gyueshevo

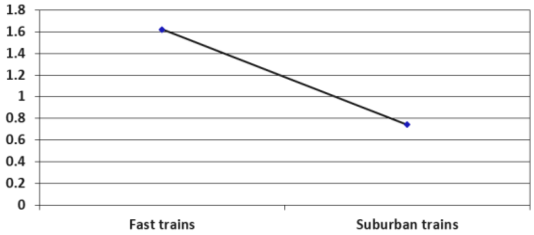

Fig.6. Transportation efficiency of the different types of trains on RWL 6

- **Railway line № 7**
  Mezdra-Montana-Vidin-Danube Bridge 2

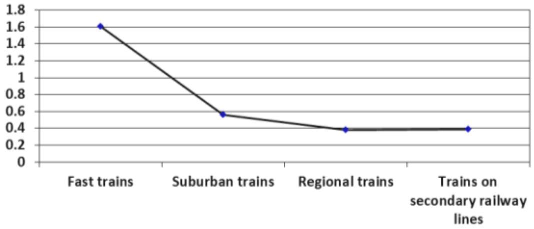

Fig.7. Transportation efficiency of the different types of trains on RWLs 7, 71 and 72

- **Railway line № 8**
  Plovdiv-Stara Zagora-Karnobat-Burgass

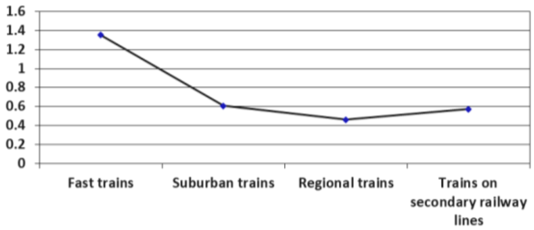

Fig.8. Transportation efficiency of the different types of trains on RWLs 8, 81 and 82

- **Railway line № 9**
  Russe-Samuil-Kaspichan

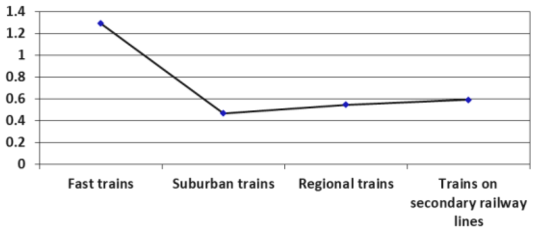

Fig.9. Transportation efficiency of the different types of trains on RWLs 9 and 91

2.2. Comparison of railway lines by main indicators

For the purposes of the analysis of passenger flow and in order to determine the appropriate rolling stock of different railway lines a comparison of the different indicators should be made. The figures below (№ 10 – № 19) show in graphical form comparative data about the nine railway lines by types of train and by the different indicators.

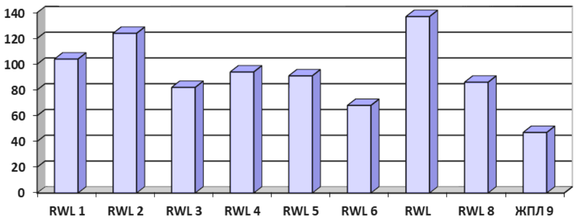

Fig.10. Average occupancy of fast trains

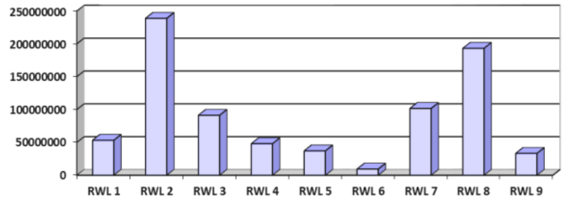

Fig.11.Transportation work done by fast trains, pkm

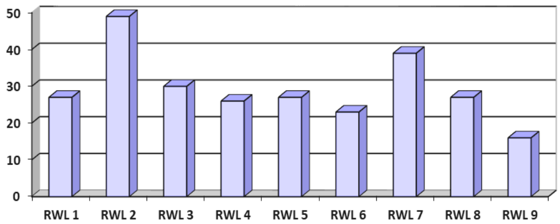

Fig.12. Cost-effectiveness of fast trains, %

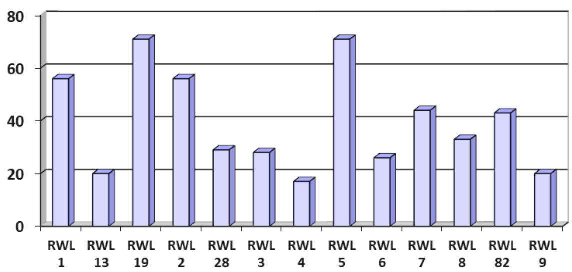

Fig.13. Average occupancy of suburban tranins

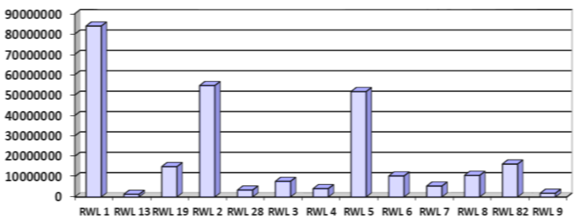

Fig.14. Transportation work done by suburban trains, pkm

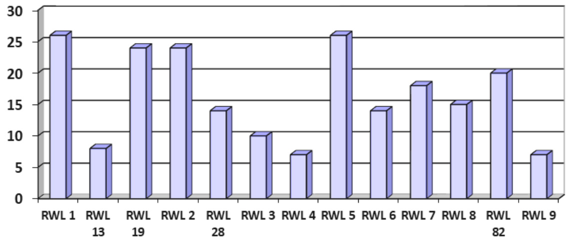

Fig.15. Cost-effectiveness of suburban *trains, %*

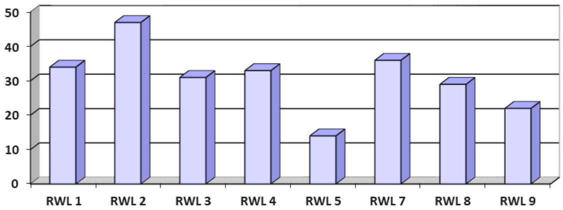

Fig.16. Average occupancy of regional trains

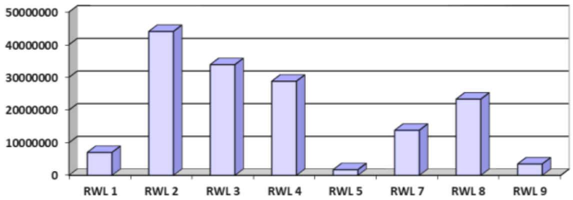

Fig.17. Transportation work done by regional trains, pkm

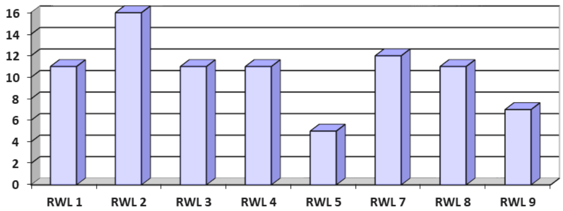

Fig.18. Cost-effectiveness of regional trains, %

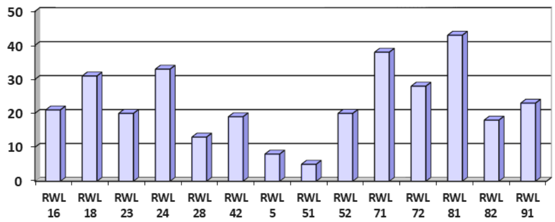

Fig.19. Average occupancy of transport on sections of railway lines with low passenger flow

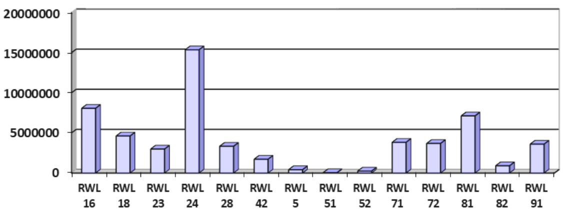

Fig.20. Transportation work done on sections of railway lines with low passenger flow, pkm

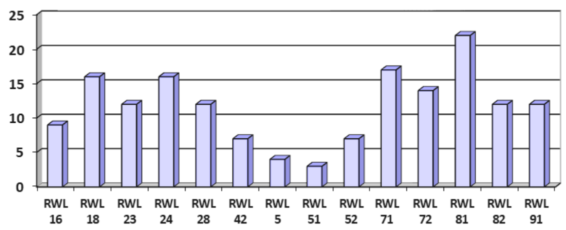

Fig. 21. Cost-effectiveness on sections of railway lines with low passenger flow, %

3. CONCLUSION

On the basis of the analysis of various indicators, several variants of renewal of the rolling stock can be put forward:

Variant 1 – Renewal of the rolling stock of fast trains with relatively high cost-effectiveness on the main railway lines. That variant will cover fast trains on railway lines 1, 2, 7 and 8. As far as RWL 3 is concerned, the National Railway Infrastructure Company (NCRI) does not envisage, at this stage, to implement projects for total reconstruction and modernization. However, the Karnobat-Varna section needs to be taken into consideration. On the other hand, the effect will be lost on RWL 5 because the main part of the transportation is done on the relatively short section between Sofia and Pernik. The advantage of this variant is that it will cover the main part of the passenger flow at the long distances in the country. Its efficiency is reinforced by the activities planned by NCRI. In this way a quality transport service will be created and it will increase both the efficiency of transportation and the competitiveness of railway against automobile transport. Cost-effectiveness in this variant would be high.

Variant 2 – Renewal of rolling stock of fast trains with a relatively low cost-effectiveness, on the main railway lines. This variant will affect transportation on main railway lines 4, 6 and 9. Largely, that refers to RWL 5. An advantage of the variant is that will create the possibility to attract additional passenger flow on these lines, although on some of the sections the possibility for doing that is quite limited. Cost-effectiveness of this variant would be comparatively low.

Variant 3 – Renewal of rolling stock of suburban trains on main sections of the main railway network. This variant would increase the overall efficiency of transportation on the main railway lines because it would ensure fast and effective "bringing" of the passengers to the main railway stations where fast trains stop. Thus, a considerable suburban passenger flow will be covered. The combination of this variant and variant 1 would guarantee significant cost-effectiveness.

Variant 4 – Renewal of the rolling stock of suburban trains on the branches of the main railway lines. This variant can be implemented successfully by redirecting part of the existing electrical multiple unit (EMU) trains with good in-service characteristics from suburban lines to the main railway lines, after implementation of variant 3. It should be born in mind that as far as branches of the main railway lines are concerned, it is necessary to improve their technical condition in order to achieve the planned speeds. An advantage of the variant is that with some suburban transportation on branches of the main railway lines, there is the possibility to attract considerable passenger flow. In spite of that the cost-effectiveness of purchasing a completely new rolling stock on these lines would be comparatively low.

Variant 5 – Renewal of the rolling stock in regional transportation and transportation on sections of railway lines with low passenger flow. Due to the low passenger flow this variant would be effective only in the case of purchasing rolling stock of low passenger capacity (one-wagon EMU type). However, there are doubts about how effective investment would be. This variant can also be implemented by redirecting EMU trains from suburban transportation.

It should be pointed out that the proposed variants are not alternatives to one another. What needs to be done is to find and justify the best combination among them, which, on the one hand, will attract additional passenger flow and, on the other hand, will make it possible to improve the cost-effectiveness of transportation.

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EVALUATION OF THE PLACE OF RAILWAY TRANSPORT IN THE PROVISION OF TRANSPORT SERVICES IN BULGARIA

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Borislav ARNAUDOV [3]
Tashko MINKOV [4]
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Abstract – *An evaluation of the state of the railway transport and its place in the transport system of the Republic of Bulgaria is presented. Major problems have been identified that lead to deterioration of the transport service and deter passengers from using the railway.*
The research was carried out as part of a task assigned to researchers from three universities. The aim of the task is to improve rail transport service in the Republic of Bulgaria by purchasing new rolling stock.

Keywords - railway transport, transport system, transport service.

1. INTRODUCTION

Railway transport is the main means of transport in all industrial countries in the world.

In 2017, a team of researchers from three higher education institutions in the Republic of Bulgaria was commissioned to justify the number and the main parameters of new rolling stock, which is to be purchased for the needs of "BDZ Passenger Services" Ltd. [1, 2, 3].

2. INDICATORS FOR EVALUATING THE PLACE OF RAILWAY TRANSPORT

In order to determine correctly the place of railway transport it is advisable that the evaluation is carried out using different indicators:

- Infrastructure
- Volume and mass of loads
- Travel time
- Cost of unit of work done
- Staff needed for unit of work to be done
- Environmental sustainability
- Safety and security

Analyses of data worldwide unambiguously show the advantages of waterborne and railway transport.

The European Commission has also noted this fact, and as a result a number of European documents ("Europe 2020" strategy and many other) have emphasized the priority development of these two types of transport. Thus, for example, the Roadmap of the EC (with an outlook of up to 2050), sets 10 goals in determining transport policy and puts forward a list with 40 initiatives for achieving these goals. One of the goals refers to passenger and freight intercity transportation and envisages:

- reducing the share of automobile transport so that 50% of all medium distance journeys are made by means of rail and waterborne transport;
- by 2030 30 % of road freight transportation over 300 km will be carried out by rail or water-borne transport, and by 2050 the figure will be 50 %;
- by 2050 most of passenger journeys over 300 km will be made by rail transport.

3. THE PLACE OF RAILWAY TRANSPORT IN BULGARIA

On the basis of official data we can establish the place the different types of transport in providing transport services in Bulgaria. The following data have been used for the period between 2000 and 2016:

- goods transported and work done by means of railway transport.
- goods transported and work done by means of

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automobile transport.
- loaded and unloaded goods in sea ports by directions
- loaded and unloaded goods in river ports by directions
- goods handled at airports.
- passengers transported and work done by means of railway transport.
- passengers serviced at airports.

On the basis of the data analysis the following statements can be made regarding railway transport:

1. For the period 2000-2016 the mass of transported goods by railway transport has decreased by 32,5%, and that of passengers by 67%.

2. The reduction of the "transportation work" indicator is respectively 48% for freight transportation and 68% for passenger transportation..

3. For the period 2005-2016 the market share of railway transport regarding the "mass of goods" indicator dropped from 10,56% to 7,43%.

4. For the period 2000-2016 the correlation of transportation work between railway transport and automobile transport changes from 1:0,78 in 2000 to 1:10 in 2016, i.e. there is a deterioration of more than 12 times to the detriment of railway transport.

5. With an improvement of the state of passenger transport it is possible to restore the number of passengers and the covered passenger-kilometres to the levels of 2000.

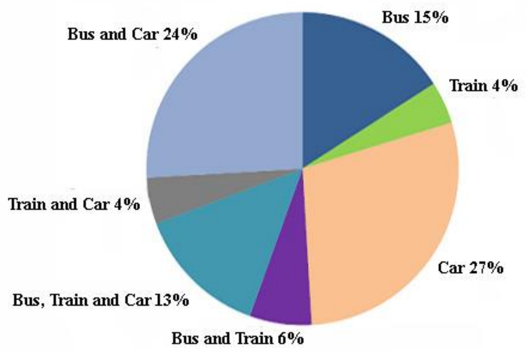

Fig.1. Relative share of passengers who use different means of transport

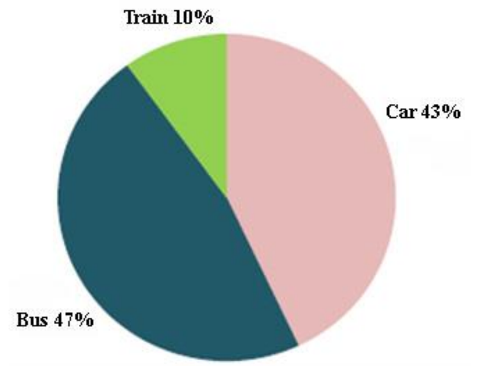

Fig.2. Relative share of passengers who use different means of transport on the basis of "number of journeys"

Fig. 1 and Fig. 2 show the results of a market study conducted by Noema company. The pie charts show: the relative share of the Bulgarian passengers who use different means of transport and passengers who use different means of transport on the basis of "number of journeys".

4. EXTERNAL TRANSPORT EFFECTS

The intensive development of automobile transport over the last few decades has led to changes in the market situation and the railway has found itself in an unfavourable situation. The governments and the society seriously support automobile transport covering a great part of the costs it incurs. Thus, these costs turn into external ones for it and it is becoming obvious that they will have to pay for these costs one way or another.

External costs are those costs, which go along with certain activity but are not covered completely by the people and organizations carrying out this activity. As they exist, they are covered by a third party and society as a whole. Apart from the fact that these costs are a burden for the society, they strongly distort the market situation as illustrated in Figure 3.

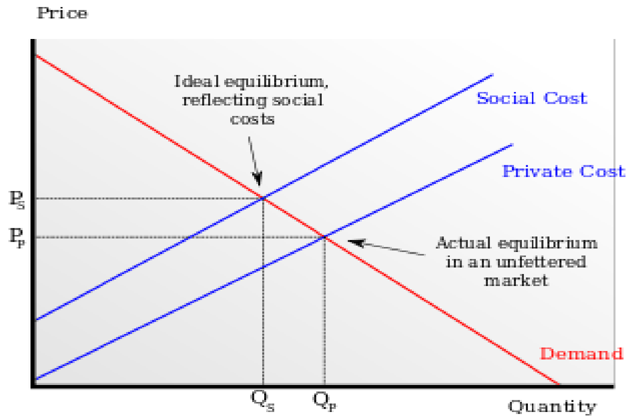

Fig.3. Distortion of market equilibrium with the availability of external costs

The demand and supply curves show that the availability of external costs leads to an overproduction of the product, which is ineffective for the society. In terms of the transport market that means we generate and use a lot more automobile transport services, and in this way it is not only the society but the railway, being its direct competitor on the market, that is, in an artificial way, put in an unfavourable situation.

The market is distorted mostly with passenger transport because it is not only artificially transferred to automobile transport, but is carried out mostly (over 75 %) by private automobiles.

Various methodologies for evaluating transport external costs have been developed and applied and they all have a common logic in determining and calculating external costs. According to them, the categories of external costs are generated by:

- construction and maintenance of infrastructure;
- global changes in climate;
- air pollution and harm to human health;
- noise generation in the environment;
- traffic accidents and incidents;
- traffic congestion and limiting the capacity of infrastructure.

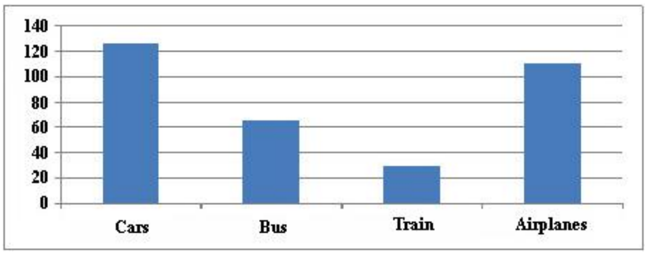

Fig.4. External costs for different kinds of passenger transport

The figure above shows that passenger railway transport has the lowest external costs as compared to all other competitors on the market - with bus transport they are twice as much. The calculations have been made with an average use of passenger capacity of trains. With a bigger volume of passengers, the effect is considerably greater. This all means that the state should carefully consider, evaluate and analyze its policy in supporting one or other kind of transport.

For the purposes of our analysis, we have examined the main railway lines in the country. On the basis of the external costs rates for 1000 *passenger km*, given by EEA and presented in the Figure above, we can estimate what approximately the effect would be if we increase the use of railway at the expense of all other types of transport. In this case, there are three possible variants:

- Variant 1 – railway transport increases the volume of transported passengers by 10%, and attracts passengers from bus transport;

- Variant 2 – railway transport increases the volume of transported passengers by 10% at the expense of private automobiles;

- Variant 3 – 50% of the increase of passenger kilometres for the railway is at the expense of bus transport and 50% at the expense of private automobiles.

The calculations based on the data about passenger flow in 2016, for the three variants presented above, are given in Table 1.

The best variant will be realized when there is a transfer of part of the passengers travelling by automobiles to trains. With only 10% increase of passenger flow, external costs, reduced public costs, for the above given five main tracks amount to over 17,5 million levs per year. The most realistic one seems to be variant 3 with which the effect would amount to 12 million levs yearly. If variants, where the percentage of transfer of passengers is higher, are adopted the effect of costs reduction would also be manifold. All that gives us enough reason to draw the conclusion that increasing the share of the railway on the passenger transport market will lead to great benefits for the society such as reduced costs and improved quality of life.

Tab.1. Costs reduced through the different variants of transferring passengers to railway transport

Railway line	**Passenger kilometres covered**	**Increase in transport by 10 %**	**Costs reduced, lv.**		
			Variant 1	**Variant 2**	**Variant 3**
Sofia - Svilengrad	144196554	158616209	1038215	2768574	1903395
Sofia – G. Oriahovitsa - Varna	337548282	371303110	2430348	6480927	4455637
Sofia - Plovdiv - Burgass	227186612	249905273	1635744	4361983	2998863
Sofia – Pernik - Kulata	91038553	100142408	655477,6	1747940	1201709
Sofia – Mezdra - Vidin	120864481	132950929	870224,3	2320598	1595411
Total	920834482	1012917930	6630008	17680022	12155015

5. TRENDS AND PROBLEMS FOR PASSENGER RAILWAY TRANSPORT

Over the last twenty years railway transport has been systematically neglected and has not been modernized, which is the main reason why there is an outflow of passengers to automobile transport.

This disturbing trend related to the sharp decrease in work done in terms of passenger kilometres is the result of two main causes:

- non-loyal competition with automobile transport based on non-payment of the total costs. Automobile transport has been placed in a better position;
- bad condition of the railway track and rolling stock.

The main problems of the provided transport service are as follows:

- problematic access to information;
- unclear price-formation;
- problems with a reservation;
- conditions on the trains and in the stations;
- difficult access of disabled people to the

platform, to the station, to the facilities, to the trains;
- not taking into account multimodal transport – bad organization and management and lack of connection to other means of transport;
- delays;
- cancellation of trains without preliminary warning;

What is needed to solve these problems is investment, appropriate schemes to secure it and funding. These need to be used in several directions:
- improvement of the parameters of rolling stock;
- design, development and introduction into operation of information systems;
- analysis of the market to discover transport segments with good prospects;
- reevaluation and simplification of the tariffs and tariff policy of passenger railway carrier;
- development of a package of investment projects to implement these measures;
- development of measures towards a preparation of an overall transport scheme of its own buses and railway transport.

6. CONCLUSION

In determining the place of railway passenger transport in this country it was established that:
- for the period 2000 – 2016 there has been serious reduction in the number of passengers and transportation work.
- "external costs" with railway transport are: 2,2 times smaller as compared to bus transport and 4,2 two times smaller to transport by automobiles.
- the main problems, which lead to deterioration in the transport service and repel passengers from using railway transport.

In order for passenger railway transport in Bulgaria to be effective, in terms of its sustainable development, it needs to meet three basic requirements.

First, it must guarantee improvement of the quality of services provided and increase their volume and accessibility.

Second, not only an increase of passenger flow must be guaranteed, but also the largest possible increase in the quality of life of the society.

Third, the benefits of a passenger railway transport of better quality should be distributed among all social groups of the population, which concerns social sustainability.

Sustainable development requires a broader view of the priorities for the development of the railway, together with other means of transport, in order to find the best balance between the needs of the economy, the society and the environment. In view of the above the main concerns are:
- railways contributing to the economic prosperity of society by ensuring opportunities for the travel of more people thus minimizing the negative impact on the environment;
- railways, which are flexible enough to adapt and respond to social changes at the same time protecting the existing infrastructure and enhancing the possibilities for its prolonged use;
- railways, which are accessible and convenient to use. This can be achieved by guaranteeing the security, safety and reliability of transportation. These must be the main aspects to be considered in buying new rolling stock.

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Other Railway aspects

STRUCTURE GAUGE REPRESENTED AS A BIM MODEL

Darja ŠEMROV [1]
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***Abstract** – Development of a fast, safe and efficient railway transport system requires adequate infrastructure. We need railway lines layouts where passengers do not feel uncomfortable in the curves, as we need such elements of the profile where trains can successfully overcome ramps and that they can safely stop. We also need effective signalling and safety devices and we need high quality and well-maintained wheels-rail contact to operate the trains. As the train occupies all three dimensions in the space, beside the line it travels on, it also needs sufficient width and height, which define suitably selected envelope profiles for the railway line. The envelope profile of the railway line is limited. The rail track rectangular plane, which must remain free of all objects, since it requires trains to run along the track without the danger of colliding with objects along or above the track. As we have different trains, we also have various envelope profiles. These envelopes are not linked to a specific vehicle, but are standardized so that traffic of all passenger and freight trains is possible through it. The envelope profile can be either calculated according to the given railway line geometry, or it can be upgraded into a graphically represented 3D model of the envelope profile. The latest being of a significant importance when doing BIM (Building Information Modelling) design which enable new analyses possibilities of the planned geometry. Verification of possible collisions with objects along the line or above it (overpasses) and combining models of planned railway infrastructure with the remaining infrastructure. The paper is describing the procedure for determining the envelope profiles defined by the UIC code 505-4 OR, in connection with latest BIM design and analysis requirements.*

Keywords – railway interoperability, gauge, kinematic reference profile, UIC CODE 505-4 OR, 3D BIM structure gauge, envelope clearance model.

1. INTRODUCTION

In Slovenia, railway lines, thanks to the Austrian Empire, were built very earl; the first railway line was built already in 1846, when Celje and Graz were connected with so-called Southern Railway. In 1944, the Germans built a second track from Zidani Most to Zagreb and since then the course of Slovenian main railway lines has remained the same. At the time when first railway lines were planned and built, one did not think about single (unified) European market, uninterrupted cross-border freight and passenger transport, and interoperability. Due to the technology of construction, they were faced primarily with the challenges of where and how it would be possible to route the railway infrastructure to establish efficient railway network. Prime goal of railway network of individual country was to provide access to major cities as well as access to main ports, thus enabling the import and export of goods and raw materials for industry. The connections between countries were not a priority, they were created spontaneously. In Western Europe, the idea of a unified system of international transport corridors came to life in late eighties, within the so-called "Single network for the single market" idea. This idea led to the creation of a Trans-European transport network names TEN-T network.

European Union [1] defined functions that TEN-T network must fulfil, namely:

- play an important role in long distance passenger transport,
- enable connection with airports,
- provide access to regional and local railway networks,
- promoting freight transport by defining and developing main lines for freight transport or establish railway lines where freight transport has higher priority,
- play an important role in combined transport
- connect maritime ports with inland waterway on short distances.

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The rail network in TEN-T network must fulfil at least one of above-mentioned functions.

2. INTEROPERABILITY OF RAILWAY SYSTEM

From the very beginning, one of the main obstacles achieving an efficient, complete, and competitive Trans-European rail network was a set of technical and safety regulations that were adopted at the level of individual countries, thus preventing the unhindered flow of goods and passengers. Therefore, in 2004 European Union stated that the most important requirements and technical characteristics of the railways would be covered by the directives on the interoperability of the Trans-European railway system. The European Parliament has adopted a number of directives in the field of interoperability, initially separately for high-speed lines and separately for conventional speed lines, which were subsequently merged into a common text – Directive on the interoperability of the rail system [2, 3]. The Directive aims to:

- establish a common approach to interoperability and safety rules to increase economies of scale for railway undertakings operating in the EU,
- decrease administrative costs,
- accelerate administrative procedures and avoid disguised discrimination,
- expand the European Union Agency for Railways' powers.

The Directive divide the rail network into subsystems (structural areas: infrastructure, energy, trackside control-command and signalling, on board control-command and signalling, rolling stock, other (movable) railway material, and functional areas: operation and traffic management, maintenance, telematics applications for passenger and freight services). Each of the subsystems shall be covered by one technical specification of interoperability; and subsystem shall comply with the technical specifications in the force.

Technical specifications for interoperability (TSI) relating to the infrastructure subsystem of the rail system are adopted with Commission regulation (EU) No. 1299/2014 [4].

Following the goal to uniform rail system within European Union, the TSI indicates basic parameters for following aspects of the infrastructure subsystem:

- line layout,
- track parameters,
- switches and crossings,
- track resistance to applied loads,
- structures resistance to traffic loads,
- immediate action limits on track geometry defects,
- platforms,
- health, safety and environment,
- provision for operation,
- fixed installations for servicing trains.

The gauge (gauge relates a reference profile in which govern the positioning of fixed objects and the distance between track centre lines) is one of five main performance parameters of TSI categorization and it directly control the trains that may run. Gauge is also important aspect, namely basic parameter of line layout, track parameter, and platforms aspects of the infrastructure subsystem.

3. GAUGE

Gauge is limited, on rails perpendicular surface in which must be free of signal equipment, devices, and other objects. International classification differentiate several different gauges, namely G1, G2, GA, GB, GC, GB1 and GB2, where G1 is the minimum gauge that should be implemented on all lines, other are enlarged and implemented in well-defined routes.

Reference profile is a base for the calculation of gauges. Reference profiles can be static, dynamic and kinematic. Existing Slovenian legislation defines profiles, where dimensions of uniform structure gauge in two border situations, namely in straight cant-free track, and in small (minimal) radius with maximal possible cant deficiency are considered. According to Standard 15273-3:2013 the static method can be used only for specific, non-interoperable applications. On interoperable networks, kinematic method based on kinematic reference profile and calculation method in Standard EN 15273-3:2013 [5] should be used. Rules covering the kinematic reference profile to determine clearance gauge take account of:

- allowances M1 that covers all random movements resulting from the movement of vehicles; these are movements due to the asymmetrical distribution of the tire, the unbalance of the suspension of the vehicle, and the effect of the transverse oscillation of the vehicle due to the dynamic interaction between the vehicle and the track, as a function of track quality and speed;
- allowances M2 includes movements due to faults in the elevation of the rails and the movement of the track layout between two maintenance cycles;
- allowances M3 is determined by the operator if necessary.

For each of the gauges, different structure gauges types can be calculated, depending on the required application, namely:

- structure verification limit gauge (minimal requirements),
- structure installation limit gauge (clearance is maintained between the various maintenance

operation),
- structure installation normal gauge (clearance is maintained in particular (extreme) conditions, e.g. heavy side wind).

Beside the kinematic reference profile and calculation, methodology to determine gauges, the standard also lists the rules to determine distance between the track centres, list the rules to be complied when building the platforms, and lists the rules to determine the pantograph gauge.

The calculation of structure gauges should be calculated for different cross sections (change in radius, speed, different conditions of the infrastructure …).

4. STRUCTURE GAUGE AS BIM MODEL

As number of clearance gauges can be evaluated on given track geometrical data for each curve and tangental sections, which include:
- maximim construction gauge,
- kinamatic gauge reference profile,
- rolling stock kinematic gauge,
- clearance gauge for lineside structures,
- raiway specific margins (exceptional loads, incresed speed etc.),
- and others.

Significant effort is required to provide horizontal and vertical limits on various points of interest along the rail track in order to define relative reference profiles on given geometry. Therfore the use of modern rail track design solutions provide instant structural gauge calculation options which is calculatred based on given 3D rail track geometry in every required point, cross section or profile. Furthermore structural gauge calculation can exceed standard horizontal and vertical gauge limits calculation as they can be represented and analysed as 3D kinematic gauges. These enable qualitative supervision options in relation to sidetrack objects, parallel and adjacent side railtracks, structures (tunnel, bridge …) and other side track objects.

More, structural gauge calculation plays significant role in analysing existing/exploatated rail tracks where rail track movements have been surveyed and track imperfections taken in consideration. With use of such survey data, rail track design solutions provide extensive analitycal tools to check unperfect rail geometry againts side track objects in most demanding situations on curves in tunels, on bridges, platforms and other.

Sigificant upgrades of existing rail tracks acording to required elictrification needs for example – taking in consideration the needed vertical space for pantograph for example, can be made much faster and more effective with automated software design and rail track maintenance tools as new requirements can be processed faster and results inspected sooner among various infrastructure stakeholders.

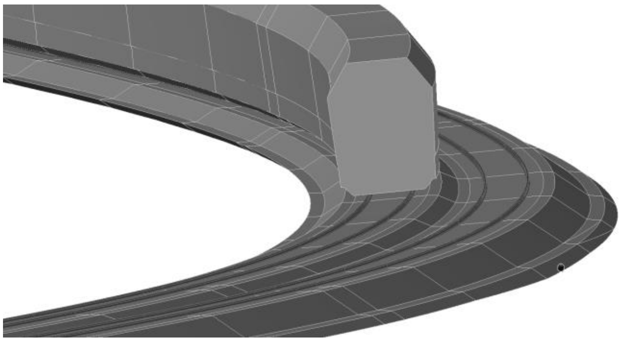

Fig.1. Desired 3D gauge created with rail design software solutions

With efforts of BuildingSMART [6] organisation, an initiative to provide world wide openBIM standards, extensive work has been put in recent years in rail sector to define its challenges and colaboration possibilityes to mitigate modern interoperability expectations.

Based on openBIM standards and its colaboration file format exchange definition (IFC) [7] 3D structural gauges calculated with various software solutions can be seamlesly upgraded from 3D geometric representation to fully supported BIM model wich enables extensive collaboration options like:
- Stractural gauge caclulation data exchage with different software vendors or solutions,
- Federate projects with different design disciplines rail track geometry design, bridge design and tunnel design, telecomunications, rail signaling design but also nearby road design, overpases, level crossings etc.,
- Open data exchange usage in rail track life cycle maintenace projects.

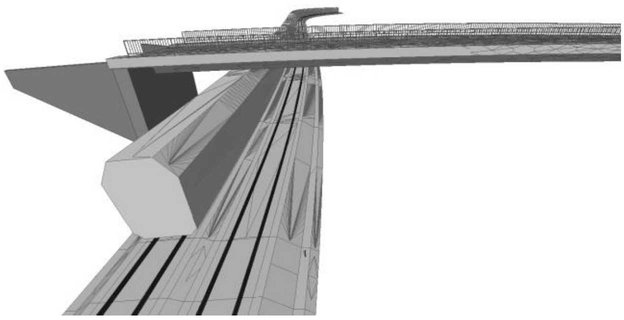

Fig.2. 3D gauge exported to IFC format and federated in one view together with road and bridge design objects

5. KOSANA RAIL STATION EXAMPLE

Great examle where software gauge calculation and analysis should be used is Košana rail station in Slovenia. Košana rail station is positioned in a curve wih 302 m radii and a platform for passengers positioned on the outside of railway track. When build in 2011, although being build based on all required design parameters and passing supervision overview with no restraints, the use of rail station after its commision proved to be challenging for passengers getting on/off the train.

Fig.3. Košana rail station, Slovenija, placed in a curve with 302 m radius with 110 mm applied cant

This problem proved esspecially difficult with the use of newest passengers trains which doors are located in the middle of the vehicle. Thus resulting the distance between platform and the door opening exceeded 45 cm.

Fig.4. Košana rail station: distance between rail platform and passengers vehicle door opening

Using BIM technologies in the design process and using 3D federated model analysis possibilities would clearly expose problems, which were noted only after the construction of the rail station was finished. Since current European legislation enables detailed calculation of the position of trains taking into account several train and track characteristics its implementation in modern design solution would empower various project stakeholders (investors, designers, supervisors, contractors...) to be aware of possible design shortcomings at early stage. Costs for correcting existing situation in Košana proved to be unfeasible after project completed and train station remains in use despite its usability inadequacy for passengers.

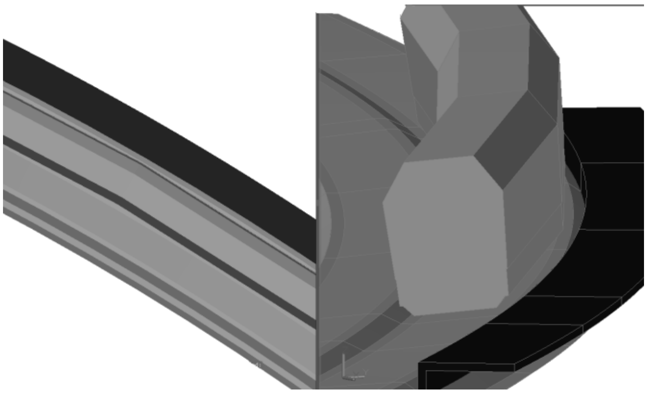

Fig.5. Plan (2D) and 3D model analysis possibilities using BIM design models

6. CONCLUSION

Full implementation of techical specifications and regulations in contemporary software solutions for design and rail track maintenance analysis with support of the openBIM standard definitions for collaboration and data exchange possibilityes, among various rail disciplines and other infrasctructure industries (road, river canal, powel line, pipes etc, building …) should provide qualitative decisions regarding common Europian rail track system development and its endeavour for interoperability.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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DEFINING THE PARAMETERS FOR SAFETY MANAGEMENT IN TRANSPORT OF DANGEROUS GOODS BY RAIL

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Abstract *– The transport of dangerous goods by rail, which in principle encompasses packaging, marking, loading, transportation and unloading, is provided by a service which safety is conditioned by numerous parameters. The safety of the transport of dangerous goods by rail depends on the fulfillment and implementation of the established rules by all participants in the transport process. Such a transport process itself implies certain risks for the safety of people, property, infrastructure and the environment. Apart from the characteristics of dangerous goods, the risk is also influenced by the process of realization of the elementary activities of the transport process. Adequate management of the safety process for the transport of dangerous goods by rail should therefore to include the assessment of safety risk by defining preventive measures, monitoring activities to meet transport safety requirements, operational undertaking of corrective measures, analyzing and assessing the safety state of implemented transport process and taking the necessary corrective management measures. In order to realize such concept in the thesis will be shown a way of defining the necessary parameters for managing the safety of the transport of dangerous good by rail.*

Keywords – Dangerous goods, Safety, Risk, Parameter, Management.

1. INTRODUCTION

The process of dangerous goods transport by rail is the sequence of, most often connected, activities where dangerous goods are carried - moved from one place to another by means of transport units (wagons and locomotives and transhipment mechanization), staff and railway communications – railway line and the accompanying infrastructure elements. In principle, it involves the activities of packing, marking, loading, transport and unloading of dangerous goods. Transport of dangerous goods by rail is subject to the terms and conditions defined under Annexes A and B of RID [7], in conformity with the requirements of the Law on the Transport of Dangerous Goods [8] and subordinate legislation passed under this Law.

About 16% of dangerous goods are transported by railway line. According to the statistical data, the greatest amount of transport of dangerous goods consists of flammable liquids, about 70% of the total volume of the dangerous goods transports.

Transport of dangerous goods is a process with increased risk due to the presence of numerous potential hazards to people, property and the environment, which are especially expressed in case of an emergency events or any other failure to observe the requirements arising out of international and national regulations governing the transport of dangerous goods by rail. The very tendency to minimize the risks against an emergency event and ascertain safe transport of dangerous goods by rail imposes a number of restrictions and/or stipulated rules and conditional procedures to all participants of the transportation process.

Transport and handling of dangerous goods are significantly different from the procedures with other types of freight. The consequences of emergency events indicate to the necessity for risk assessment in case of the transport of any dangerous goods. The basic rule is that the transport of dangerous goods is forbidden unless performed according to the terms that are accurately prescribed under the national legal regulations or ratified international agreements. Such rule suggests that the process of dangerous goods

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transport cannot take place without knowledge of the terms and conditions according to which it is feasible.

For these reasons, all participants in the process of dangerous goods transport by rail need to be trained for the jobs they perform, which is also provided for by the legal provisions.

2. SAFETY MANAGEMENT PARAMETERS OF THE TRANSPORT OF DANGEROUS GOODS BY RAIL

Safety of the transport of dangerous goods by rail means the performance of the service of dangerous goods transport. It can be and has to be managed. Considering that safety of the transport is conditioned by the manner in which particular activities are executed by every participant in the transportation process, their mandatory actions can be singled out as management parameters. Basically, they are the parameters, elements or factors of safety. Having in mind the nature and specificity of the process of dangerous goods transport, the parameters defined in such a manner are the basic lever for the transport safety management.

The process of dangerous goods transport is decomposed into the following activities: packing, loading, filling, dispatching, transport, acceptance and unloading. In the sources [7, 8] that are relevant for the field of dangerous goods transport, the basic and elementary activities of the process of dangerous goods transport are mentioned, therefore, based on that, meeting of the following requirements can be deemed as the parameters for safety management in the transport of dangerous goods:

- classification, acceptance and transport of dangerous goods according to RID,
- providing the required data, information, transport documents and accompanying documents,
- use of allowed and suitable packaging for transport of dangerous goods,
- proper marking of the packaging with dangerous goods,
- compliance with the requirements on the manner of dispatching and forwarding restrictions of the consignment of dangerous goods,
- proper marking and labelling of loaded rolling stock and transport units with hazard labels, orange-coloured plates and necessary markings;
- Visual ascertainment that wagons, transport units or dangerous goods have no obvious defects,
- verifying that the requirements related to packing, loading, unloading and handling are met,
- compliance with the requirement which forbids mixed packing,
- ascertaining that the deadline for the next test for tank-wagons has not expired,
- verifying that the wagons are not overloaded,
- ascertaining that the equipment prescribed in the instruction is in the engine driver's cabin,
- ascertaining that the train staff is aware of the loaded dangerous goods and their position on the train,
- absence of deferment in acceptance of the goods without compelling reasons,
- in case of determined deficiencies and irregularities, ascertaining that unloading is not carried out until appropriate measures have been taken,
- before or during unloading, checking whether the packaging, the tank, the wagon or container have been damaged to an extent which would endanger unloading operation,
- checking the compliance of the unloaded dangerous goods with indications in the transport documents,
- during unloading, checking for possible damages of the packaging, the goods and transport means,
- removing of any dangerous residues which have adhered to the outside of the tank, wagon or container during the process of unloading,
- checking of the closure of valves after unloading of the tank, inspection of the openings, degree of closure and tightness of empty and uncleaned tanks,
- ensuring that the prescribed cleaning and decontamination of the wagons and containers is carried out,
- ensuring that hazard labels, orange-coloured plates and necessary markings on the empty and cleaned wagons and containers have been removed or covered.

Breach of the aforementioned parameters and/or failure to meet the prescribed and established compulsory requirements endanger the safety of dangerous goods transport by rail, thereby imposing the need for safety management.

3. SAFETY MANAGEMENT OF THE TRANSPORT OF DANGEROUS GOODS BY RAIL

Safety management of the transport of dangerous goods by rail has to begin with designing and implementing of the necessary preventive measures, which have to be the result of adequate safety risks management (Figure 1).

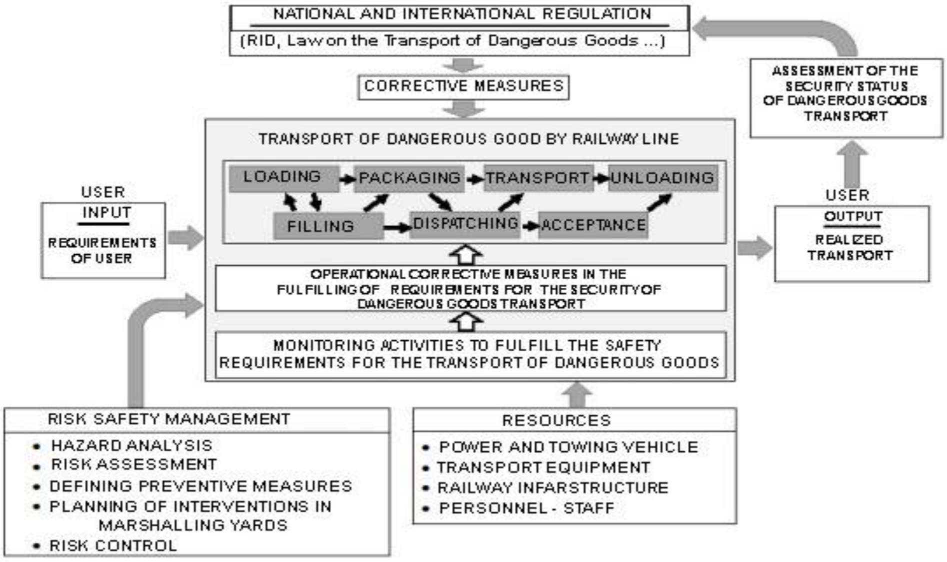

Fig.1. Safety Management of the Transport of Dangerous Goods by Rail

During realization of the transportation process, from its beginning to the final activity, compliance with the prescribed obligations and/or requirements is monitored. As such, due to various objective and subjective circumstances, there may appear some minor or major deviations and/or non-conformities, which can endanger the safety of transport of dangerous goods.

After the failures (deviations from or non-conformity with the requirements) have been observed during realization of the transportation process activities, the process participants - decision-makers and direct executers are warned against the failures and thus appropriate corrective actions are systematically prescribed with regard to the specificity of the transportation process, potential dangers and possible risks to safety, they have to be implemented and/or dealt with immediately.

Hence, after performed transport of dangerous goods, the safety status is analyzed and assessed and the extent of conformity with the requirements arising from the national and international regulations is reviewed. Based on the results of conducted analysis, possible weaknesses are determined and necessary management corrective actions are defined and they should result in improvement of the overall safety of the transport of dangerous goods by rail.

The safety management system of the transport of dangerous goods by rail should pay particular attention to preventive measures in order to avoid the hazards and probable adverse consequences. Thus defined, the prevention implies management of the risks which cannot be completely eliminated and which inevitably exist as constant follower of all activities. The process of the transport of dangerous goods by rail is accompanied by the risks related to the sources of threats to health and life of the rail employees (professional risks) and the threats for occurrence of an emergency events in traffic, chemical incidents, fire and explosion (ecological risks).

Presence of the threat means that during the transport of dangerous goods by rail exist real risks that endanger people, material properties and the environment. Prior to the transport, it is necessary to estimate the risks and establish the preventive measures and protective measures, as well as the disaster preparedness measures, the response to an emergency event and recovery from its consequences, in the light of all established hazards. These activities are, at the same time, the fundamental principles of risk management. In principle, risk management consists of risk analysis and control, where the analysis has to comprise hazard analysis, risk assessment, decision-making of risk acceptability and prescribing of preventive measures [9].

4. CONCLUSION

Significant quantities of dangerous goods are transported by the railway transport. Transported dangerous goods, in their nature, impose numerous potential risks to health, property and the environment, which together with potential emergency events and a number of nonconformities by the participants in the transportation process make it a risky process. The greatest number of failures refer to nonconformity with the requirements defined in the relevant international and national regulations. The resulting conclusion is that there is a need for appropriate qualification of all participants in the transportation process. The qualification should be foreseen in such a manner so as to ensure a training which result is connected with the requirements imposed by the transport of dangerous goods in the scope of particular work obligations, responsibilities and competences of the participants in the transportation process.

The primary objective in realization of the process of dangerous goods transport by rail has to be its accurate development under maximum security to people, property, environment and the transported goods. To achieve such objective, it is necessary to establish the safety management system of the transport of dangerous goods by rail as one of the vital performances of the transportation service.

The basic management parameters in the proposed model for safety management of the transport of dangerous goods by rail are prescribed, required mandatory procedures of all participants in that process, that are also the principal factors of safety and security.

The proposed model consists of four basic steps:

- designing and implementation of the necessary preventive measures aimed at avoidance of the risks and potential consequences, which have to be the result of adequate safety, risk management. The prevention interpreted in that way means the management of the risks which cannot be completely eliminated and which inevitably exist as constant follower of all activities,
- Monitoring of the fulfilment of prescribed obligations and/or requirements of the regulations that govern the transport of dangerous goods by rail, by all participants in the transportation process, determining of nonconformities and taking of the necessary operative corrective measures.
- Analysing and estimation of the safety status of realized transport, and
- Projection and taking of the necessary management corrective measures.

If all participants in the process of the transport of dangerous goods by rail, rail official personnel and personnel of the railway infrastructure manager make their greatest efforts in monitoring, implementation and fulfilment of the prescribed requirements, then satisfactory results concerning transportation safety may be expected.

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SOFTWARE MODULE FOR THE VISUALIZATION AND PLANNING OF MARSHALLING YARD OPERATIONS

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Aleksandar MILTENOVIĆ[3]
Milan TRIFUNOVIC[4]

Abstract *– Software solutions applied for the management of the marshaling yards are important elements of today's freight transport. There are various software applications developed for real time management of marshalling yard, and, usually, module for the visualization and planning of yard operations and infrastructure, is included. This module enables yard operators to perform wagon classification and other operations, by using supplied software tools. Generally, the process is not fully automated, and it requires a lot of experience from the users of the system. In order to propose a new approach to the visualization and planning of marshalling yard operations, novel software solution was developed. This solution includes optimization, and visualization and planning modules for automatic wagon classification in marshalling yard. The main ides is to create one smart and responsive automated system, which will improve yard operations, minimize user engagement, and therefore enable better freight transport.*

Keywords – Software, Marshalling yard, Visualization, UML, Database.

1. INTRODUCTION

Marshalling Yard (MY) is a complex system, and it contains many processes, which should be properly performed. The main processes in marshalling yard are: Pre-notification of incoming and outgoing trains, Arriving and checking incoming trains, Disaggregating/aggregating trains; Wagon shunting within the yard; Throwing wagon using the hump and/or the locomotive; Checking and departure outgoing trains. All processes mentioned above are standard processes and part of the standard and usual daily data flow [1,2]. The standard processes are automated on satisfaction level with various IT applications [2]. Regarding to that, the focus of research and innovation activities is on the providing adequate response on deviations from standard processes. The special attention is given to deviations of decision-making processes in marshalling yard. Different types of deviations are presented in [3,4] and can be summarized as the following:

Deviations of the incoming train – later (delay) or earlier than timetable plan; Deviations of the outgoing train - later (delay) or earlier than timetable plan; Deviations in personal resources – lack of train driver or other staff for operations in MY; Deviations in individual wagons modification; Unexpected repair or breakage of sections of rail line; Unexpected repair or breakage of wagons; Deviations or incorrect weight of incoming trains or wagons; Priorities in cases of congested infrastructure or other priority policies; Extraordinary requests; Not defined deviations

All deviations can be grouped related to four factors: time, the present state of infrastructure, personal resources and additional cargo operators' demands. The main factor is time and that is the reason why first two above deviations are also one of the consequences of all other deviations.

Each of these deviations has some own causes, consequences of deviations, decisions needed to be realized and consequences of selected decisions.

There have to exist the list of criteria for deviations because not all deviations should be taken into account as trigger inputs for SMART Real Time Management System (RTMY) starting and giving some optimal solution. Inputs can be inserted manually or automatically from existing IT system. In

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that sense, inputs and outputs are stored and exported in XML and JSON format. These formats allow easy adaptation for standard rail formats (e.g. RailML).

In general, developed software solution SMART Real Time Management System (RTMY) would give real time response to deviations, decrease time for making adequate decision by providing advisory system with optimal optional solutions based on selected criteria and optimization objectives. It will be beyond state of the art solution. In that sense, the role and the position of the SMART RTMY system regarding to existing IT applications, can be presented in Fig 1.

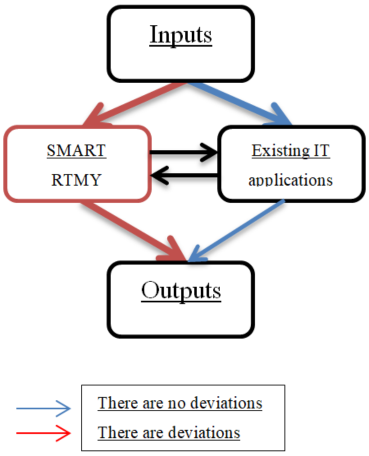

Fig.1. The role and position of SMART RTMY system regarding existing IT system in MY

2. DEVELOPED SOFTWARE SOLUTION

SMART RTMY is currently in development stage. Some features are created, and others are in the process of development. SMART RTMY in general, is composed of visualization and optimization module. Visualization module (presented in this paper) is used for data presentation, and optimization module is used for data processing. In order to properly define functional and technical requirements of the SMART RTMY, Unified Modeling Language (UML) is used. UML diagrams are created for all specific software requirements, and used for the development of visualization software module. As it has already stated, there are nine selected types of deviations in decision making processes in marshalling yards, and they can be described as use cases in UML. They are modelled and presented in Fig.2. There are many responsibilities of yard staff and they play significant role in the entire system. In order to demonstrate roles and responsibilities, some of them are modelled as Use case diagram and presented in Fig.3.

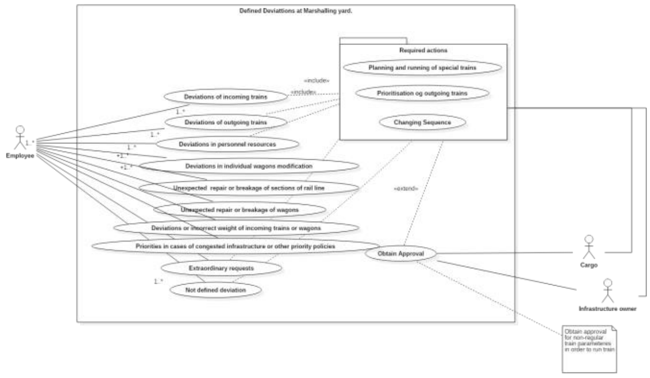

Fig.2. Use case diagram of all types of deviations in marshalling yard

Fig.3. Use case diagram of yard staff – roles and responsibilities

In order to properly model deviations and data included in marshalling yard management systems, relational database was created. Database structure was defined with separate tables for trains, wagons, sidings, timetable, traffic directions and users. Database is defined according to established static and dynamic parameters, presented in Fig 4 and described in [5]. The database was created and its logical schema is presented in Fig 5.

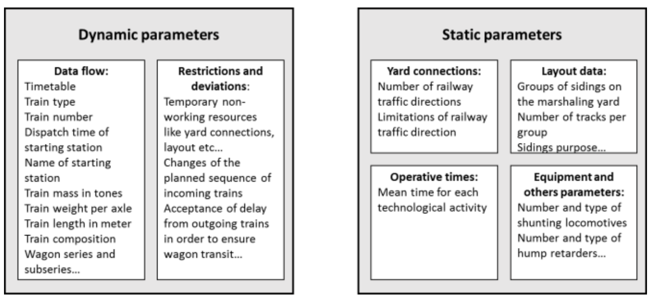

Fig.4. Parameters for real-time marshalling management

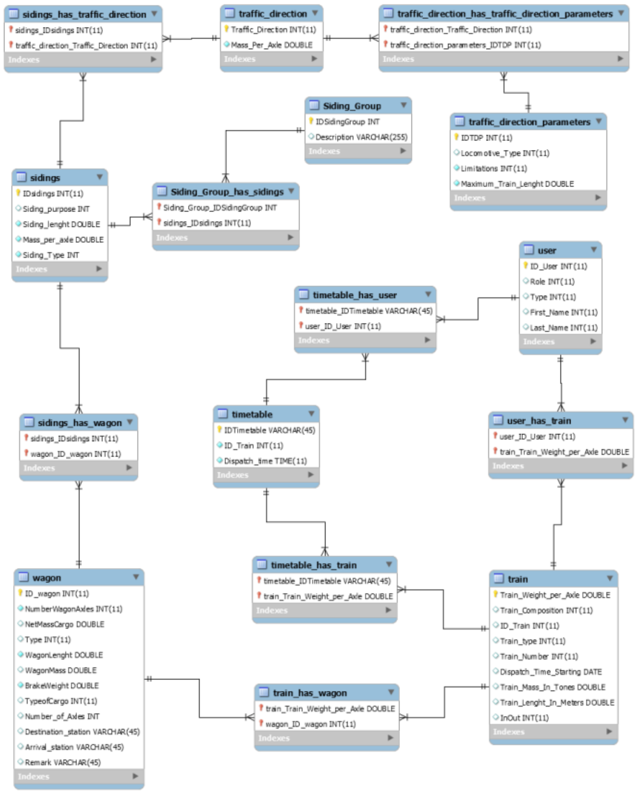

Fig.5. Database structure of RTMY system

This schema defines the structure of a Marshalling yard data model on which object model depends. Database structure and its logical schema includes all requirements and limitations that are restricting the use of freight transport in the marshalling yard as well as freight transport that is going to be processed in the marshalling yard. The defined composition of database, allow input and processing of all the described deviations and inputs or outputs. Static and real data from different marshalling yards was inserted to database, for further manipulation and processing.

2.1. Visualization and planning module

Visualization and planning module is currently in the last phase of development and it can display potential status of the marshalling yard to the user, based on data entered manually by the user, or acquired automatically from a railway information system. This module will also be able to display the future state (advisory proposition) of the marshalling yard based on input data and the outputs of the optimization module for specific occurred deviation. The methods used for modelling marshalling yards and inbound and outbound traffic information, as well as methods implementing the algorithm for optimal marshalling process planning will be extracted and encapsulated into a publicly available software library. This library will enable users to model their own marshalling simulation scenarios and perform marshalling process planning using the developed optimization algorithm outside of the information system for supervision and management of marshalling yards. Visual representation will be available for different kind of users, e.g. dispatchers. Visualization and planning process is shown in Fig. 6.

Based on the defined requirements, and module specifications, class diagram which defines module objects is shown in Fig.7.

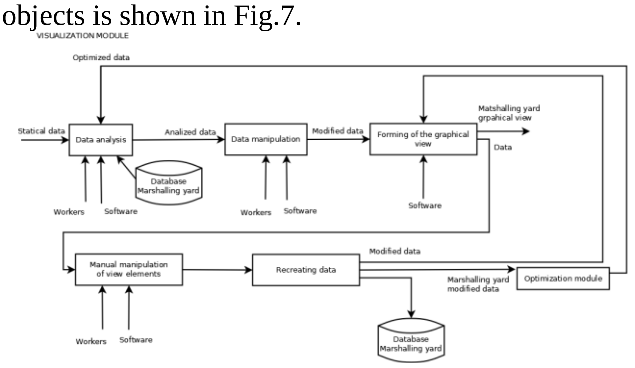

Fig.6. Process and data flow for Visualization and planning module

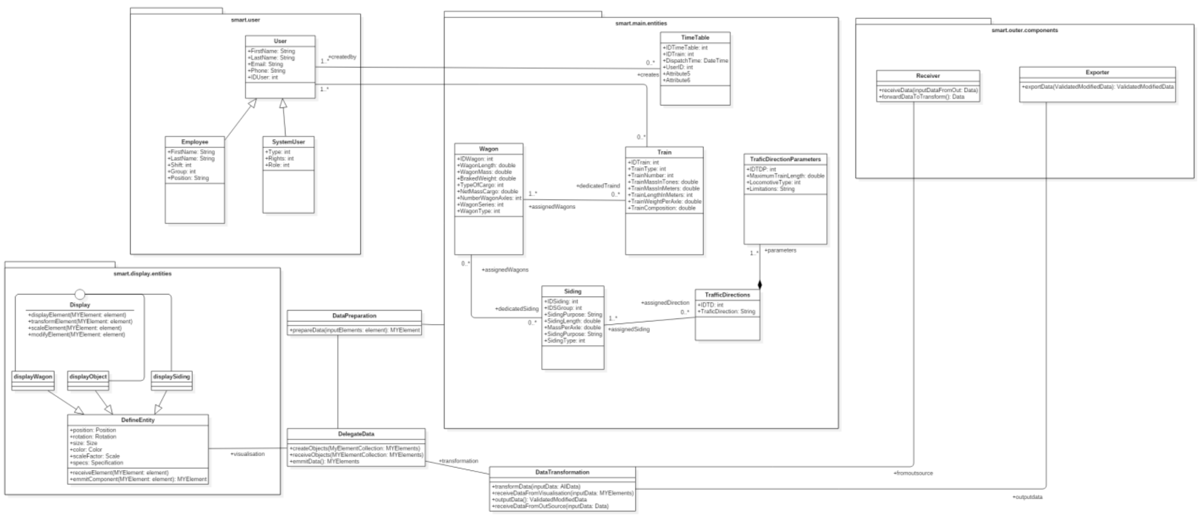

Fig.7. Class diagram of Visualzation and planning module

The module was developed by using following technologies: Front End – JQuery (standard, generally known JavaScript library) and D3.js (Data-Driven Documents); Back End – Currently php is used as main platform. The first version of RTMY Visualization module has already done and next three figures show some aspects of user interface of RTMY Visualization module. In Fig. 8 image of Popovac marshalling yard with defined infrastructure is presented. One solution for wagons classification in a case of time deviation is shown. Some aspects of visualisation module are presented in Fig. 9 and 10.

3. CONCLUSION

This software module presented in this paper is used for modelling input and output requirements, and for visualization and planning of marshalling yards operations. The special attention was dedicated to UML modelling of the visualization and planning processes and theirs realization. It can be concluded that modelled processes are complex, and that final claim about developed module can be made after the completion and integration with optimization module, which will be the next step in the SMART RTMY software system development.

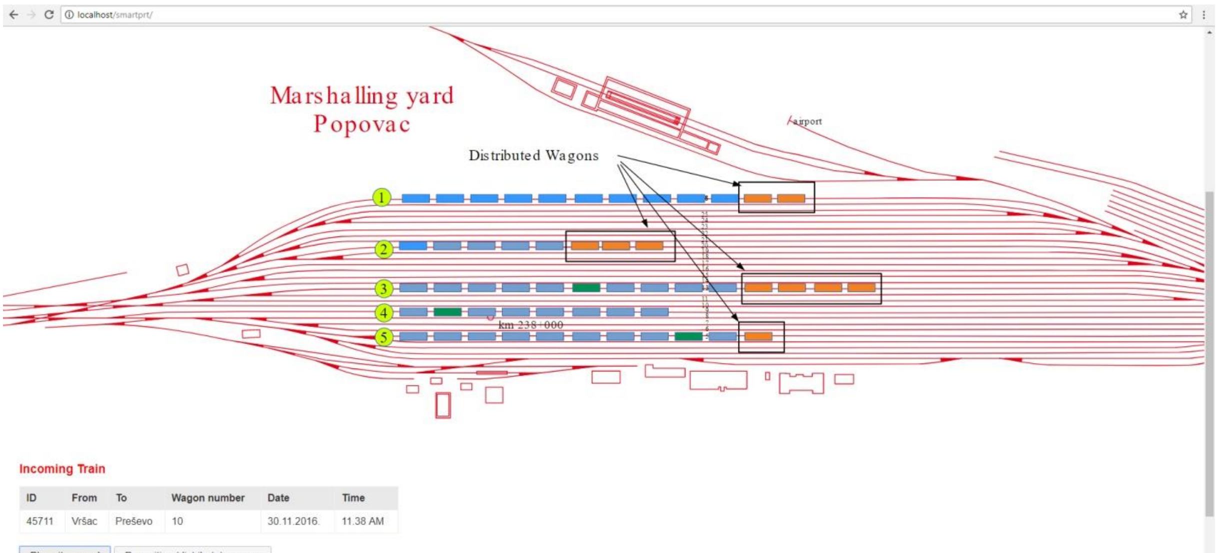

Fig.8. Visual representation of Wagon classification in Marshalling yard Classification bowl

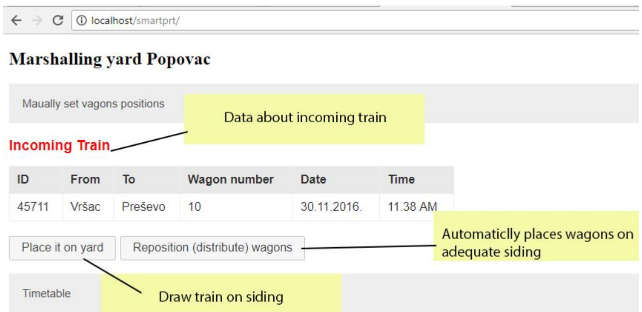

Fig.9. Visual representation of Incoming Train

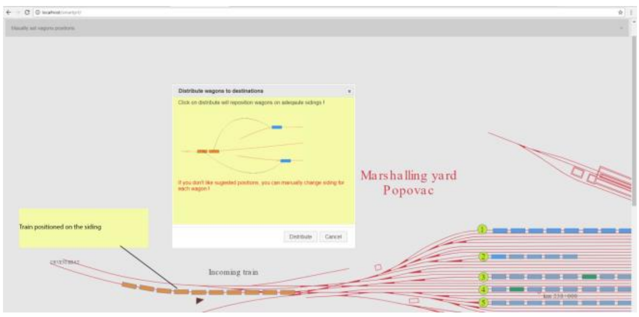

Fig.10. Visual dialog for wagon classification

The paper presents the case that resulted from application of the research project Smart Automation of Rail Transport (Project reference – 730836), H2020, founded by European Union.

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ANALYSIS OF THE DRIVER BEHAVIOR AT PROTECTED RAILWAY CROSSINGS

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Abstract *– Railway crossings create serious potential conflict points for collisions between road vehicles and trains producing one of the most severe in all traffic crash types. Driver behavior at railway crossings is the major collision factor. The purpose of the present analysis was to study driver behavior in railway crossings and to relate measures of driver behavior to variables believed to be associated with increased risks of accident***.** *Driver's behavior was observed in four different crossings, with driver head movements as the major dependent variable. This variable exhibits wide variability among drivers. Field data collection using video recording was conducted to measure driver behavior at crossings with different protection systems, namely: flashing lights/bell and half boom-barrier with flashing lights. This paper describes the field data collection and analysis and subsequently draws conclusions on driver compliance with respect to different types of protection systems. The results showed that many drivers turned their head to look for trains at railway crossings although the crossings were equipped with flashing warning lights or half boom-barrier.*

Keywords – railway crossing, protection systems, driver behavior, field survey.

1. INTRODUCTION

In several studies, aspects of driving behavior and attention during the approach towards railway crossings have been investigated in different settings and countries [1-3]. In Australia, an observational study by [3] observed driver's behavior at railway crossings with a focus on head movements that served as an indicator of the quality of the search for a potentially oncoming train during the approach towards a railway crossing. In Sweden, an observational study by [1] showed that many drivers turned their heads to look for trains although the crossings were equipped with flashing warning lights. He found no reason for this. However, upgrading passive crossings to active ones still seems worthwhile.

Measures of vehicle speed and of drivers' head movements at rail-highway crossings have been found to be highly interrelated with fewer head movements at higher speeds [4-5]. They have suggested that the development of vehicular speed profiles is an important variable to be considered in characterising driver behavior at crossings. The same relation between head movements and speed has also been observed in ordinary road crossings [6]. In the previous studies, the normal behavior of drivers at flashing-light crossings have also been reported to be very heterogeneous.

As restricted visibility, according to [7] is associated with increased risk of accidents, this factor was of specific interest. It was assumed that drivers might acquire information about trains, indirectly. by looking at the flashing lights and/or, directly, by scanning along the tracks at the crossing. It was also assumed that drivers are more or less motivated to acquire information directly as well as indirectly. At crossings where great efforts are required to look for trains because of for example, restricted visibility, the impulse to scan the track area will not be strong enough and the scanning behavior might not occur. One factor assumed to affect drivers motivation to acquire information at a crossing is their earlier experience of trains at that crossing.

The hypothesis of the present study, as suggested

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by earlier research, were first that different types of warning devices used at crossings significantly influence drivers' behavior. The second hypothesis is that the number of drivers who turn their head to look for trains will decrease with restrictions of the drivers' visibility at the crossings.

2. METHODOLOGY

In order to identify factors which influence driver behavior at active crossings, a video-based observations were carried out at four different railway crossings in railway transport of Powerplants "Nikola Tesla" doo Obrenovac - TENT were selected. Of the four different sites, three have half boom barrier and one flashing lights only. In one of these sites, the railway and the road ran parallel to each other before crossing. The visibility to warning devices at all the sites was adequate. Tab.1. summarizes the crossing characteristics, traffic and train volume for the four sites.

The video-based observations on all four sites were carried out in March and April 2018 during three days in 14 ours. The video images were replayed on a personal computer in order to compile data. The variables observed were driver compliance, driver head movements and estimated vehicle speeds (slow down, did not slow down).

Driver compliance of each vehicle to the warning devices at four crossing was recorded. For crossing with flashing lights and ringing bell, two categories of compliances were recorded: the vehicle stopped (comply); or drove through (non-comply). These two categories were also recorded for crossing with gates after warning devices had been activated. In the case of flashing light railway crossing where a total of 3.5 hours of video material was recorded in a sample of 46 road vehicles and six trains, irregular behavior (non-comply) was recorded in one road vehicle that passed 20 seconds before the train. In the case of half boom barrier crossings a total of 10 hours of video material was recorded. In the sample of 239 road vehicles and 29 trains, irregular behavior (non-comply) was recorded in one road vehicle which began to cross the track while the light signaling started, and crossed five seconds after the start of the half boom barrier descent.

Different types of warning devices used at crossings significantly influence drivers' behavior [8-10].

Tab.1. Specific characteristics of selected study sites

No	Railway crossing	Protection Systems	Number of tracks	Daily train volume	Traffic lane	Average Daily Traffic	Crossing Angle (°)
1.	km 7+709	flashing light	1	48	2	200-300	40
2.	km 5+413	half boom barrier	1	64	2	300-400	49
3.	km 13+810	half boom barrier	2	64	2	300-400	60
4.	km 26+700	half boom barrier	2	50	2	1000-1200	45

3. DATA ANALYSIS

The main dependent variable in the present investigation was driver head movements. Of all drivers, 66% looked to both sides before crossing. In Sweden, an observational study by [1] showed that many drivers turned their heads to look for trains although the crossings were equipped with flashing warning lights. He found no reason for this. The correlation between driver head movements and vehicle speed is significant. About the same percentage of drivers slowed down before crossing (63%) and looked at both sides (66%). Head movement behavior of these drivers and vehicle speed activity is presented in Tab. 2.

In the four railway crossings, 285 drivers were observed. The main results of the behavioral analysis are presented below.

Driver visibility

For each crossing and for each direction of travel the left side and the right side of the road were compared to each other with respect to restricted visibility. The railway crossing on km 5+413 has restricted visibility of one sight triangle on both side of crossing. Railway crossings on km 7+709 and on km 26+700 have restricted visibility on both side of crossing, two sight triangles on one side, and one on the other side. Railway crossing on km 13+810 is parallel crossing on one side of the road. On the other side, restricted visibility is in one sight triangle.

Tab.2. Percentage of driver's vehicle speed activity and head movements activity

No	Head movement and vehicle speed activity	Number of vehicles
1.	A total of drivers passed these railway crossings	285
2.	They slow down before crossing	179 (63%)
3.	They didn't slow down before crossing	106 (37%)
4.	Drivers looked to both sides	187 (66%)
5.	Did not turn their head at all	98 (34%)

A comparison was made between roadsides with restricted visibility and roadsides with unrestricted visibility. A total of 285 drivers passed these crossings and among them 98 did not turn their head at all. Remaining 187 drivers looked to both sides. In the direction where visibility was restricted on one side of 216 drivers passed, 76 (35%) did not turn their head at all while 140 (65%) looked to both sides. In the direction where visibility was restricted on two sides 69 drivers passed, among them 47 (68%) looked to both sides, while 22 (32%) did not turn their head at all.

According to Analysis of Variance (ANOVA) test $(F = 0.103, p = 0.778)$ the difference beetwen these two groups are not significant.

Half boom barrier crossing

One of the crossings investigated offered an opportunity to study effects of restricted and unrestricted visibility on driver search behavior. For a driver traveling through this crossing from the west side it was almost necessary to enter the track area to be able to look for trains. At the same time, a driver travelling in the opposite direction had unrestricted visibility to one side of the road. A diagram of the crossing is given in Fig.1.

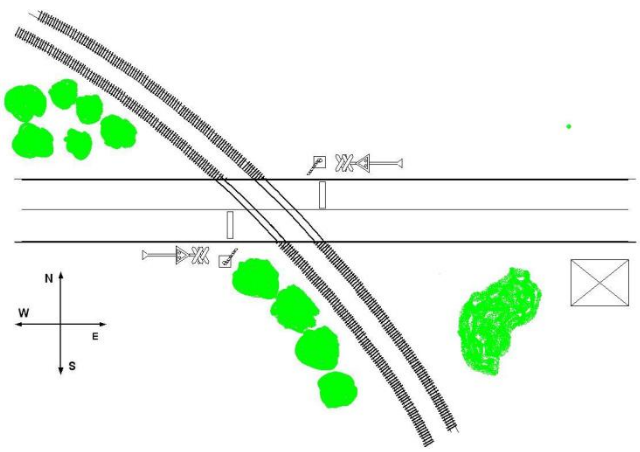

Fig.1. Diagram of half boom barrier crossing on km 26+700

Tab.3. Percentage of drivers with head movements at a railway crossing with unrestricted visibility in one direction of travel and restricted visibility in the opposite direction (km 26+700)

No	Head movement activity	Unrestricted Visibility on one side (Travel Direction E-W)	Restricted Visibility on both sides (Travel Direction W-E)
1.	Both sides	18 (55%)	25 (61%)
2.	None	15 (45%)	16 (39%)
3.	Number of observations	33	41

The geometry of this site allowed a comparison of driver behavior in one crossing and under different sight conditions. The number of drivers that were observed to turn their head to look along the tracks at crossing on km 26+700 is presented in Tab. 3. According to Analysis of Variance (ANOVA) test $(F = 0.711, p = 0.487)$ the difference beetwen these two groups is not significant. Results show that percentage of drivers who turned their head to look along the tracks when the visibility was unrestricted was the same as percentage of drivers who looked when the visibility was restricted.

Flashing light crossing

In the flashing light crossing investigated, the visibility is restricted in three of four sight triangle. For a driver traveling through this crossing from the north side the visibility is restricted on both side of road. At the same time a driver travelling in the opposite direction had unrestricted visibility to one side of the road. A diagram of the flashing light crossing is presented in Fig. 2.

Tab.4. Percentage of drivers with head movements at a railway crossing with unrestricted visibility in one direction of travel and restricted visibility in the opposite direction (km 7+709)

No	Head movement activity	Unrestricted Visibility on one side (Travel Direction S-N)	Restricted Visibility on both side (Travel direction N-S)
1.	Both sides	17 (94%)	22 (78%)
2.	None	1 (6%)	6 (22%)
3.	Number of observations	18	28

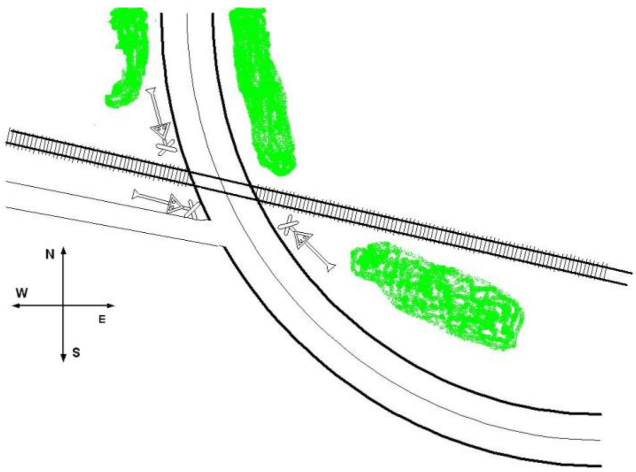

Fig.2. Diagram of flashing light crossing on km 7+709

Forty six drivers were observed driving in both directions at this crossing, while 39 drivers (90%) turn their head to look along the tracks on both sides. Head movement behavior of these drivers is presented in Tab. 4.

4. CONCLUSION

Results showed that many drivers turned their head to look for trains in railway crossings although the crossings were equipped with half boom barrier or flashing warning lights. Differences in looking behavior between flashing lights and the boom barrier are significant. On flashing light crossing drivers are more careful. Over 90% of the drivers slow down in front of the railway crossing, and looks at both sides to see if a train is arriving. On half boom barrier crossings drivers are much freer to behave. They have confidence in the warning devices, so almost 50% do not slow down and does not look along the track before crossing over. This is according with first hypothesis that different types of warning devices used at crossings significantly influence driver's behavior. This is supported with conclusion drawn in [9, 11] that different types of warning systems resulted in varying driver responses at crossings. According to [11] the compliance rate with boom barrier (77%) is slightly higher than with flashing lights (70%), although [12] found the opposite with drivers tending to commit more violations at gated level crossings compared to those with only flashing lights. These differences are thought to exist due to different localised site conditions, driver behavior and other environmental conditions.

The second hypothesis is that the number of drivers who turn their head to look for trains will decrease with restrictions of the driver's visibility at the crossings. Number of drivers who turned their head to look along the track when the visibility was restricted was not much different than number of drivers who looked when the visibility was unrestricted.

One factor assumed to affect driver's motivation to acquire information at a crossing is their earlier experience of trains at that crossing. For instance, familiarity with a crossing can influence driver behavior in a variety of ways. According to [13] noted in his Australian study that 85% of those killed lived locally and were familiar with the crossing. In the United Kingdom, [14] also found that the majority of drivers who violated activated warning systems were regular users of the level crossings.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

ANALYSIS OF THE LOAD OF THE RAILWAY LIFTING PLATFORM

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Abstract *– In this paper, a functional, structural and parametric analysis of the railway lifting platform is presented. In the second part of the paper, a mathematical model for analysis of the load of the railway lifting platform with the scissor concept is defined. As an example, an analysis of the load of the lifting platform which have 10.000 kg capacity, is given using the developed software.*

Keywords – Railway lifting platform, scissor mechanism, hydraulic.

1. INTRODUCTION

For installation and dismantling of a structural, drive and control modules of locomotives and wagons, lifting platforms of different concepts are often used. Among them, the lift platforms with a scissor mechanism are especially distinguished (Figure 1).

For the installation and dismantling of specific modules of locomotives and wagons, lifting platforms with one pair of scissor mechanisms (Figure 1a) are used, while lifting platforms with two or three pairs of scissor mechanisms (Figure 1b) are used to lift complete wagons and locomotives.

We can classify lifting platforms on mobile and stationary. If it is necessary to achieve a higher lifting height then the pairs of scissor mechanisms that are connected to each other are used.

They have simple construction, where the platform can be shaped according to the dimensions of the load.

Lifting platforms used in the railway industry are not part of the serial production but they are a product of special purpose for lifting heavy loads such as locomotives and wagons.

For rail transport functions the lifting platforms are used with two or more pairs of scissor mechanisms with a maximum load capacity of 10000 and up to 30000 kg and a lift height of 2 and up to 2.5 m.

World manufacturers of lifting platform are companies: Bolzoni, Hywema, Atlas.

The previous research of the lifting platforms relates to the dynamic stability analysis [1], the structural analysis of members of the kinematic chain [2], the optimization of the drive system [3], the numerical simulation of the platform's work [4] and the design of lift platforms [5-6].

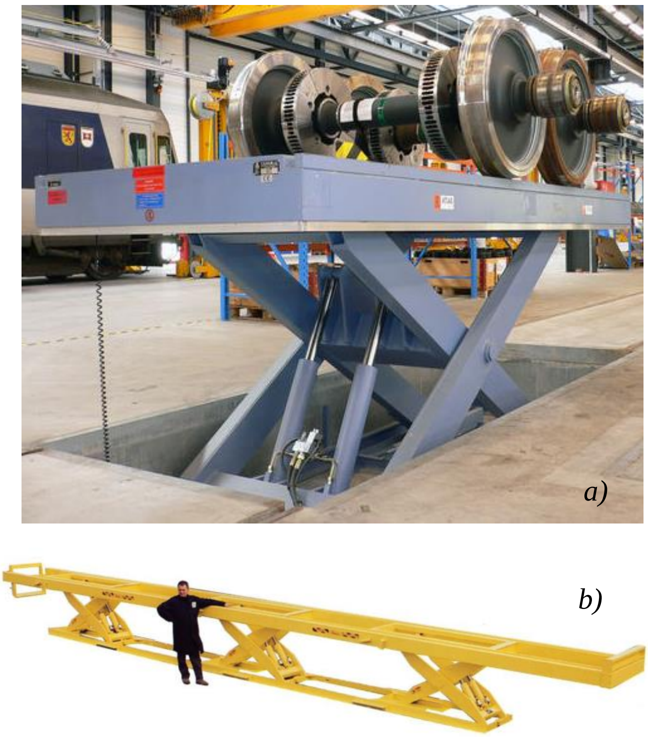

Fig.1. Lifting platforms with a scissor mechanism used on the rail

This paper analyzes the change of the maximum platform load depending on the lift height, which is important for the correct and safe use of the platform. For determination of the maximum load capacity in

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the entire platform raising range, it is assumed that the maximum pressure of the drive system acts in the hydraulic cylinders of the platform scissor mechanism.

2. MATHEMATICAL MODEL OF LIFTING PLATFORM

The general model of a scissor platform is considered with a kinematic chain consisting of: a stand (immobile or moving) L_1. Levers L_2 and L_3 are at the center of their kinematic length bound by the rotational joint O_{23}. The ends of the levers L_2 and L_3 are on the one side, with rotary joints O_{21} and O_{34} connected to the stand L_1 and the platform L_4, and on the other side, with the joints O_{24} and O_{31} for rolls that can freely roll on the tracks on the stand and platform.

Raising the platform is achieved by pulling out the most commonly one pair of hydraulic cylinders C_5, which is powered by, via the valves C_4, hydraulic pump C_2 driven by an electromotor C_1. The maximum pressure in the system is limited by the safety valve C_3 and the lowering speed of the platform is adjusted by the flow control valve C_6.

The assumptions of the platform's mathematical model are: members of the kinematic chain are regarded as rigid bodies; the platform's external loads are the gravitational forces of the load and members of the kinematic chain; friction in the platform's joints and rolling resistance in rolls is ignored.

In the mathematical model, the members of the platform's kinematic chain are defined, in their local coordinate system $O_i x_i$, with a set of parameters:

$$L_i = \{\mathbf{e}_i, \mathbf{s}_i, x_{ci}, y_{ci}, \mathbf{t}_i, m_i\} \qquad i = 1,....4 \tag{1}$$

where: $\mathbf{e}_i$ – is the unit vector of a rotary joint by which the member L_i is connected with the previous member L_{i-1}, $\mathbf{s}_i$ – is the position vector of the center of the joint by which the member L_i is connected to the next member L_{i+1}, x_{ci}, y_{ci} – coordinates of the position of the center of the joints in which hydraulic cylinders are connected, $\mathbf{t}_i$ – vector position of the center of the member mass, m_i – mass of a member.

Hydraulic cylinders, as a driving member of the platform scissor mechanism, have defined the sets of sizes:

$$C_5 = \{n_{c5}, d_{51}, d_{52}, c_{5p}, c_{5k}, \eta_{c5m}, \eta_{c5v}\} \tag{2}$$

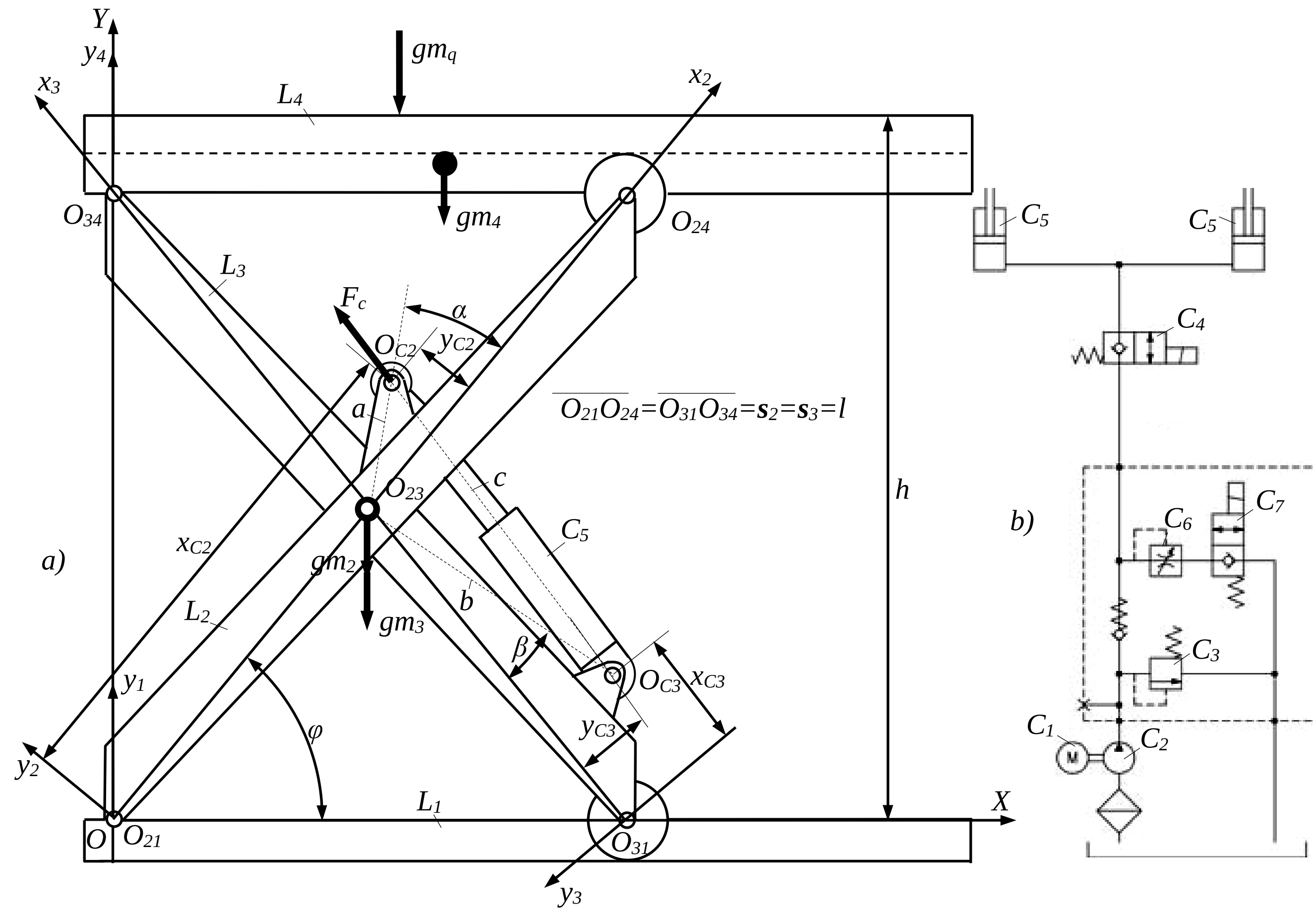

Fig.2. Model of lifting platform with scissor mechanism: a) kinematic chain, b) hydrostatic lifting system

Based on the presented physical model of the platform, a mathematical model was developed for determination of the platform load capacity depending on the lifting height.

where: n_{c5} – the number of hydraulic cylinders, d_{51}, d_{52} – the diameter of the piston and piston rod of the hydraulic cylinder, c_{5p}, c_{5k} – the initial and final length of the hydraulic cylinder, η_{c5m}, η_{c5v} – mechanical and volumetric level of efficiency of the hydraulic cylinder.

The possible load capacity of the platform - mass m_q, throughout the lifting range, is determined depending on the force of the hydraulic cylinder F_c using the principles of virtual works.

The principle of virtual works for the mechanical system of platform when the system is in equilibrium can be written in the form:

$$\Sigma\delta W = F_c\ \delta c - g\left(m_q + m_4\right)\delta y_{24} - g\left(m_2 + m_3\right)\delta y_{23} = 0 \quad (3)$$

where: δc - the virtual displacement of the hydraulic cylinder, δy_{23}, δy_{24} - the virtual displacement of the center of the joint O_{24} - the platform with the load and the joint O_{23} - the centers of the mass of the levers L_2 and L_3.

Force of hydraulic cylinder when lifting the platform:

$$F_c = n_{c5} \cdot \frac{d_{51}^2 \pi}{4} \cdot p \cdot \eta_{c5m} \quad (4)$$

where: p – pressure that act on hydraulic cylinder.

The length c and the virtual displacement δc of hydraulic cylinder is determined by the following equations:

$$c = \left(a^2 + b^2 - 2ab \cdot cos\left(2\varphi + \alpha - \beta\right)\right)^{\frac{1}{2}} \quad (5)$$

$$\delta c = \frac{2ab \cdot sin\left(2\varphi + \alpha - \beta\right)}{c}\delta\varphi \quad (6)$$

where: φ - the generalized coordinate of system - the angle of position O_2x_2 axis of the member L_2 in relation to the OX axis of the absolute coordinate system, a, α, b, β - the connection length and connecting angles of the hydraulic cylinder on the levers L_2 and L_3 that are defined by the following equations:

$$a = \left[\left(x_{c2} - 0{,}5 \cdot l\right)^2 + y_{c2}^2\right]^{\frac{1}{2}} \quad (7)$$

$$\alpha = arctg\frac{y_{c2}}{x_{c2} - 0{,}5 \cdot l} \quad (8)$$

$$b = \left[\left(0{,}5 \cdot l - x_{c3}\right)^2 + y_{c3}^2\right]^{\frac{1}{2}} \quad (9)$$

$$\beta = arctg\frac{y_{c3}}{0{,}5 \cdot l - x_{c3}} \quad (10)$$

Coordinates y_{23} and y_{24} of the joints O_{23} and O_{24} and their virtual displacements are determined by the following equations:

$$y_{23} = \frac{1}{2} \cdot l \cdot sin\varphi \quad (11)$$

$$\delta y_{23} = \frac{1}{2} \cdot l \cdot cos\varphi \cdot \delta\varphi \quad (12)$$

$$y_{24} = l \cdot sin\varphi \quad (13)$$

$$\delta y_{24} = l \cdot cos\varphi \cdot \delta\varphi \quad (14)$$

By changing the values of virtual displacements δc, δy_{23}, δy_{24} determined by equations 6, 12 and 14, in equation 3, the value of the load mass of the platform is obtained:

$$m_q = 2 \cdot F_c\ \frac{a \cdot b \cdot sin\left(2\varphi + \alpha - \beta\right)}{g \cdot c \cdot l \cdot cos\left(2\varphi + \alpha - \beta\right)} - \frac{m_2 + m_3 + 2m_4}{2} \quad (15)$$

On the basis of the defined mathematical model, a program for the analysis of the change in the load capacity of the platform has been developed, depending on the lifting height.

The input of the program are the parameters of the kinematic chain members L_i, the parameters of the hydraulic cylinders of the platform scissor mechanism C_5, the pressure p in the hydraulic cylinders when the platform is lifted and the desired number of platform positions N_P in the lift range.

The output of the program, among other things, are the position angle φ of the lever L_2 of the scissors mechanism, the lift height h and the mass m_q of the allowed load at the appropriate height and at the pressure p of the hydraulic cylinders.

3. EXAMPLE

Using the developed program, an analysis of the lifting platform load capacity with the parameters given in Table 1 was performed.

Tab.1. Program parametars

Parametar	Dimension	Value
$s_2 = s_3 = l$	*m*	*3,25*
x_{c2}	*m*	*2,10*
y_{c2}	*m*	*0,34*
x_{c3}	*m*	*0,30*
y_{c3}	*m*	*0,00*
m_2	*kg*	*250,00*
m_3	*kg*	*240,00*
m_4	*kg*	*1000,00*
n_{c5}	-	*2*
d_{c51}	*m*	*0,14*
d_{c52}	*m*	*0,08*
c_{5p}	*m*	*1,00*
c_{5k}	*m*	*1,80*
η_{cm}	-	*0,94*
η_{cv}	-	*0,95*
p	*MPa*	*9, 10, 11, 12, 13*
N_p	-	*500*

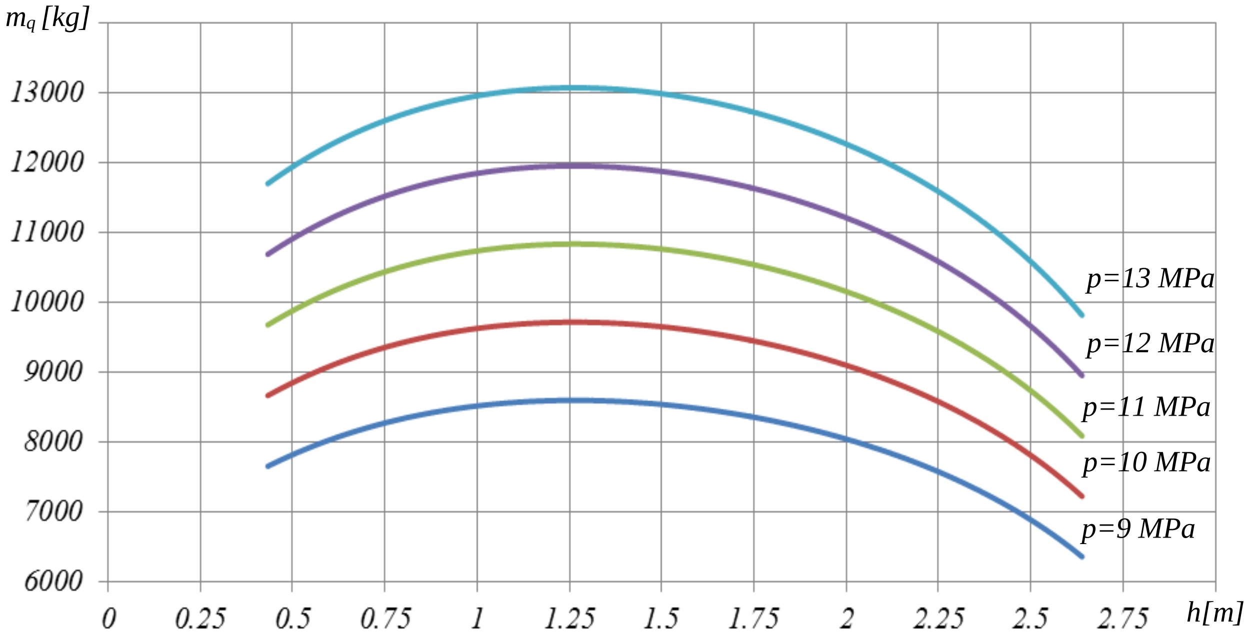

Fig.3. Change of the lifting capacity of the lifting platform with a scissor mechanism depending on the lift height

The obtained results of the analysis are shown in the diagram (Figure 3) showing the change in the permissible load capacity of the platform m_q depending on the lift height of the platform and the pressure level of the hydraulic cylinders.

It is characteristic that the load capacity varies at the same pressure with the change in lift height. The relevant load capacity throughout the platform lifting range at the same pressure of the hydraulic cylinder is the minimum load capacity - which in this case occurs at the highest lifting height.

For example, for pressure $p = 12$ *MPa*, the relevant load capacity of the platform would be $m_{qd} = 9000$ kg, which is almost *3,000 kg* less than the maximum load at lifting height $h = 1{,}25$ *m*, and for *1700 kg* less than the load at the start of the platform lift.

4. CONCLUSION

Lifting platforms with scissors have been widely used in the assembly and dismantling of systems and assemblies of locomotives and wagons.

The conducted analysis shows that the lifting platforms with the scissor mechanism have a characteristic change in the load depending on the height of the platform.

A significant change in the load capacity of the lift platforms with scissors is possible with the change of the pressure of the platform's drive system by simply adjusting the control valves.

Changing the load depending on the lift height can be reduced by optimizing the platform's drive mechanism.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

ADHESIVE BONDING OF RAILWAY VEHICLES AND PARTS

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Abstract *–Adhesive bonding is a broadly used method for connecting two or more components together. It enables the most efficient, durable joining of virtually all combinations of materials. Adhesive bonding is an alternative to more traditional mechanical joining methods used in railway industries. Adhesives are applied for bonding of exterior and interior parts of railway vehicles in order to deliver its superior performance and durability. Bonding faults in industrial products arise mostly due to adhesive application errors. These faults can be prevented by complying with the DIN 6701 standard „Adhesive bonding of railway vehicles and railway vehicle parts". The aim of this standard is to manage the organization of the whole bonding process. This paper presents an overview of the using of adhesive bonding on railway vehicles and parts, which application must be in accordance with railway standards DIN 6701.*

Keywords – Adhesive, adhesive bonding, railway vehicles, application, DIN 6701.

1. INTRODUCTION

With development of more complex products, there is a need for economically acceptable and simple ways of joining parts from different materials and with different shapes, sizes and thicknesses. One of the usual methods for connecting two or more components together is adhesive bonding. According to DIN 16920, adhesives are "non-metal materials which bond assembly parts by means of surface adhesion and internal strength" [1].

Bonding is the surface-to-surface joining of similar or dissimilar materials using a substance which is mostly of a different type, and which adheres to the surfaces of the two adherents to be joined. According to DIN EN 923, an adhesive is a nonmetallic substance capable of joining materials by surface bonding (adhesion), and the bond possessing adequate internal strength (cohesion) [2]. Bonding is a material joining technique that, in the traditional sense, cannot be broken without destruction of the bond. Adhesively bonded joints are an increasing alternative to mechanical joints in engineering applications, offers great design flexibility as it can easily integrated into almost all available industrial sequences of single-piece work or mass production.

Modern light weighting design is a trend across many industries. Reducing weight in transportation vehicles has great benefits, ranging from improved product design, their performance and a decreased end-user cost to less environmental impact.

The need to design lightweight structures and the increased use of lightweight materials in industrial fields, have led to wide use of adhesive joints in recent years. Today adhesive bonding is one of the most important joining techniques in railway vehicle manufacture. The specific reasons for this include the fact that joints have lifetimes of up to 30 years, high resistance to dynamic loads and have high strengths and resistance on temperature, in the range between -40°C and +80°C and under impact-like stress [3]. They also have very good resistance to aging, even in moist environments.

In this paper, the application of adhesive bonding for assembling exterior and interior parts on railway vehicles is presented. Application of adhesive must be in accordance with railway standards. These standards contain detailed and precise specifications and introduces a certification system in order to make the use of adhesive bonding in the railway vehicle manufacturing sector safer and more reliable.

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2. APPLICATION OVERVIEW

Railway is an important service provider to the global society, due to its infrastructure and capacity. It provides with the core of transportation for a sustainable economy. The railway manufactures must increasingly rely on novel knowledge in order to provide new and smart solutions to achieve high quality, safety and modern railway. In addition, reliability and durability in combination with continuous reduction of vehicle production and operating cost, are demanded and required by operators and railway manufactures. Modern railway designs are reflected in lighter, faster, more aerodynamic and energy efficient vehicles and part, with lighter weight materials and sleek designs. Many of adhesive manufacturers offers customized solutions and develops new systems for the railway market, which help to fulfill these requests for improved quality and reduced production cost.

2.1 Passenger Railway Exterior

Railway vehicles are very characteristic with many obligatory demands due to its development, design and production. Because of that, manufactures has tough and complex challenges for many assemblies and parts of passenger exterior. It can be noticed in problems connected with safety, high speeds, different weather and environmental conditions, required aerodynamic, etc. However, it is not allowed that any of these problems affect on normal and on-time functioning of railway. Adhesives in passenger railway exterior can be used in door assembly where is important to take care of safety; roof sealing and protection where resistance on weather conditions is significant, in direct glazing where larger glass tiles which reduces the overall weight of rail vehicles can be used and many other parts and assemblies (Fig. 1).

Fig.1. Application of adhesive in passenger railway exterior [5]

2.2 Passenger Railway Interior

Modern railway vehicles interior has great effect on quality, safety and general impression of passengers traveling by train. Beside expectation that interiors should look stylish, attractive and inviting, and also to be finished to a very high standard, there are many other things which are also very important. Travelling comfort, lower vibration and better sound isolation is imperative in modern railway. High quality and durability, as well as long life expectancy must be reached in order to meet the day-to-day requirements of transporting people. On the other side, railway operators need high performance and reliability from their interiors as repairs and breakdowns should be low-cost and as simpler as possible. Interior panels, brackets, sub-assemblies and lighting systems can all be built rapidly and reliably with adhesives. In certain application, fire resistant characteristic is essential for products, which must be in accordance with local and international railway standards. The combination of fast assembly, rapid cure, flexibility, strength and performance can be achieved using one of a number of proven adhesive systems. Application of adhesive in passenger railway interior is shown on Fig. 2 [4].

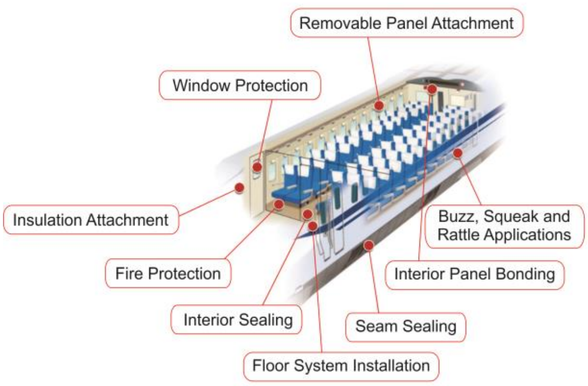

Fig.2. Application of adhesive in passenger railway interior [5]

The adhesive selection process is difficult because many factors must be considered, and there is no universal adhesive that will fulfill every application. It is usually necessary to compromise when selecting a practical adhesive system. Some properties and characteristics that are desired will be more important than others, and a thoughtful prioritization of these criteria will be necessary in selecting an adhesive. One must first go about finding an adhesive that will satisfy the high priority requirements of the application. The lower priority ''requirements'' may then need to be compromised to find the best fit.

Many types of tapes and liquid adhesives can be used for railway vehicles bonding, either alone or in combination. Adhesive must be created to stay ahead of changes in railway regulation and vehicle design. In fact, adhesives must meet the full range of hazard levels and to exceed upcoming European and North American safety standards for smoke, flame and toxicity – such as EN45545 and NFPA 1. The three all have a different chemistry with different structures and physical characteristics that make them suitable for targeted applications and specific processing requirements [5,6,7].

For exterior parts, epoxy adhesives are the type of adhesive most commonly used, which offers the advantages of excellent chemical resistance and thermal stability even in temperatures ranging as high as 140°C. The methacrylate-based adhesives tend to be used in applications to interior panels, where their fast curing properties provide significant time saving advantages. By contrast, polyurethanes with their flexible properties are the material of choice for joining tough-to-bond engineering thermoplastics, rigid plastics and composites, finding application in frame bonding for example [5,6,7].

Tab.1. Adhesive systems for railway vehicle bonding

Type of adhesive	**Exterior**		**Interior**	
	Roof	**Glazing**	**Floor**	**Interior**
LOCTITE	- Terophon-123 WF	- Terostat-2759 - Terostat-8590	- Terokal-8597 - Terostat-939	- Terophon-112 DB
3M	- 3M™ Water-BasedProtective Sealant 320 - 3M™ Hybrid Adhesive Sealant 760	- OEM Polyurethane Glass Adhesive Sealant 590 - Multi-layer Protective Tape 1004	- Structural Flooring Adhesive 7231 - Toughened Epoxy Adhesive LSB60	- Scotch-Weld™ Acrylic Adhesive DP8425NS
SIKA	- SikaPower®1200 - Sikaflex®-268	- Sikaflex®-558 - Sikaflex®268	- SikaFast®-5560 - SikaFast-5215	- SikaSense®-4490 - SikaMelt®9209

3. STANDARDS FOR ADHESIVE BONDING

Adhesives used today in production are high quality products. The correct use of adhesives enables zero-defect production – from the planning up to the bonded product. Nevertheless, bonding errors still arise. These errors result in more than 90% of all cases from application errors. Exactly this contradiction, *"zero-defect production vs. occurring bonding errors"*, is the subject of DIN 2304 *"Adhesive Bonding – quality requirements for adhesive bonding processes"* [8].

DIN 2304 is an application standard which is based on ISO 9001. The goal of DIN 2304 is to establish the best organizational design for the application processes in adhesive bonding. The adhesive user should become able to control his whole process from the idea, via the development, and up to the production of the bonded product. DIN 2304 is valid for all classes of adhesives independent from their strength and deformation properties. The standard is also valid for all branches and every adhesively bonded joint which has the primary function in the transfer of mechanical loads [9].

The series of standard, which refers to railway vehicles manufacturing industry, is DIN 6701 *„Adhesive bonding of rail vehicles and rail vehicle parts"*, whereas DIN 2304 applies for all load-bearing bonded joints in other sectors of industry. The standard DIN 6701 represents comprehensive set of regulations for quality assurance in adhesive bonding technology for railway vehicles. Furthermore, this national standard serves internationally as a foundation for adhesive bonding processes, not only for the railway vehicle industry.

The standard contains detailed and precise specifications and introduces a certification system in order to make the use of adhesive bonding in the railway vehicle manufacturing sector safer and more reliable. The standards in the DIN 6701 series was published in May 2006 and comprise [10]:

- DIN 6701-1: Basic terms and basic regulations
- DIN 6701-2: Qualification of manufacturer
- DIN 6701-3: Guideline for construction design and verification of bonds on railway vehicles
- DIN 6701-4: Manufacturing controls and quality assurance
- Additional: A-Z-Guideline of the „Workgroup adhesive bonding DIN 6701" (Collection of supplementary definitions, regulations, restrictions and interpretations relating to the DIN 6701 series of standards).

DIN 6701 establishes 4 types of unions according to their criticality and impact that can lead to failure [10]:

- A1 - Unions executed in railway vehicles involving high safety requirements, such elements can cause fatal cases where falls during operation of the vehicle or endanger the operation thereof. For example, the windows bonding as well as other elements located outside the vehicle which at the failure of the bond can be thrown hitting any passenger or pedestrian.

- A2 - Unions executed in railway vehicles means involving safety requirements which can cause personal harm or damage during operation. For example, the adhesive bonds used to anchor the vehicle interior furnishings or seats anchored to the ground.
- A3 - Unions executed in railway vehicles involving low safety requirements which can cause a decline in the comfort of the vehicle without causing injury. For example, the adhesive joints made on the floor covering, mirrors...
- Z - Unions executed in railway vehicles without safety requirements

As is the case with other standards, DIN 6701 is basically concerned with ensuring that manufacturers [10]:

- Have the human resources (technicians, managers and operators) with sufficient knowledge to design, industrialize and properly execute any adhesive bonding.
- Have the material resources and facilities necessary to carry out the correct design and execution of the adhesive bond.
- Have a quality system to record and verify the correct execution of adhesives.

Adhesive bonds on railway vehicles have differing safety requirements. For this reason, February 26th 2008, the German Federal Railway Authority (EBA: Eisenbahn-Bundesamt) defines that the DIN 6701-2 is considered as „state of the art“ for adhesive bonding in railway vehicle industry. Resulting requirement [10,11]:

- All adhesive processes for production and maintenance of railway vehicles and parts of rail vehicles need to correspond to the „state of the art“ of adhesive bonding.
- This applies to all railway vehicles which are using the railroad network controlled by the German Federal Railway Authority.
- The compliance with the „state of the art“ of adhesive bonding can be demonstrated by certification according to DIN 6701 or with a „case-by-case“ review.

According to DIN 6701 the railway adhesive bonding user-companies have been restructured concerning their equipment, their staff, their production workshops and process organization [12]. By now international experience with DIN 6701 shows that the expenditures mentioned above will provide medium-term benefit in a technological as well as in an economic way. Companies that want to offer bonded products or related services in accordance with the standard must have the relevant production facilities audited and certified.

4. CONCLUSION

Within the last few decades, adhesive bonding technology has given engineers new opportunities to optimize and innovate their constructions and final products. In the railway vehicle manufacturing sector, the use of adhesives has become a real alternative to traditional joining techniques such as welding and riveting. The reduction in vehicle weight, improved space usage, new design opportunities, less corrosion and easier repairs and disassembly have made adhesive bonding attractive in the field of railway.

In this paper, the use of adhesive bonding to assemble parts of railway vehicles is presented. Bonding of materials incolves a seguence of operations, all of which need strict control and complete procedural documentation. Therefore the use of adhesive bonding must be in accordance with the quality standard for adhesive bonding, DIN 6701. This standard contains set of regulations for quality assurance in adhesive bonding technology and introduces a certification system in order to make the use of adhesive bonding in the rail vehicle manufacturing sector safer and more reliable. According to DIN 6701 the railway adhesive bonding user-companies have been restructured concerning their equipment, their staff and their production workshops and must meet the quality standard if they want to offer bonded products or related services.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '18

OPTIMAL MACHINE LEARNING FOR PERCEPTION MODULES OF AUTONOMOUS SYSTEMS

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Abstract – *There is a growing interest in using machine-learning techniques combined with computer vision techniques in order to create autonomous perception modules of autonomous systems. For Autonomous Train Operation (ATO) vision based obstacle detection system capable to safely and reliably detect obstacles within existing mainline infrastructure is of highest importance. With the recent machine learning boom, more and more algorithms have become available that perform exceptionally well on a number of tasks. However, successful application of a machine learning method depends upon appropriately setting of its hyperparameters to achieve high-quality results. Concept solution of proposed method is to find a structured way to do the selection of machine learning methods for particular set of data and to develop a novel method for automatic optimization of the hyperparameters of selected machine learning method in order to improve the machine learning-based object classification for obstacle detection on rail tracks.*

***Keywords* – Machine learning, Hyperparameters optimization, Railway safety, ATO, PSO.**

1. INTRODUCTION

Utilization of computer vision system in the field of railways, for increasing safety and avoiding accidents, can be very important. An important part of the autonomous operation of cargo haul should be complete, safe and reliable obstacle detection system to be used mainly for initiation of long distance forward-looking braking and short distance wagon recognition for shunting onto buffers. Such vision based multi sensory obstacle detection system can be integrated into Autonomous Train Operation (ATO) in order to provide fail safe and reliable obstacle detection at short (up to 20 m) and long range (up to 1000 m) during day and night operation, as well as operation during impaired visibility (such as in the case of fog and bad weather condition) [1]. Furthermore, computer vison systems are used for detecting the existence of any living or/and non-living objects in front of a moving train which represent an obstacle. Due to complexity of a real time obstacle detection problem a machine learning approach is suggested in this paper.

In the last 15 years, machine learning methods have been increasingly used in computer vision for solving different problems such as, among others, image registration, segmentation, 3D object reconstruction, human and object detection (including classification), recognition and tracking.

One of the difficulties in application of machine learning algorithms is that they require setting of hyperparameters before using the models. The performance of learning algorithms is critically sensitive to the choice of hyperparameters.

One of the goals is setting those parameters to optimal values that going to enable completion of a learning task in the best possible way. Determining the proper set of hyperparameters is a challenge because it often requires expert experience and there is no mathematical formulation for calculating the appropriate hyperparameters so the selection relies on trial and error with a model selection criterion [2]. The tuning of parameters of a machine learning technique can be considered as a process which performs the best once when it is defined what “best” actual is.

One of recent endeavors for automatic optimization/tuning of hyperparameters are grid search and intelligent numerical optimization strategy. In grid search approach [3][4], each hyperparameter of interest is discretized into a desired set of values in

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order to be studied. In addition, models are trained and assessed for all combinations of the values across all hyperparameters. Although grid search is very simple for performing it can be also quite expensive because with growing of the number of hyperparameters and the number of discrete levels of each, the computational cost is exponentially increased. The other non-grid automatic approaches developed in recent years include gradient-based hyperparameters optimization [2], Bayesian optimization [5], and evolutionary algorithms [6]. Although, these methodologies for optimization hyperparameters gave good results in finding the optimal hyperparameters and significantly reduced computational time there are some problems. For example, Bayesian optimization does not work well in high dimension, and gradient based may be stuck in the local minima if objective function is not convex. Evolutionary algorithms require their own parameters tuning such as number of generations, number of populations, mutation rate, mutation percentage on population, and crossover percentage on population. For tuning these parameters, it is again necessary expert knowledge, which makes it difficult to use these algorithms. In addition, evolutionary optimization algorithms are generally difficult to find the global optimum solutions for multimodal problems due to premature convergence.

Population based metaheuristics optimization algorithms such as particle swarm optimization (PSO), are recently used as very promising method in tuning of hyperparameters. Particle swarm optimization (PSO) is a popular population-based heuristic algorithm that simulates the social behavior of individuals such as birds flocking, moving to a potential position to achieve particular objectives in a multidimensional space. PSO is found to have the extensive capability of global optimization for its simple concept, easy implementations, robustness, and fast convergence. It employs only simple mathematical operators and is computationally inexpensive in terms of both memory requirements and speed. In [7], particle swarm optimization (PSO) is used to optimize the feed-forward artificial neural network's (ANN's) architecture design. The proposed methodology automatically designs the ANN based on determining the set connections, the number of neurons in hidden layers, the adjustment of the synaptic weights, the selection of bias, and transfer function for each neuron. The obtained results in the design of the ANN were very promising, but unfortunately, when solving complex multimodal problems, the conventional PSO algorithm can easily fly into the local optima and lacks the ability to jump out of the local optima.

Therefore, hyperparameters optimization of machine learning methods as well as the improvements of optimization algorithms in terms of the search efficiency and convergence speed is still an open problem.

2. PRELIMINARY WORK, PROGRESSS REPORT

The starting point for this research is previous work of the authors, on using the basic particle swarm optimization (PSO) for defining the optimal parameters of the control module of a mobile robotic system which autonomously follows the human collaborator as detected and tracked by robotic vision. Beside achieving good result in using the basic PSO for building optimal mobile robot control, the insights on the possible way for improvement of PSO for particular purpose also was gaining.

In the basic PSO, particle swarm consists of n particles, and the coordinates of each particle represent a possible solution. At each iteration, particle move towards an optimum solution, through its present velocity, personal best solution obtained by themselves so far and global best solution obtained by all particles.

The velocity of the particle and its new position will be determined according to the following two equations:

$$\boldsymbol{v}_i^{(m+1)} = w\boldsymbol{v}_i^{(m)} + c_1 r_{1i}\left(\boldsymbol{b}_i^{(m)} - \boldsymbol{x}_i^{(m)}\right) + c_2 r_{2i}\left(\boldsymbol{p}_g^{(m)} - \boldsymbol{x}_i^{(m)}\right), \tag{1}$$

$$\boldsymbol{x}_i^{(m+1)} = \boldsymbol{x}_i^{(m)} + \boldsymbol{v}_i^{(m+1)}, \tag{2}$$

where r1 and r2 are random variables in the range [0,1]; c1 and c2 are acceleration coefficients regulating the relative velocity towards global and local best and w inertia weight, parameter which adjusts the influence of the previous velocities in the process.

Through empirical experiments, it was found that a larger *w* can bring a better global convergent ability while a smaller *w* can manipulate a better local search. By researching the convergence, it was shown that higher values of cognitive acceleration coefficient c_1 ensure larger deviation of the particle in the search space, while the higher values of the social acceleration coefficient c_2 signify the convergence to the present global best (gbest). Increasing population size had hardly any effect on the performance of PSO. Number of particles in swarm is usually between 30 and 50.

The main reason of the PSO stucking in local minima is a fast information interaction among particles that leads to a decline of swarm diversity and rapid clustering of particles. In other words, PSO could prematurely converge in case of loss of diversity. The diversity is the measurement of exploration and exploitation. In the other words, the diversity is the measurement of convergence in PSO search process.

Some techniques have been proposed the keep swarm diversity and thus avoid premature convergence. These techniques include linearly decreased inertia weight *w* over time [8], a fuzzy control of inertia weight [9], time-varying acceleration coefficients [10], or some of the swarm's particles are periodically replaced by artificial ones [11]. In [12] a negative feedback mechanism into particle swarm optimization has proposed in order to control diversity by tuning of the inertia weight. These techniques show rapid convergence, but often fail in some multimodal functions and some of them are very difficult to implement.

3. CONCEPT OF A NOVEL METHOD FOR HYPERPARAMETERRS OPTIMIZATION

Maintaining an appropriate swarm-diversity according to the current search state by adaptively modifying of the parameters of PSO in order to ensure better global search and avoid premature convergence is one of the aims of this paper. The idea of controlling diversity of swarm by using classical and modern control technique has been exploited by other authors. For example, in [12], the parameter adjustor was designed as a ratio controller that was expected to modify the inertia weight under the control of the swarm-diversity through the negative feedback during the search.

Regarding to this, the main idea behind proposed Adaptive PSO with multivariable feedback control (Fig.1) is to control the diversity of the swarm by adaptively adjusting all three parameters (inertia weight and acceleration coefficients) of particle swarm optimization in a closed-loop manner. Parameters adjustment is proposed to be under the control of the swarm-diversity, the degree of change in the value of the global best fitness (gbest) and number of iterations through the negative feedback during the search. This approach should ensure that optimization algorithm pushes the particles to move to the entire solution space at the begging of search. If the swarm-diversity decreases quickly, controller-parameter adjustor is supposed to adjust values of inertia weight and acceleration coefficients in order to enhance the exploration ability. On the other side, a slow decrease of swarm-diversity is indicator that the exploitation should be increased. The degree of change in the value of the global best fitness (gbest) and number of iterations should pull the particles to global solution. If the value of the global best fitness is not changed during some predefined number of iterations, controller-parameter adjustor should set parameter’s values in order to force particles to converge to global optimum and quickly decrease swarm-diversity.

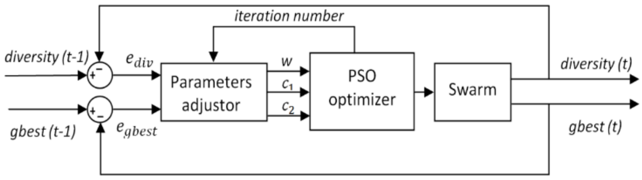

Fig.1. The Architecture of Adaptive PSO with multivariable feedback control

In order to ensure the optimal classification performance, a proposed Adaptive PSO with multivariable feedback control will be used for tuning the hyperparameters of most suitable machine learning algorithms to classify the objects in the images of the scene in front of the locomotive, including the rail tracks and possible obstacles on the rail tracks

The novelty of proposed system is in used optimization techniques and evaluation criterions. In addition to the standard statistical evaluation criteria such as, accuracy of prediction, mean square error, etc., the computational time will be also considered as evaluation criteria in selection of the most suitable machine learning algorithm for real-time object recognition.

The most suitable machine learning algorithms for 3D object recognition such as Support vector machines, neural networks and deep learning and their hyperparameters are organized into a large hierarchical space. At the lowest level of the hierarchy, the algorithms with hyperparameters that must be set appropriately are placed. Algorithms are also divided into different classes they belong (neural networks, Support vector machines, deep learning). For example: neural networks can use a variety of topologies and learning algorithms. Some of types of ANNs algorithms are feedforward neural network, recurrent neural network, etc. A novel optimization technique supposed to explore and evaluate a large number of algorithms with their hyperparameters in order to find the ones that exhibit the best performance for a given categorical configuration. The best one passes to the next level of the hierarchy and the process is repeated until the best single algorithm remains and which will be used for object classification in vision data.

4. CONCLUSION

One of the ways to increase of efficiency of existing infrastructure is to automate the cargo haul. Trains are more suited for autonomous operation than other types of vehicles (especially road vehicles) as they are moving on a fixed and known track. Very important part of the autonomous train operation is the vision based obstacle detection system for usage in automation of cargo haul.

The robust and reliable object classification is essential for object/obstacle detection and autonomous train operation in modern railway traffic systems. Therefore, the automatic approaches that can optimize the performance of any given learning algorithm and which are good enough for solving the particular problems are needed in further development of machine learning algorithms.

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MODEL OF TRANSPORT RISK ASSESSMENT DUE TO DERAILMENT

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Goran TEPIĆ [2]

Abstract *– The paper presents a methodological approach for the assessment of transport risk based on the application of the Bayesian framework and Monte Carlo simulation. Implementation of the proposed model is realized on the case of transport accidents with dangerous substances. The risks that accompany the rail transport of explosive and inflammable materials are very often an integral part of the accident chain - the domino effect. The basis for the assessment of transport risk involves identifying the probability of the occurrence of that event. Consequences of transport accidents are assessed according to potential scenarios. Derailment is an initial event for the analysis of transport risks on the railway and allows assessment the probability of potential scenarios. Probabilistic models of risk assessment are based on the using of the conditional probability distribution of the events that preceded the accident. Any influential event preceding the occurrence of a railway transport accident shall be interpreted by appropriate discrete distributions. Support for the formation of discrete distributions derives from the FRA REA database for period 2006-2015. The methodology presented is applicable to a wider range of other types of transport accidents on the railways.*

Keywords – Transportation, accident, railway, risk assessment, derailment.

1. INTRODUCTION

Derailments are the most common type of railway accidents [1]. The causes that lead to the derailments include track irregularities and damage to the railway vehicle. Over the last ten years, about 500 accidents per year have been recorded in the EU due to the derailments [2]. About 7% of these accidents have catastrophic consequences [3]. Catastrophic accidents follow an average of 30 fatalities per year and a cost of £ 10 million [4]. Railway transport of dangerous goods follows significant risk, as the consequences of such accidents can be catastrophic. Fully eliminating risks in the transport of dangerous goods is not possible or would be economically unjustified. Therefore, there is a tendency to develop integrated risk optimization frameworks [5]. Contemporary research of an accident risk assessment due to derailments is based on several approaches, such as Artificial Neural Networks (ANN), Naïve Bayes, Decision Treee and Genetic Algorithm [6]. An important role in the analysis of railway accidents has the FRA database [7]. The use of the FRA database was the basis for carrying out the probabilistic analysis of the railway transport risk [8]. A probabilistic analysis requires knowledge of several parameters such as point of derailment (POD), number of cars derailed, number of tank cars derailed, number of tank cars releasing contents and realease consequence [8]. *Anderson* and *Barkan* show that the point of derailment can best be approximated by Beta distribution [9]. *Bagheri et al.* proposed the statistical model for estimating the total number of cars derailed [10]. *Glickman et al.* assume that the tank cars derailed corresponds to the hyper-geometric distribution [11]. Release of dangerous substance from the tank cars corresponds to the Poison binomial distribution [8]. *Xiu et al.* have presented a zero-truncated negative binomial (ZTNB) regression model is developed to estimate the conditional mean of train derailment severity [12]. Track and equipment failures are the primary causes of train derailments on main tracks, whereas the use of switches and switching rules has a substantial effect on derailment frequency on siding and yard tracks [13]. The application of Monte Carlo simulations in determining the probability of railway accidents with dangerous substances is presented in [14]. In the continuation of the work, a probabilistic framework based on the Bayes classifier for predicting catastrophic railway accidents initiated by the derailment will be exposed.

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2. PROBABILITY OF RAILWAY ACCIDENT

The probability of an accident due to the derailment is estimated through the discrete distribution resulting from accidental data or recommendations from literary sources.

A probabilistic model for the assessment of accidental risk uses the probability of events that precede the occurrence of accidents identified through relevant accidental data (*Fig. 1*). A transport accident is preceded by a sequence of events that includes [8]:

a) Initialization of derailment – $P(X_i) = P(A)$,
b) Derailment of railway cars – $P(X_j \mid X_i) = P(B)$,
c) Derailment of the HAZMAT cars – $P(X_k \mid X_j, X_i) = P(C)$ and
d) Release of dangerous substance from the HAZMAT cars – $P(X_l \mid X_k, X_j, X_i) = P(D)$.

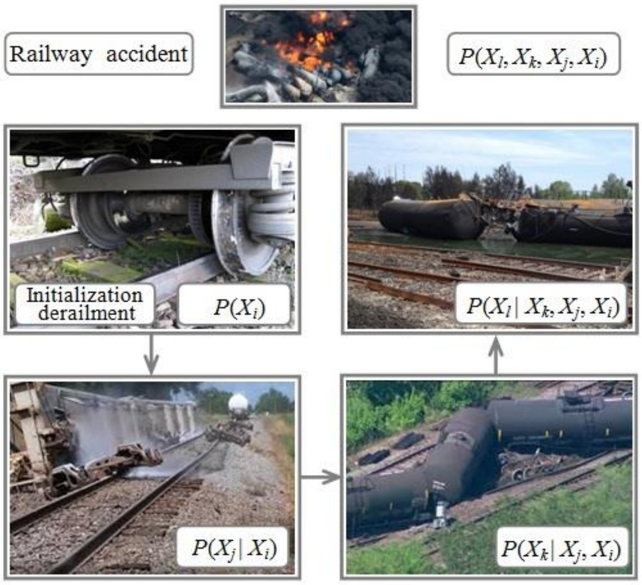

Fig.1. Sequential events initiated by a derailment

The probability of the occurrence of a transport accident due to the derailment of the train with a heterogeneous composition of railway vehicles is given by the conditional probability formula [8]:

$$P(X_l, X_k, X_j, X_i) = P(X_l \mid X_k, X_j, X_i)\cdot P(X_k \mid X_j, X_i)\cdots \cdots P(X_j \mid X_i)\cdot P(X_i) \quad (1)$$

Where are discrete random distributions:
X_i – derailment initiated in the i^{th} position of the train,
X_j – derailment of j railway cars from the train,
X_k – derailment of k tank cars,
X_l – releasing the dangerous goods from l tank cars,
i – the position of the first of the derailed car,
j – the total number of derailed the cars ($0 < j \le n$),
k – the number of derailed the tank cars ($0 \le k \le j$),
l – the number of tank cars exposed to release or leak dangerous substances ($0 < l \le k \le j \le n$),
n – total number of railway cars ($n \ge 2$).

Thus, determining the probability of derailment implies knowledge of the probability of sequential events for the interval number of the railway cars according to Table 1.

Tab.1. The number of railway cars corresponding to the sequential events of derailment

No	$n(A) = x$	$n(B) = y$	$n(C) = z$	$n(D) = k$
1.	≤ 25	≤ 8	≤ 3	≤ 1
2.	≤ 25	≤ 16	≤ 3	≤ 1
3.	≤ 25	≤ 8	≤ 8	≤ 1
4.	≤ 25	≤ 16	≤ 8	≤ 1
5.	≤ 25	≤ 8	≤ 3	≤ 3
6.	≤ 25	≤ 16	≤ 3	≤ 3
7.	≤ 25	≤ 8	≤ 8	≤ 3
8.	≤ 25	≤ 16	≤ 8	≤ 3
9.	$25 < x \le 75$	$8 < y \le 16$	$3 < z \le 8$	$1 < k \le 3$
10.	$25 < x \le 75$	$y > 16$	$3 < z \le 8$	$1 < k \le 3$
11.	$25 < x \le 75$	$8 < y \le 16$	$z > 8$	$1 < k \le 3$
12.	$25 < x \le 75$	$y > 16$	$z > 8$	$1 < k \le 3$
13.	$25 < x \le 75$	$8 < y \le 16$	$3 < z \le 8$	$k > 3$
14.	$25 < x \le 75$	$y > 16$	$3 < z \le 8$	$k > 3$
15.	$25 < x \le 75$	$8 < y \le 16$	$z > 8$	$k > 3$
16.	$25 < x \le 75$	$y > 16$	$z > 8$	$k > 3$

The probability of sequential events and the derailment for the interval values of the railway cars from Table 1 are shown in Table 2.

Tab.2. The probability of railway accident through the probability of sequential events

No	$P(A)$	$P(B)$	$P(C)$	$P(D)$	$P(X_l, X_k, X_j, X_i)$
1.	0.5139	0.4840	0.5200	0.4790	0.061953
2.	0.5139	0.8050	0.5200	0.4790	0.103042
3.	0.5139	0.4840	0.9000	0.4790	0.107226
4.	0.5139	0.8050	0.9000	0.4790	0.178342
5.	0.5139	0.4840	0.5200	0.8890	0.114982
6.	0.5139	0.8050	0.5200	0.8890	0.191240
7.	0.5139	0.4840	0.9000	0.8890	0.199007
8.	0.5139	0.8050	0.9000	0.8890	0.330993
9.	0.3712	0.3210	0.3800	0.4100	0.018564
10.	0.3712	0.1950	0.3800	0.4100	0.011277
11.	0.3712	0.3210	0.1000	0.4100	0.004885
12.	0.3712	0.1950	0.1000	0.4100	0.002968
13.	0.3712	0.3210	0.3800	0.1110	0.005026
14.	0.3712	0.1950	0.3800	0.1110	0.003053
15.	0.3712	0.3210	0.1000	0.1110	0.001323
16.	0.3712	0.1950	0.1000	0.1110	0.000803

3. A MODEL OF EXPECTATION OF ACCIDENTS

The model for predicting the severity of accidents is based on the application of the Bayesian classifier. This type of classifier is derived from the Bayesian rule which reads:

$$P(\beta|\alpha)=\frac{P(\beta)\cdot P(\alpha|\beta)}{P(\alpha)} \tag{2}$$

Where is:

α – hypothesis,
β – evidence related to the hypothesis α,
$P(\alpha)$ – probability of hypothesis α (a prior probability),
$P(\beta)$ – probability of evidence, ie. the states indicated by the collected data
$P(\alpha|\beta)$ – conditional probability of evidence β if the hypothesis α is valid (a posteriori probability),
$P(\alpha|\beta)$ – conditional probability of hypothesis α if the hypothesis β is valid (likelihood).

Classifier based on Bayes' rule introduces two assumptions over attributes:

- All attributes are a priori equally important and
- All attributes are statistically independent (the value of one attribute tells us nothing about the value of another attribute).

The Bayesian classifier uses the MAP hypothesis (Maximum A Posteriori) and implies such a hypothesis for which $P(\beta|\alpha)$ has the maximum taking into account the data presented. Then we have:

$$h_{MAP}=\arg\max_{\alpha_i\in\beta} P(\beta_i|\alpha) \tag{3}$$

$$h_{MAP}=\arg\max_{\alpha_i\in\beta} \frac{P(\beta_i)\cdot P(\alpha|\beta_i)}{P(\alpha)} \tag{4}$$

Probability $P(\alpha)$ can be omitted, as it is constant and then it is:

$$h_{MAP}=\arg\max_{\alpha_i\in\beta} P(\beta_i)\cdot P(\alpha|\beta_i) \tag{5}$$

Where β_i represents the available data related to the attribute i. The assumption of the independence of the attribute significantly simplifies the calculation of the conditional probabilities and then applies:

$$\begin{aligned} P(\beta|\alpha)&=P(\beta_1,\beta_2,\ldots,\beta_n|H)\\ P(\beta|\alpha)&=P(\beta_1|H)\cdot P(\beta_2|H)\cdot\ldots\cdot P(\beta_n|H)\end{aligned} \tag{6}$$

The assumption of the independence of the attribute in the case of derailment is fully met, so it can be applied (5). The considered attributes for derailment include: mass, velocity and temperature of derailment, as well as the number of injured and killed in railway accidents. The Bayesian classifier uses the examples in Table 3 to classify a new data, i.e. vector which is not in the existing table. Bayesian classifier is a simple and effective tool for vector data.

Tab.3.Characteristic accidents parameters:2006-2015

No	Mass [t]	Velocity [mph]	Temper. [^0F]	K illed	Injured
1.	2,136	7	10	0	1
2.	5,054	19	70	0	4
3.	3,740	24	85	0	197
4.	13,149	3	46	0	1
5.	14,815	31	26	0	1
6.	14,107	23	53	0	2
7.	5,764	47	62	0	2
8.	8,287	36	70	0	2
9.	7,279	28	28	0	1
10.	9,041	50	81	0	1
11.	2,598	34	53	0	2
12.	2,144	23	39	0	1
13.	13,335	42	-1	0	2
14.	12,319	23	74	0	3
15.	7,500	0	88	0	1
16.	9,321	8	34	0	385
17.	8,654	22	40	0	1
18.	4,627	21	28	0	1
19.	7,722	38	60	0	2
20.	5,217	49	90	0	2
21.	2,389	26	28	0	2
22.	6,213	47	60	0	2
23.	2,380	13	25	1	1
24.	3,928	16	58	0	1
25.	8,192	53	91	0	1
26.	11,125	34	66	1	11
27.	12,283	25	37	0	1
28.	7,186	55	53	0	1
29.	6,821	25	97	0	2
30.	10,990	17	72	0	2
31.	39,000	21	58	0	2
32.	6,600	11	58	0	4
33.	2,352	4	65	0	6
34.	0	20	85	0	1
35.	810	10	96	0	1
36.	3,459	35	38	0	2
37.	6,407	30	5	0	34
38.	7,920	61	60	0	1

4. RESULTS AND DISCUSSION

The considered attributes allow classifying new vectors that do not exist in Table 3. Existing data is used to learn in terms of estimating parameters for the attributes of the sought vector. The learning process was carried out on a sample of 38 accidents with at least one injuries. The analyzed statistical sample refers to the period 2006-2015.

The main purpose of the study relates to the prediction of vector attributes that follow more serious accidents with at least one killed or 18 injured. In this respect, it is necessary to define four new vectors that adequately describe these accidents:

X_1 = (Mass > 7,760; Velocity < 27; Temperature < 55)
X_2 = (Mass < 7,760; Velocity > 27; Temperature < 55)
X_3 = (Mass < 7,760; Velocity < 27; Temperature > 55)
X_4 = (Mass > 7,760; Velocity > 27; Temperature > 55)

Estimates of accidents probability defined by these vectors are realized with (4) and (5), whose values are shown in Table 4.

Tab.4. The probabilities of catastrophic accidents

Case	$P(X_1)$	$P(X_2)$	$P(X_3)$	$P(X_4)$
Yes	0.00004	0.00004	0.00004	0.00002
No	0.05052	0.06204	0.11427	0.05052

The probabilities of catastrophic railway accidents initiated by the derailment does not exceed $4 \cdot 10^{-5}$, taking into account the requirements of the FRA database. The values obtained are completely consistent with the probabilistic approach given in [14]. The lower mass and velocity of the train at a higher ambient temperature significantly creates preconditions for accidents with less than 18 injured.

5. CONCLUSION

The paper proposes a model for the assessment of railway accidents based on statistical data, Monte Carlo simulation and the Bayes classifier. Statistical data on accidents are taken from the FRA database. Monte Carlo simulation uses these data to obtain discrete distributions for sequential events that precede an accident. These distributions are used to estimate the probabilities according to the interval number of the railway vehicles for the considered sequential events. A model of expectation of accidents based on the Bayes classifier and data on serious railway accidents (more than one killed and 18 injured) is presented. Four accidents were analyzed, the attributes of which include the mass, velocity and temperature. The probability of serious accidents that are considered by the vectors X_1, X_2, X_3 and X_4 are in the range of $(2\text{-}4) \cdot 10^{-4}$. Railway accidents are followed by a derailment of up to 8 HAZMAT cars that was initiated among the first 25 train positions and damaging upwards 3 HAZMAT cars.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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OVERVIEW OF MODERN SAFETY REGULATION CONCEPT OF CABLEWAYS

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Abstract: *Capacity and complexity of cableways designed to carry persons are constantly growing and the cableway market, both in Europe and all over the world, is rapidly increasing, as well as the number of innovations in this field. Therefore, the cableway safety represents an actual issue constantly facing new challenges. At the EU level, a unique cableway safety system has been established in 2000 by the adoption of the Directive 2000/9/EC laying down a set of essential safety requirements, scope of application and conformity assessment which must be the same for all the EU member states, without flexibility in its transposition. All the other aspects of safety regulation are completely left to national rules leaving a lot of space to adjust the solutions to local specificities. On the other hand, we have harmonized standards in the field of cableways with detailed requirements and rules in the area of safety, whose implementation into the national legislation is however not mandatory. In March 2016, there was adopted the Regulation on Cableways 2016/424/EU which applies as of April 2018 and repeals the Directive 2000/9/EC and which defines more precisely certain segments of cableway safety and thus reduces the possibilities of inconsistency in national rules.This paper presents an overview and analysis of certain segments of cableway safety regulation. A special mention is made of the safety segments regulated by the EU legislation. Those are first of all the instruments which allow achieving higher safety, including, among others, a compulsory safety analysis, safety reports and conformity assessment of the safety components and cableway subsystems. Besides that, it mentions the fields regulated exclusively by national rules including the answer to the question whether this undermines the uniformity of the cableway safety system. Finally, the paper analyses and discusses how these segments have been regulated in the Republic of Serbia and gives possible future solutions in accordance with the EU trends.*

Key words: cableways, essential safety requirements, safety analysis, safety management.

1. INTRODUCTION

From the point of view of safety, it is only when a serious accident occurs that cableways designed to carry passengers attract great public attention with questions of who is responsible and what is the real cause of the accident. Generally, the main causes of cableway accidents are mechanical faults (derailments of cable, cable breakdown, etc) and external causes (wind, ice, avalanches, etc), but in many cases the cause also lies in the behaviour of passengers (imprudence, forbidden or law-breaking behaviour etc).

As illustration, we will mention only some of the larger and characteristic cableway accidents including a large number of casualties:

- 1999 France: Derailment of cabin from the bearer cable - 20 casualties;
- 2003 India: Broken cable, 3 cabins fell on the ground - 7 casualties;
- 2005 Austria: Gondola hit by a helicopter propeller - 9 casualties.

Records and statistics of emergencies on cableway installations are mandatory and available, especially of those which resulted in at least one seriously injured or dead person. However, at the moment there are no set criteria which could serve as basis for analysis illustrating how safe the cableway transport really is and which is the acceptable risk rate. For example, in railway traffic there is a generally accepted safety criterion which consists of the number of casualties by train-kilometre. When cableways are concerned, there is still no such criterion, that is, it has

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not been set yet, so we cannot mutually compare emergencies in cableway transport or compare those events with other modes of passenger transport.

International meeting of national authorities in charge of cableways (ITTAB[1]) is the most important international summit dedicated to the safety of cableway operation and transport. ITTAB has established a unique system of classification of emergencies according to the cause and consequences, as well as codes for their identification including the type of installation where they occurred and number of minor and serious injuries suffered by the participants, either passengers or cableway workers or third persons.

All the participating countries of ITTAB (34 countries from all around the world[2]) are asked to provide data on emergencies in the previous year according to the prescribed classification of emergencies on cableways and specific traction installations before the meeting. That analysis covers the most important and most frequent problems leading to emergencies and measures taken to prevent them.

The table 1. presents cumulative data for all the members of ITTAB for 2015 regarding emergencies on cableways and specific traction installations.

Tab.1. Emergencies on cableways and specific traction installations for 2015

Ord. No	Type of cableway or traction installation	Total number of all emergencies	No of slightly injured persons	No of seriously injured persons	No of casualties
1	Reversible cable cars	30	8	1	1
2	Uni-directional cable cars	267	237	80	4
3	Funicular railway	12	4	1	0
4	Drag lift	69	68	13	0
5	Specific traction installations	15	13	2	0

This table shows that emergencies on uni-directional cable cars were by far the most numerous (267) which also resulted in the most harmful effects. However, the final opinion on the level of safety cannot be given without data on the work realized regarding the number of transported passengers for each of the cableways separately or the total number for one type of installation, one country or total number according to another criterion in case we provide a general analysis or estimation.

An analysis aiming at reducing the number of emergencies shall certainly include an overview of parameters to be included in standards and rules in the field of cableways in order to reduce the risk of unwanted events and confirm whether this is enough, as well as answer the question of which instruments are necessary in order to regulate safety of cableways. In order to answer all those questions, we shall first analyse the parameters affecting the safety of cableways.

2. CABLEWAY SAFETY PARAMETRS AND INSTRUMENTS USED FOR THEIR REGULATION IN THE EU RULES

From the theoretic point of view, the safety of cableways is dominantly affected by the quality of equipment and structure of cableway installations, manner of putting in place, manner and control of operation and environmental conditions.

That influence can be defined through parameters affecting safe operation of a cableway which can be divided into:

- Technical-technological,
- Operational-technical,
- Organizational and
- Parameter of environmental influence.

Technical-technological and operational-technical requirements for maintenance and exploitation are laid down by basic safety requirements in the Directive 2000/9/EC, that is, in the Regulation 2016/424/EC[3] and they are applied to design, construction and placing in service of a cableway installation.

Those parameters are generally presented in the basic safety requirements and they are included, with more details, in harmonized standards of which the following represent the key standards:

- EN 1709- Safety requirements for cableway installations designed to carry persons – Pre-commissioning inspection, maintenance, operational inspection and checks
- EN 1908 - Safety requirements for cableway installations designed to carry persons – Tensioning devices
- EN 1909 - Safety requirements for cableway installations designed to carry persons – Recovery and evacuation

[1] International Meeting of Technical Authorities for Cableways

[2] Republic of Serbia become participiant of ITTAB in 2016.

[3] Regulation 2016/424/EC entered into force on 21.4.2018 and repealed the Directive 2000/9/EC, but national rules of the EU member states are at the moment still mostly harmonized with the repealed Directive 2000/9/EC

- EN 12397 - Safety requirements for cableway installations designed to carry persons - Operation
- EN 12927-1 to EN 12927-8 - Safety requirements for cableway installations designed to carry persons –All requirements for cables
- EN 12929-1 - Safety requirements for cableway installations designed to carry persons - Part 1: Requirements for all installations
- EN 12930 - Safety requirements for cableway installations designed to carry persons - Calculations
- EN 13107 - Safety requirements for cableway installations designed to carry persons – Civil engineering works
- EN 13223 - Safety requirements for cableway installations designed to carry persons – Drive systems and other mechanical equipment
- EN 13243 - Safety requirements for cableway installations designed to carry persons – Electrical equipment other than for drive system
- EN 13796-1 to EN 13796-3 - Safety requirements for cableway installations designed to carry persons - Vehicles

The Regulation 2016/424/EC also prescribes the manner of proving the conformity of safety components and cableway subsystems with the basic safety requirements through conformity assessment.

The conformity assessment is carried out before placing parts of a system on the market by a designated body for conformity assessment and each cableway safety component and subsystem placed on the market must bear a conformity designation and conformity documents, which are made mandatory for manufacturer, distributor and importer by these rules and which guarantee the safety of components installed on new cableways.

Moreover, there is an additional instrument of EU legislation related to the regulation of these two parameters consisting of safety report and safety analysis which shall be drafted within the design of a cableway installation and attached to the main design.

Namely, safety analysis is realized according to one of the recognized methods of risk assessment taking into account the environmental conditions and the most inconvenient circumstances. The analysis contains a list of risk factors and dangerous situations. The result of this analysis must be provided in form of a safety report including a list of measures for overcoming of all risk factors.

Regarding the parameter of environmental influence the following effects are taken into account:

- wind (causes inadmissible lateral movements of vehicles, derailment of cable, etc)
- ice (ice formed on the cable or other parts of the structure can cause many problems),
- temperature (the design of cableways must take into account extreme values of the outside temperature),
- geological-climate conditions (watercourses, landslides, soil erosion and avalanches)
- earthquake and
- fire.

These effects are partially included in the basic safety requirements, that is, harmonized standards, and safety analysis, but not completely. That is why some of the EU member states study and treat each of those effects as separate scientific units, especially avalanches as one of the most unpredictable and complicated effects concerning safety.

3. PARAMETERS AND SEGMENTS AFFECTING THE SAFETY OF CABLEWAYS WHICH ARE REGULATED ONLY BY NATIONAL RULES

Parameters related to the organizational structure of cableway manager, competences of managers and professional qualifications of the executive staff, internal control, possession of the appropriate documents (instruction manuals, maintenance manuals, evacuation manuals, etc) and defined feed-back procedures, are not prescribed by the EU legislation. They are completely regulated by national rules or acts drafted by cableway manager, that is why this cableway rules are not uniform. The same goes for the administrative framework, that is, institutions drafting cableway rules, issuing authorisations for cableway operation and supervision of cableway operation.

Rules related to the authorisations for operation and supervision of cableways, professional competence of executive staff and expert-technical inspection of cableways, which represent mandatory segments within the regulation of this field, are also given over to national legislation. Although in the EU there are no uniform rules related to these fields, in practice, this uniformity is reflected in the establishment of cableway institutions which the most usually belong to the railway sector and are also in charge of drafting cableway rules. There is also a uniform approach regarding the issuance of authorisations for operation of cableway installations, as well as the elements related to the expert inspection of cableways. The part related to professional competences and training is usually regulated by acts drafted by cableway managers.

The practice has shown that all the institutional and legal instruments of safety control of cableways are indispensable, but not sufficient when we are talking about safety, since legislation cannot anticipate all the safety risks. That is why in a certain number of EU countries there is a trend of introducing Safety Management System (SMS) in national legislation related to cableways, with France as the leading country introducing gradually a mandatory SMS for cableway managers.

Safety Management System (SMS) in the field of cableways represents a systematic application of management policies and procedures to the activities related to risks, that is, represents organisation and measures established by cableway managers in order to guarantee safe management of their activities. Since obligatory character and manner of application of SMS have not been laid down by the EU cableway legislation, as prescribed for the railway sector, although cableways belong to this sector, at the moment its application represents quite a challenge for national legislations.

4. REGULATION OF SAFE OPERATION OF CABLEWAYS IN THE REPUBLIC OF SERBIA AND POSSIBLE SCENARIO FOR FUTURE SOLUTIONS

In the Republic of Serbia, by the adoption of the Law on Cableways Designed to Carry Persons in 2015, our legislation was harmonized with the EU legislation in the field of cableways and the Action Plan for the harmonized field - (Chapter1 – Free movement of goods) provided for the competent ministry to adopt a new Law on Cableways in the fourth quarter of 2019, which will be completely harmonized with the Regulation 2016/424/EC. This harmonization will not require essential changes comparing to the applicable law.

Therefore, the applicable law and its by-laws include all the parameters affecting safety of cableways laid down by the EU legislation. Moreover, national legislation includes all the mandatory segments related to the regulation of this field which have been prescribed according to the examples of best practice from the countries with rather rigorous safety controls and requirements (for example, more frequent expert-technical inspections of cableways). The reason why such an approach has been chosen is because until now this field has not been legally and institutionally regulated and therefore the role of the state must be stronger in the initial period.

The implementation of cableway rules is expected shortly in the Republic of Serbia. The practice will soon show all the positive and negative sides of this approach according to which the rules regulating this field will be corrected.

Moreover, the following period will require a discussion on the necessity to introduce a mandatory SMS for cableway managers and the manner of its implementation.

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COLLISIONS OF RAILWAY CABLES ON NIS - PRESEVO RAILROAD AND E75 HIGHWAY INFRASTRUCTURE IN GRDELICA GORGE

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Abstract *– Transport Corridor 10 through Serbia is spatially defined by the railway and highway lines in the same infrastructure corridor. Depending on space constraints, the width of the corridor varies from several hundred meters to less than one hundred meters. Of course, the parts where the minimum width of corridor infrastructure, inevitably leading motorway at minimum legally permissible distance from the railway line (eight feet measured from the end point of the upper shaft end of the highway to the railway tracks), resulting in encroachment into truck area. In accordance with the above limits, the inevitable occurred collision railway cables on the railway line Belgrade - Mladenovac - Nis - Presevo State Border and infrastructure of highway Belgrade - Nis - Presevo - FYRM Border (highway E75), especcially in Grdelica Gorge.*

Keywords - collisions, highway, railway, railway cables.

1. INTRODUCTION

Transport Corridor 10 through Republic of Serbia is spatiallu defined bu the railway and highway lines in the same infrastructure corridor.

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 about 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 [1] (in the specific case, the highway E75 Belgrade - Nis - Presevo - FYRM border and the railway Belgrade - Mladenovac - Nis - Preševo - State border - (Tabanovce)).

This caused a significant problem in terms of spatial constrains. The sections where the minimum width of corridor infrastructure, inevitably leading motorway at minimum legally permissible distance from the railway line (eight feet measured from the end point of the upper shaft end of the highway to the railway tracks), resulting in encroachment into truck area. In accordance with the above limits, the inevitable occurred collision railway cables on the railway line Belgrade - Mladenovac - Nis - Presevo State Border and infrastructure of highway Belgrade - Nis - Presevo - FYRM Border (highway E75), especcially in Grdelica Gorge.

Fig.1. Highway E75 and the international railway line Belgrade - Mladenovac - Nis - Presevo - State border - (Tabanovce) in Predejane, Grdelica Gorge (photo by Aleksandar Naumović)

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2. PROBLEMS DURING THE CONSTRUCTION OF THE E75 HIGHWAY

During the construction of the E75 highway in Grdelica Gorge, despite the fact that the Main design was adhered to, the railroad cable was often damaged by heavy machinery (see figure 2). The aforementioned damage led to the interruption of traffic on the international railroad, which resulted in significant unplanned costs, both by the Serbian Railways and by the Corridors of Serbia. This also caused serious disagreements on the Serbian Railways - Contractor - Corridors of Serbia, which resulted in a negative impact on the dynamics of the construction of the highway. Disagreements were solved most by the efforts of responsible people in the Serbian Railways and Corridors of Serbia.

Fig.2. Damaged railway cables during the construction of the highway in Grdelica Gorge (photo by Aleksandar Naumović)

In order to prevent further damage, the representatives of the Corridor of Serbia and the Railways of Serbia agreed that it is necessary to change the Main design in the field of protection and relocation of railway cables.

3. CHANGING OF THE MAIN DEISGN

Due to inadequate quality geodetic maps, the collision solutions within the Main Designs were not of sufficient quality. For this reason, during the execution of the works, Main Designs were changed in the field of protection and relocation of railway cables, in cooperation with the experts of the Serbian Railways.

Adopted solution was the laying of railway cables in concrete channels, with the maximal optimization of the cable line from the aspect of protection and maintenance (see figure 3).

This was applied on Gredlica - Tunnel "Predejane", Tunnel "Predejane" - Caricina Dolina and Caricina Dolina - Tunnel "Manajle" subsections.

Fig.3. Relocation of the railway cables in Grdelica Gorge, laying in the concrete channels (photo by Aleksandar Naumović)

4. RELOCATION OF THE RAILROAD

Extreme problem was reported in Grdelica Gorge, where the final solution of the Main Design has resorted to the relocation of the railway line in a distance of 2 km, to allow placement of the international railway line, highway E75, main road and side road to a very limited space (see figure 5) [2].

Fig.4. Relocated railway line in Grdelica Gorge (photo by Aleksandar Naumović)

Fig.5. Railway line in Grdelica Gorge before relocating (photo by Aleksandar Naumović)

Alternative design solutions would include construction of a long road tunnel (with two tubes) or construction of a road viaduct (two long bridge structures, again) over the railroad. These alternatives were more expensive, and they are dropped in the final solution.

Complete railway infrastructure was relocated in length of two kilometers, including signaling and telecommunicated cables.

Fig.6. Construction of relocation of the railway line in Grdelica Gorge (photo by Aleksandar Naumović)

5. CONCLUSION

Due to the limited spatial conditions in Grdelicka Gorge, the E75 highway has been designed and built at a considerable distance directly to the international railroad. This has led to a significant collision between the highway infrastructure and railway cables. During the construction of the highway, frequent damages to the railway cables occurred, which caused the change of the Main designs.

This would be a treadmill to be a lesson for future designers to take great care of the position of the all underground installations.

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NR/CSM/WOOD FLOUR POLYMER COMPOSITES IN RAILWAY INDUSTRY

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Abstract *– Wood flour composites can be optimized to obtain new materials for a part of the railroad infrastructure. Curing, mechanical and morphological characteristics of carbon black– and silica-filled natural rubber (NR)/chlorosulphonated (CSM)/wood flour rubber blends were studied. Results indicate that the minimum torque and maximum torque increase with increasing filler loading in the compounds, whereas scorch time shows a decreasing trend. The cure time of carbon black–filled NR/CSM/wood flour rubber blends decreases with increasing filler loading whereas silica-filled NR/CSM/ wood flour rubber blends show an opposite trend. Incorporation of filler loading has improved the tensile strength and hardness. However, elongation at break exhibit a different trend. For tensile strength and hardness optimum values were obtained at 30 phr for carbon black and 40 phr for silica, respectively. Overall results show that carbon black (N330) is more suitable to be used as a filler in natural /chlorosulphonated rubber/ wood flour compared to silica (Vulcasil S). Possible application of wood flour rubber blend composites in the manufacture of rubber metal parts for railway vehicles can be expected.*

Keywords –* NR/CSM *rubber blends, carbon black, silica, wood flour, mechanical properties, railway infrastructure.

1. INTRODUCTION

Composite materials are a combination of two or more materials that have different properties, such that the combinations render a product which has intermediatory characteristics of the components. Rubber is one of commercially used polymeric matrix mainly due to the good energy absorbing properties. It can undergo much more elastic deformations under stress than other materials and still return to its original shape without permanent deformation after the stress is released [1]. This unique property gives rubber an extensive variety of applications

The properties of polymer blend composites can be controlled by regulating blend morphology, blend compositions and processing condition. Wood flour (WF, wood finely ground to a powdery consistency) has been used as a filler in synthetic plastics, primarily thermosetting polymers (e.g., phenolics) for decades.

Natural rubber (NR) and chlorosuphonated polyethylene rubber (CSM) have been blended for a long time [2].

The carbon black (CB) and silica (SiO_2) are two basic groups of reinforcing fillers that are able to form their own network in a polymer matrix that is consistent with the specific surface, structure and especially surface reactivity (filler-filler and polymer-filler interaction).

By creating a multi-phase system, characteristics of individual phases can be partly preserved or significantly changed due to the influence of intermolecular interactions. The wood itself is a complex, three-dimensional, polymer composite made up primarily of cellulose (45–50% by weight), hemicellulose (20–25%), and lignin (20–30%).

Therefore, the modern research and industrial practice of rubber industry leaders are directed towards the use of existing starting polymers and the new materials as a filler such as wood flour for a part of the railway infrastructure.

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2. EXPERIMENTAL

Materials: Polyisoprene rubber, NR SMR-20 was supplied by Malaysia; Chlorosulphonated polyethylene rubber (CSM), Hypalon 40S, produced by Goodrich Chemical (q ¼ 1.18 g/cm3, Mw ¼ 5.52 3 105, Mw/Mn ¼ 1.97), contains 35 wt% by weight of chlorine and 1–1.5% by weight of sulphur as sulphonyl chloride (SO_2Cl) units; Fillers: wood flour (WF), a 250–300 lm ponderosa pine was supplied by Kosla Metal Powder (India), q ¼ 2.7 g/cm^3 and carbon black (N-330), primary particle 60 nm, q ¼ 1.32 g/cm^3; silica (Vulcasil S), primary particle 15 nm. Very fast accelerator– tetramethylthyuram disulfide (TMTD) and low fast accelerator– N-cyclohexyl-2-benzothiazol sulphenamide (CBS). The content of fillers: wood filler was 10phr; carbon black type N-330 (primary particle size 28-36 nm) - Volgograd (Russia) and silica filler (Vulcasil S) were 10, 20, 30, 40, 50 phr.

The curing system was: N-cyclohexyl-2-benzothiazolsulfonamide - CBS (1,4 phr); diphenyl guanidine, DPG, (1 phr); N-(cyclohexylthio)phthalimide, CTP 100 (0.2 phr) and sulfur (2 phr). In all rubber, blend compounds the network precursor ratio was NR/CSM/WF 80/20/10 (w/w/w). The content of zinc oxide was 3 phr. The stearic acid content was 2 phr. Plastificator as naphthenic oil content was 10 phr.

All samples are mixed in a laboratory two roll mill Rheometer curves were carried out using an Alpha technologist Rheometer MDR 2000 according to at 160°C and are there used to determine the start of crosslinking t_{s2}, optimum of crosslinking t_{C90}, as well as the maximum and minimum torques (M_{max} and M_{min}). The crosslinking was carried out in an electrically heated hydraulic press (E-604 Metroohm Herisau) under a pressure of 20 MPa and 160°C. The scorch time (t_{s2}), optimum cure time (t_{c90}) and maximum (M_{max}) and minimum torque (M_{min}) were determined from rheometer data.

Tensile tests were performed on dumbbell samples that were cut from elastomeric sheets (2 mm thick). The tensile strength (TS) and the elongation at break (E_b), were determined at room temperature using a Zwick 1425 universal tensile testing machine. The tests were performed according to ASTM D41298a. The given results are the mean value of three specimens. The error in these measurements was ±0.5%. Samples with flat surface were cut for hardness test. The measurement was done using Durometer Model 306L Type A.

3. RESULTS AND DISCUSSION

3.1 Cure characteristics

Silica achieves a more pronounced filler-filler interaction, that is, a larger network of fillers in the polymer matrix, while the carbon black produce a stronger polymer-filler interaction

The cure characteristics as a function of the CB and silica loading (10, 20, 30, 40, and 50 phr) of the NR/CSM/WF (80/20/10) rubber blends are show in Figure 1.

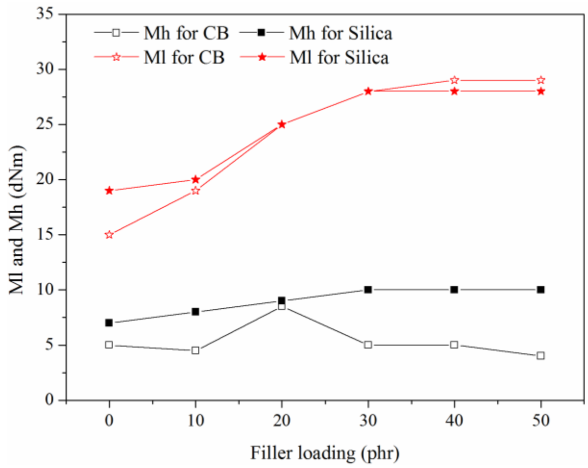


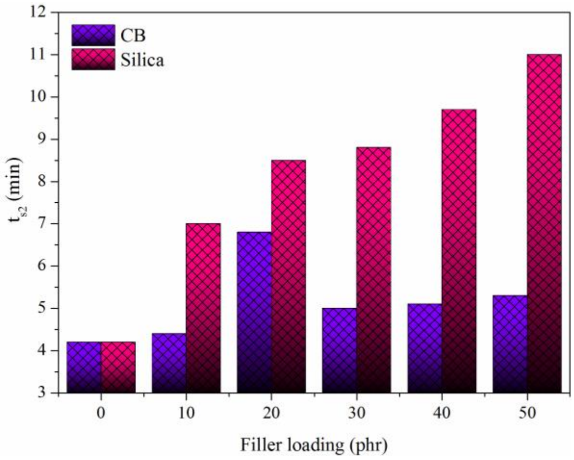
Fig.1. The effect of CB and silica loading on M_h and M_l in NR/CSM/WF rubber blend.

The variation of torque during crosslinking of rubber compounds at 160ºC given in Fig. 1 shows that the maximum torque increases gradually as loading of carbon black and silica in NR/CSM/WF (80/20/10) rubber blend increases. The increase in maximum torque is attributed to the better polymer-filler interaction that becomes more pronounced in 30 phr filler loading. It is reported that maximum torque depends on the crosslink density and chain entanglements. The minimum torque, a measure of the stock viscosity, shows a slight increase with increasing filler loading. This indicates that the processability of the compounds becomes a little more difficult.

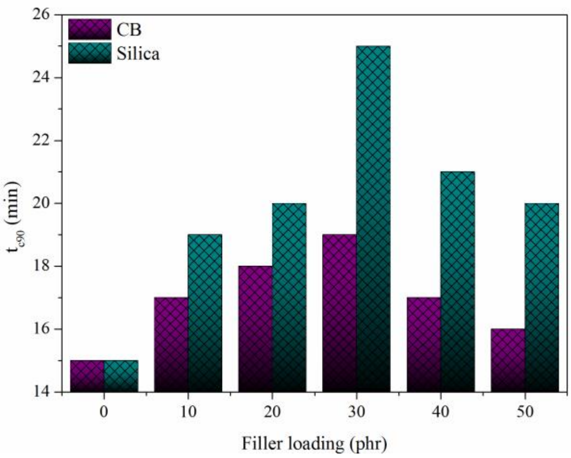
The increase could be due to the agglomeration of carbon black or silica particles in the NR/CSM/WF rubber matrix. The other possibility is that filler is already crosslinked, and do not easily flow in the matrix, so an increase in filler loading will reduce the flow and consequently increase the torque.

WF is non-reinforcing filler and has a particle size bigger than carbon black and silica. The other possibility is that WF in NR/CSM present are already crosslinked, and do not easily flow in the matrix, so an increase in carbon black or silica loading will reduce the flow and consequently increase the torque.

WF presence in NR/CSM rubber blend also influenced to the optimum curing time (t_{c90}) values, as shown in Fig. 2. The cure time values are reduced with carbon black increase but increase with silica increase, substantially. Similar trends were also observed by many authors [3] using different types and sizes of WF particles. The composite based on NR/CSM/WF rubber blends are decreased with CB content increase, i.e. crosslinking process became faster. Lower values of the scorch time indicate that a "period dissolving" of the compound reduces, i.e. crosslinking process starts sooner.



a)



b)

Fig.2. The effect of CB (a) and silica (b) loading on t_{s2} and t_{c09} in NR/CSM/WF rubber blend

3.2. Mechanical Properties

WF is low-cost natural material and the most widely used. A disadvantage of using WF as extender and reinforcement for rubber is that the resulting composites usually have reduced mechanical properties. This is a result of poor adhesion between the hydrophilic filler material and the hydrophobic polymer matrix.

The relationships between carbon black and silica with NR/CSM/WF rubber blend and values of the mechanical properties of NR/CSM rubber blend are shown in Figs. 3–6.

Figure 3 shows the effect of CB and silica loading on the tensile strength of NR/CSM/WF rubber blend. Tensile strength required to break the composite, depends on the rubber macromolecule structure, i.e. on the rubber blend, and to the greatest extent on the filler activity, filler dispersion degree in the elastomeric matrix, and filler-elastomer interaction degree. The maximum value for NR/CSM/WF rubber blend composites reinforced with carbon black is obtained at 30 phr, and with silica filler at 40 ph. Higher values have carbon black reinforced rubber blend composites, according to agglomerates are dispersed to aggregates, where a big contribution to the breaking strength is given by formation of permeating crosslinks polymer-polymer, polymer–filler, and filler–filler. Enhanced tensile strength and reduced elongation are considered as the criteria for better interfacial adhesion. These two properties are also related to the nature and number of crosslinks.

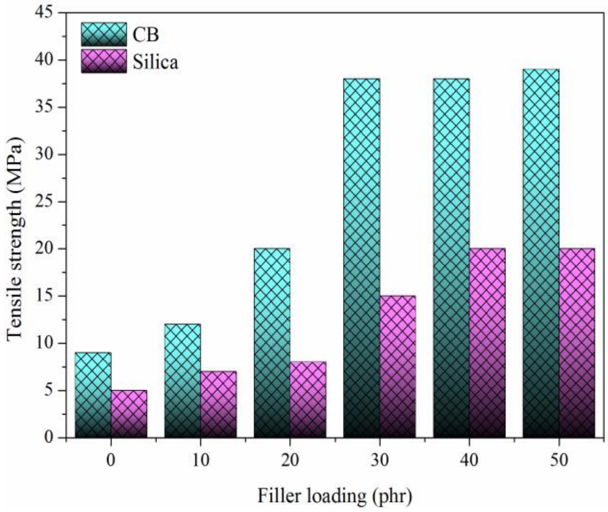


Fig.3. The effect of CB and silica loading on the tensile strength of NR/CSM/WF rubber blend

It is obvious from Fig. 4 that the hardness of NR/CSM/WF rubber blend reinforcing by carbon black shows higher values than those reinforced by silica. The extent of the hardness of the vulcanizate generally depends upon its degree of crosslinking. When the crosslink density increases hardness also increases.

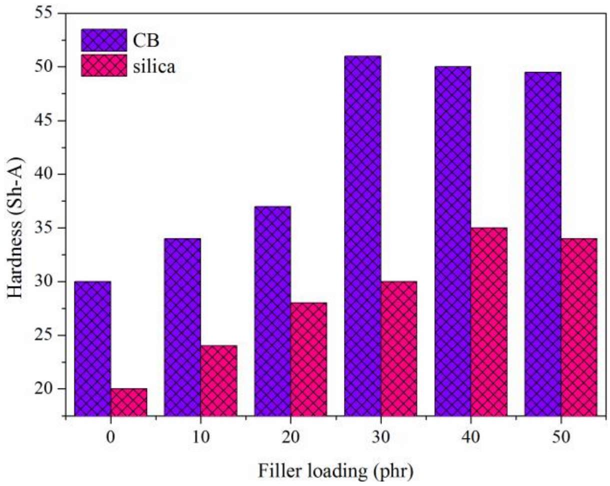


Fig.4. The effect of CB and silica loading on the hardness of NR/CSM/WF rubber blend

Increasing the filler loading in NR/CSM/WF rubber blend reduces the elongation at break of (Fig. 5). By the carbon black ratio increase to 30 phr, and silica ratio increase to 40phr, the filler-polymer interaction increases, elastomeric components ratio in the total quantity of the crosslinked material is reduced, and the rubber chains elasticity is reduced around 60%.

The optimal charging for rubber composites is assumed that all agglomerates fillers are dispersed to the aggregate.

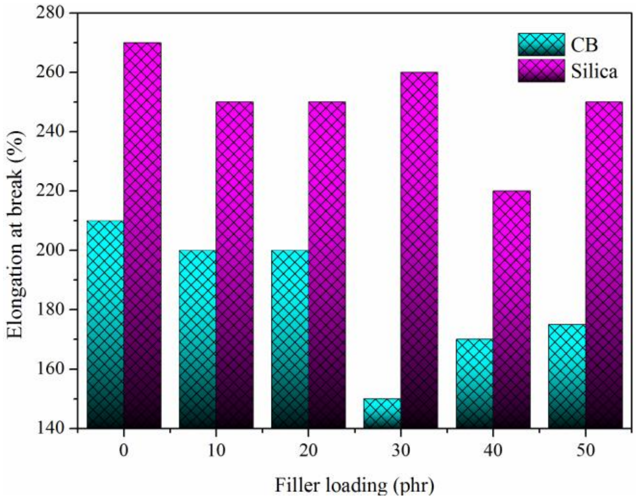


Fig.5. The effect of CB and silica loading on elongation at break of NR/CSM/WF rubber blend

Consequently, the crosslinking density increases when the filler loading is higher what results in a substantial increase in the modulus.

3.3 Morphological study

Figure 6 shows the scanning electron micrograph (SEM) of the tensile fracture surface of NR/CSM/WF (80/20/10) rubber blends with 30 phr of carbon black filler at 2000 magnifications, respectively. Less tearing lines can be observed on fracture surfaces in Figure 6, which indicated that the blend cannot withstand high stress and breaks easily and good adhesion between carbon black and NR/CSM/WF matrix can be observed.

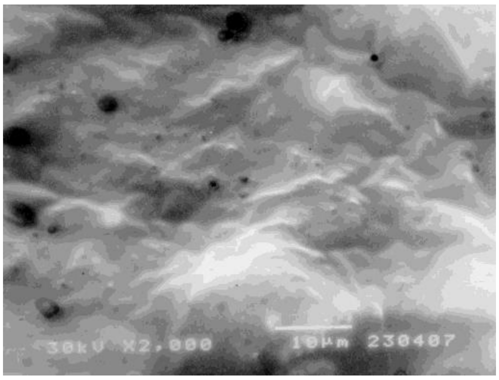


Fig.6. The SEM micrograph of NR/CSM/WF/CB (80/20/10/30) rubber blend at 2000 magnification

4. CONCLUSION

Some conclusions can be drawn as follows:

1. By monitoring crosslinking regime in systems obtained from NR/CSM/WF rubber blend composites, it was found that when CB and silica content increase, the values of the minimum (M_{min}) and maximum (M_{max}) torque, scorch time (t_{s2}) and optimum cure time (t_{90}) are an increase.
2. The hardness and tensile strength are an increase, but elongation at break values are decreasing with filler loading.
3. Morphological study noticed good adhesion between carbon black and NR/CSM/WF matrix.

Possible application of wood flour rubber blend composites in the manufacture of rubber metal parts for railway vehicles can be expected.

ACKNOWLEDGMENT

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SAFETY AND ECONOMIC RISKS DURING THE LIFECYCLE OF RAILWAY VEHICLES

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Abstract *– For the efficient operation of railway vehicles, well-designed technical specification respecting the requirements for their future safe and reliable utilization, development and production meeting the requirements and good quality of operation and maintenance are of great importance for the efficient operation of railway vehicles. One of the major factors for the assessment is the Life Cycle Cost (LCC). They are of great importance to both manufacturers and users, and they play a decisive role both in the market and in the operation of the product throughout its life. Objective life-cycle costing is difficult and brings a whole host of risks. The contribution focuses on the safety and economic risks arising from the decision making and realization of the development, production and operation of railway vehicles, the associated costs, and measures to eliminate or minimize risks from the point of view of both the manufacturing enterprise and the user.*

Keywords – safety, reliability, failure rate, lifecycle costs, risk factors, modernization.

1. INTRODUCTION

Effective and safe operation of vehicles is the goal of both manufacturers and operators. This optimal state prevents the risk factors occurring in the entire process of their development, production and operation. To minimize the negative consequences of risk is necessary to know individual risk factors and to take measures to prevent or minimize the negative consequences resulting from them, or to transfer them to another entity subject [1]. With the development of industry and demonstrated the risks in business processes having a significant impact on the efficiency and overall economic performance and safe operation [2]. Now for the reduction of risk in investing in major engineering products including means of transport has been formulate, the cost of product life cycle, the content and the inherent risks in its application are the subject of this paper.

2. THE METHOD OF LIFE CYCLE COSTS

The principle of the method of life cycle costs LCC - Live Cycle Costs - is objective determination of costs of the various phases of the product life cycle – based on calculations or measurements. These costs include two major time phases of the product: the first - development and production and the second - the proper use and disposal of the product. From the user perspective on the results of the first stage depend purchase price of the product and the results of the second stage of the costs of its operation, and include both the costs of operation and maintenance, as well as any additional costs associated with lower security and reliability, and end of life disposal costs.

The first includes the cost of:

- Market research, development and product design
- Manufacture and eventual preservation, sale, installation and commissioning

and in the second stage of using of the product costs:

- Operation, maintenance and repair of the product, including the cost of any reconstruction and modernization
- Exclusion and disposal of the product.

Interest of product users is to minimalize the total cost of the product life cycle, and that their size was supported reliably and demonstrably. Then you can compare with the same or similar basic technical, safety and operational parameters of the products of their effectiveness and profitability. Basic risks when determining the life cycle cost consists precisely in reliability and provability costs of the various phases and their components, and the difficulty of comparing products with different basic technical and operational parameters.

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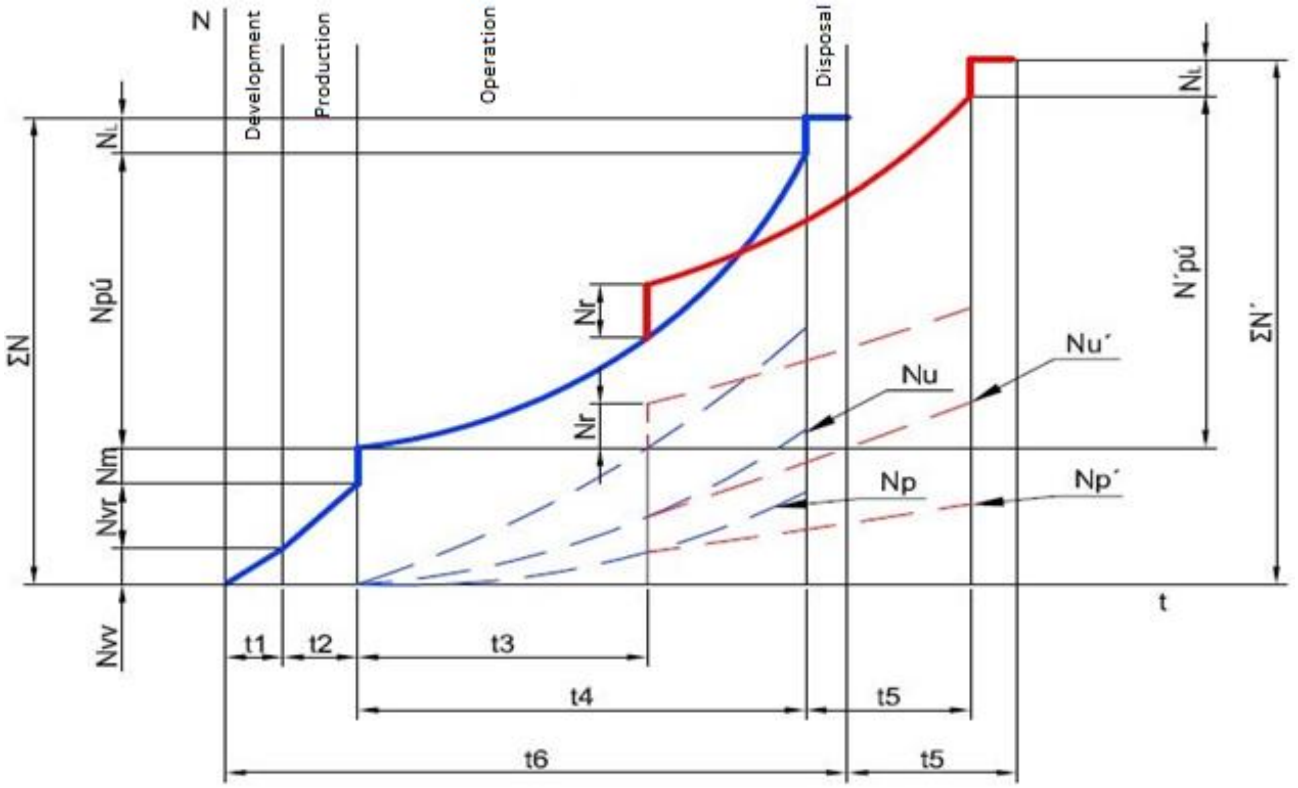

Fig.1. Scheme of dependence lifecycle costed on time

Very important operating parameters significantly affecting the operation of vehicles are safety and reliability and conditions that are necessary for its achievement in service to provide. Already at the beginning of development, it is necessary to establish requirements for these parameters during the development, design and manufacture of products to provide a testing and operation is verified. Similarly, it is necessary during the life cycle to enter pre-defined requirements for environmental effects. It is obvious that the more demanding requirements for the reliability, safety, environmental effects, and for the life of the product, the higher the cost will be mainly in the stage production, which will be reflect in the cost of transport. Even more important component of the costs associated with the operation.

Fig. 1 is a diagram of the life cycle costs. There Nvv shows costs for research and development; Nvr production costs; Nm margins manufacturer; Npú operation and maintenance costs; Np operation costs; Nú maintenance costs; Nl disposal costs; Nr the costs of reconstruction and modernization; N´pú operation and maintenance costs after reconstruction; Np´ operating costs after reconstruction; N´ú maintenance costs after reconstruction; ∑N live cycle costs; ∑N´ live cycle costs after reconstruction; t1 playtime in research and development; t2 production time; t3 playtime increase uptime reconstructed; t4 operating time transport equipment; t5 increase the operating time after reconstruction and t6 live cycle (reconstruction of).

Diagram of the life cycle shows how costs depending on time for a product for the life undergone reconstruction. blue and drawn for a product, which after time t3 renovated - the period after reconstruction drawn in red. The cost in time t2 and t3 are formed in a manufacturing company and after adding the margin enterprise forms the basis of the cost for the operator of the vehicle. Costs in operation in most cases are constant, but grows with time due to operational wear and increasing the cost of operating materials and wages of employees operating and maintenance costs. Has a certain effect and technological progress, the development of new materials and technologies on the one hand and changes in legislation bringing to outdated technical solutions, higher costs, especially in the field of environmental protection. It is therefore necessary during operational use of the product follow the actual reliability of the product and the associated maintenance costs and other costs of operation and considering the effectiveness of any reconstruction or modernization of transport. In many cases, after suitable reconstruction and prolong the lifetime of the whole product. Decisions on the effectiveness of reconstruction and determine the appropriate timing and extent of reconstruction is one of the most risky decisions during use.

The ratio between the cost of acquisition of means of transport (ie. the costs of the development, design, manufacture and possibly commissioning and operation costs) and disposal from the customer's perspective are very important. For complex engineering products are usual costs in the second phase of a product are increasing, which generally exceeds the cost of the first phase. Their objective determination and underlay credible data is very difficult and complicated products and demanding, again including labor and material costs [3]. An important part of this is compliance with the manufacturer's recommendations and technical diagnosis of the actual condition of the vehicle. Now determination of operating costs during the development and construction of means of transport brings a number of risks, whose origin and factors that influence them, you need to know.

3. RISKS WHEN DETERMINING THE COST OF DEVELOPMENT AND CONSTRUCTION

Risks at this early stage of the product life are severe and can significantly affect the cost of the product lifecycle. To minimize the risks should be clearly and specifically define the requirements for the overall reliability and its selected parts, safety, environmental protection, quality and consumption of operating materials or energy depending on performance or time and qualifications [3]. After completion of the tender or other choice of the manufacturer, it is necessary to discuss these requirements and, after completion of development to fix in terms of binding technical product that they could be verified.

When developing a new vehicle there are risks, especially in the fulfillment of certain conditions and finding ways of their implementation in design, technology and manufacturing as well as in identifying the operational requirements for the use of the product. To minimize the risk it is necessary a good knowledge of the most advanced technical solutions in the field of design, technology and energy performance, reliability and safety characteristics verified calculations or tests and perfect cooperation with the design, technology and manufacturing components.

Construction of a new product or upgrade, or upgrade existing product, usually with more advanced technical and operational requirements is based on market requirements, or specific customer and to a large extent responsible for the production and operating costs. Underestimation of risk in this stage is difficult to repair. In terms of cost of production is the most serious risk of poor technology of production, which can bring significant additional costs and results from imperfect cooperation structural sections and the production. It is important for producers and users to ensure the typing and unification with similar products, appropriate technology and design tolerances on parts, which must be ensured interchangeability, demountability parts subject to wear and tear and the right choice of materials and processing technology of the securing specified requirements.

4. RISKS IN PETTING OF THE PRODUCTION AND SELLING COSTS

Risks during petting of production costs consist primarily in that it does not ensure optimum manufacturing process and preparatory, logistics and control processes that secure it and directly affect production costs. A separate area then the risks are related to the area of cost of sales before the beginning of the actual operation of the vehicle. Minimize these risks is a critical concern manufacturing company because they are critical for its competitiveness and indirectly to ensure safe and reliable operation of the user. The main requirements are:

- preparation and quality control of the production process
- maintenance and quality control of the production equipment
- consistency between the requirements of design and manufacturing capabilities
- quality control system

Sales and marketing expenses directly related to the price at which the future user buys the product and the economic effect of the product vendor. In terms of application methods LCC user monitors overall life-cycle costs of various products offered and the time of purchase for him a decisive purchase price and the amount and verifiability costs of other life cycle stages and evidence of meeting the required parameters.

5. RISKS IN ESTABLISHING THE COST OF OPERATION AND MAINTENANCE

Operation costs include the costs of operating materials, or delivered energy and labour costs. Maintenance costs include all costs for preventive maintenance and repairs to correct faults arising in the operation, including cost of material and personnel. Specific categories of costs of operation and maintenance costs are upgrading or reconstruction. Risks in all three of these areas lie mainly in line with actual costs determinable or contractually enshrined costs, in terms of security for compliance with the prescribed mode operation and stability, possibly a correct estimate of trends in prices and labor costs associated with the operation and maintenance.

5.1. Risks in setting the costs of operation

Risks for the actual cost of operating the appliance lie in the following areas:

- specific consumption of operating materials or energy depending on the time of performance or operation of the equipment does not correspond to the values declared by the supplier

- qualitative parameters of operating materials and energy are lockable
- the product does not achieve the declared performance parameters
- prices of consumables, energy and labour costs have developed differently, generally less favorable than expected
- the product is not sufficiently exploited.

As is evident from the above list, is the cause of risks for both the supplier and in some cases also on the operator's side. Minimize the impact on users in the event that it proves that the actual values of operating costs do not match the declared values declared by the manufacturer during scrutineering or warranty service under the conditions of operation specified by the manufacturer, can be achieved if the quality contractual documents. Then you can request adjustments or compensate for additional costs. Any increased costs associated with the inadequacy of means of transport is necessary to solve organizational or its variation.

5.2. Risks in setting the maintenance costs

Objective setting of maintenance costs of newly developed and manufactured engineering products is very difficult and it usually account for a substantial part of the cost during operational use of the product. In principle, it needs to establish and verify the reliability parameters and characteristics of individual elements of the product, or their operating time in the necessary maintenance or fault and durability [4].

In doing so, it is necessary to pay attention to the nature of possible defects and their consequences in order to avoid such disruptions, which could lead to security threats or significant costs for the consequences of failure. This raises the need to build necessary monitoring and protective elements, which is reflected in the cost of development and production, and consequently in the price of the product.

Risks when setting maintenance costs consist primarily in the following areas:

- lack of reliability characteristics and durability of the new elements of transport
- defects in the design documentation
- unexpected interaction of individual elements in product operation failure to power and operational parameters.

Most of these risks should be eliminated or minimized during the development, validation and approval of the product. Like the operating costs can be causes of risk in actual maintenance costs and subsequent repairs on both the manufacturer and the operator side. Similarly, it is also necessary to take measures to minimize the impact of these risks to the overall costs.

6. RISKS ASSESSMENT IN SETTING THE COST OF DISPOSAL

For economic and ecological reasons, it is necessary in accordance with applicable legislation means of transport after the expiry of his real-life discarded. Therefore, the cost of disposal belongs to the life cycle costs. Depending on the nature of the product in some cases may be some units that are acceptable and technically compliant, further use eg. as spare parts. Risks in this final stage of the product life lie mainly in the following areas: transport does not end after the real-life and disposal costs are higher than expected.

7. CONCLUSION

The method of defining life-cycle costs is especially important when deciding on the order of a particular vehicle with predefined requirements.

Minimizing risks can achieve by the client compliance in terms of required technical and operational parameters and operating in accordance with specified conditions. By the potential supplier thorough analysis conditions and the ability to meet specified requirements of knowledge or background check, assumptions, reliability and durability of the product and its components and the resulting costs for the individual phases of the product lifecycle.

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THE ROLE OF HUMAN RESOURCES IN THE IMPLEMENTATION OF THE INVESTMENT POLICY IN THE RAILWAY INFRASTRUCTURE

Mira ZAFIROVA [1]

Abstract *– The main strategic goal of the national railway infrastructure policy is the development of a good and high-quality transport network. The strategic location on the territory of the country as a transit country between countries rich in natural resources from the Middle East, Western and Central Asia and the economically and industrially strong countries of Western and Central Europe and the accession of Bulgaria to the European Union are the factors, which promote interoperability with the trans-European rail system.*

Transport and communications generate 11.7% of the country's gross added value and provide direct employment to over 138,000 people.

Each project is dynamic and involves a continuous transition - in time, money, participants, therefore there is always a certain risk that needs to be managed.

The purpose of this paper is to present the specificities of investment policy in railway infrastructure in the context of the national strategy and operational program for the period 2014-2020.

Keywords – rail infrastructure, human resources, risk.

1. INTRODUCTION

The "National Railway Infrastructure Company" is the manager of the railway infrastructure of the Republic of Bulgaria at present. The main activities are:

- repairs, maintenance and operation of the railway infrastructure;
- ensuring the use of railway infrastructure by licensed carriers on a level playing field;
- development of train timetables, train management of railway infrastructure in compliance with safety, reliability and safety requirements;

In the territory of Bulgaria, 5 of the 10 pan-European transport corridors pass on the territory of Bulgaria - IV, VII, VIII, IX and X. Their total length amounts to 1694 km.

Bulgaria's accession to the European Union reinforces the need to use territorial and social factors for growth and sustainable development. These objective realities require Bulgaria to pursue a regional policy of reducing interregional disparities in employment and income of the population and, above all, implementing regional and cross-border cooperation. For this purpose, a number of documents have been developed and adopted.

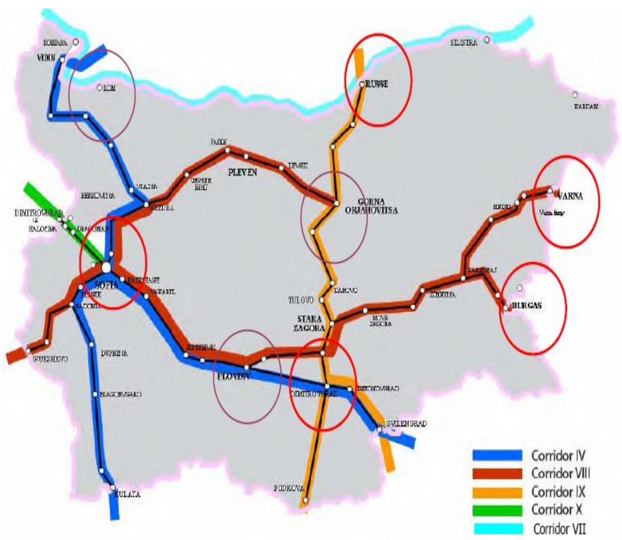

Fig.1. pan-European transport corridors passing through the territory of Bulgaria

The purpose of this report is to present the specificities of investment policy in railway infrastructure in the context of the national strategy and operational program "Transport and Transport Infrastructure" for the period 2014-2020.

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1.1. Analysis of the state of the railway infrastructure in the country

Most of the railway infrastructure in Bulgaria was built more than 50 years ago with geometric parameters, constructions and facilities suitable for speeds up to 100 km / h. The total length of the railway lines in Bulgaria is 6 474 km.[1]
The characteristic features of the railway infrastructure in Bulgaria are:

- Unbalanced territorial distribution of railways lines in the country. In the southwestern region of country there are the highest density of railway network (length per unit area- 44.8 km / 1000 sq. km);
- Relations with neighboring countries are relatively limited;
- Of the total length of the railway network, 70% are electrified. Compared with other European countries, their share is satisfactory;
- The railway facilities (bridges and tunnels) have a high degree of depreciation;
- A large part of the insurance, telecommunication and power supply systems are outdated (put into operation in the period 1965-1985) and at a technological level that does not meet the current requirements for interoperability.

1.2. Priority objectives

In order to adapt Bulgaria's railway infrastructure to European standards, national priorities need to be aligned with those of other EU Member States to improve the European transport system. For this purpose, the following main actions should be emphasized:

- Development and construction of the Trans-European Transport Network (TEN-T);
- Transfer / relocation of goods from road to rail;
- Building an integrated European railway area;
- Development of modern railway transport in order to reduce the emissions of carbon monoxide;
- Increasing the share of private capital in transport development schemes;
- Development of combined transport.

Overcoming the lagging behind of the railways in the Republic of Bulgaria in technological and technical terms requires efforts to focus on:

- the reconstruction and renewal of the railway lines in order to increase the design speeds and the throughput of the railway network on the territory of the country;
- implementation of permanent track maintenance and high level of safety;
- building new intermodal terminals and improving the technical and technological parameters of existing terminals.

After Bulgaria's accession to the European Union, we are working hard to improve the railway infrastructure.

Achieving the goals set has been significant in recent years. The planned larger infrastructure projects for rehabilitation and new construction of the railway infrastructure are:

- Electrification and reconstruction of the railway line Plovdiv-Svilengrad - Turkish border;
- Modernization of the railway section Septemvri - Plovdiv;
- Modernization of the railway section Sofia - Elin Pelin - September;
- Rehabilitation of the railway infrastructure in sections on the railway line Plovdiv – Bourgas;
- Modernization of the Vidin-Sofia railway line;
- Modernization of the railway line Sofia - Dragoman - Serbian border;
- Construction of an intermodal terminal in Sofia;
- Modernization of the Sofia-Pernik-Radomir-Gyueshevo-Macedonian border railway line;
- Restoration of the design parameters of Rousse - Varna railway line.

2. REALIZASION

Each project is dynamic and is associated with a continuous transition - in time, money, participants, therefore there is always a certain risk that needs to be managed.

The risk management process focuses on the needs and priorities of the client and includes methods, techniques and tools specifically designed for that purpose. The process is often run by a risk manager or by an analyst responsible for creating a framework to extract information from key project personnel through risk identification and evaluation. [6].

Risk is an event of a probabilistic character with unfavorable consequences. Risks can be classified according to their implementation to the construction phase of the construction site and have a different focus: risk associated with implementation deadlines, design risk, financing risk, implementation schedules, construction risk, etc. [3].

Structure production is also characterized by its stochastic nature - construction sites are carried out in the open and are often accompanied by natural-natural risk situations that occur independently of human behavior and knowledge.

The most common way to perform a risk assessment is to gather key personnel for risk identification sessions. [6]

A risk workshop is a brainstorming session that consists of three aspects:

- identification-identify each risk that the project is subjected to;
- estimation-determine how important each risk is based on an assessment of two factors such as

probability and impact;

- evaluation-determine whether each is acceptable or not, and if not the actions that can be taken to make it more acceptable.

Financial risks are associated with significant increases in costs and delays in implementation. Under the Transport and Transport Infrastructure OP 2014-2020, EUR 572 million is foreseen for the development of the railway infrastructure. The funding for Bulgaria under the cohesion part of the Connecting Europe Facility (MEF), amounting to EUR 350 million, will be mainly geared to railway projects. [5] No matter how detailed the infrastructure assets are calculated, there is an increase in costs and a corresponding delay in terms of time.

A study of 258 projects in 20 countries, with approximately $ 90 billion, found that in transport infrastructure projects the planned costs are not being met. Significant cost increases are a rule, not an exception, and increased costs are associated with significant delays. For railways, the average price of overtaking above the projected price is 45%, for tunnels and bridges it is 34%. [5] Large costs and delays, are becoming major financial risks.

The successful implementation and implementation of each project depends on both the management team (the project manager and his team) and the contractors.

The efficiency of business management is primarily determined by the approach to configuring the main elements of the management system in the implementation of the overall site. The main factors influencing the process of taking and implementing management decisions are [2]:

- knowledge of the characteristics of the surrounding environment;
- knowledge of the mechanisms of targeting throughout the hierarchy of the system;
- knowledge of management technologies and mechanisms;
- knowledge of the system of resources;

According to Mancheva [5] in the realization of the project "Preparation of Detailed Development Plan and Technical Projects for the project: Modernization of Sofia-Plovdiv railway line: railway sections Sofia-Elin Pelin and Elin Pelin - Septemvri" for Ihtiman-Septemvri section " "The lack of quality and effective project management" is 79.43%. The probability of the risk of "lack of coordination and interaction between the individual participants in the overall process of project preparation is defined as 73.85%;

The achievement of the project objectives is a complex and responsible task and is related to good knowledge of all production structures and control throughout the lifetime of the site implementation.

The criteria for the evaluation of bids in conducting the procedures for the selection of contractors for construction or engineering (design and construction) are "the lowest price" or "the most economically advantageous tender"[3]. These criteria are essential in identifying the risk. Under the "lowest bid" criterion, bids are only evaluated in terms of the bid price. This criterion does not give assurance to contracting authorities about the quality of public procurement performance.

The "most economically advantageous tender" criterion includes different indicators - calendar planning (implementation deadline), financial evaluation, technical evaluation, etc. Employers determine the relative weight of each of the indicators in the submitted bids and after the combination they form the final grade for each candidate.

Many bids are won on the "lowest price" basis, where the latter are only valued in terms of the bid price. This criterion does not give assurance to contracting authorities about the quality of public procurement performance. Poor quality is often caused by the lack of skilled labor.

In the June-August 2016 , was conducted a study with 31-participants [4]. Participants are conected with infrastructure projects practicing in the construction industry, consultancy and design firms and in organizations - contracting entities of infrastructure projects, which are representatives of municipal and state structures. Some of the participants are Project Management Managers.

The questionnaire contains 56 risk factors, divided into 4 categories and 12 subcategories. A risk profile is created through a relative impact index (EAR) for each risk based on its impact on time and cost of project implementation. the analysis of the results is as follows:

- The probability of a risk factor affecting the cost due to the shortage of qualified hand is 12.56% This risk is fourth in importance.
- The probability of a risk factor affecting the performance schedule due to shortage of qualified hand is 15.55%. This risk is first of all significant.

The reasons for the financial risks can be of a different nature given the dynamic and stochastic nature of construction production. The robustness of processes and the reduction of risks depend on the elucidation of ongoing processes.

Risks will always exist. To date, the projects are developing in an extremely dynamic environment due to the pace of development of our entire society - materials, tools, technologies. No organizational and economic system can exist without human resources.

Managing human resources within a project is a multi-stage process. Yeah, they're like that:

- planning;
- recruitment and selection;
- payment and motivation;

- training;
- promotion, decrease, relocation, dismissal.

But this process can be carried out in the presence of such cadres and the conditions for their development.

Human resource planning should be considered on the one hand with regard to the activity of the construction company and on the other hand as a long-term resource that requires special attention. Managerial actions and impacts are needed both to enhance motivation, attract young people, and use individual human qualities and train them in the specific field for competitiveness.

3. CONCLUSION

Railway transport has significant advantages over other modes of transport. But the role of our society is to develope this kind of transport in order to make use of these advantages. To this end, good management and executive staff is needed. Creating good staff is a long-term commitment and responsibility for the whole of society.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

THE RIGHT TO EDUCATION OF RAILWAY WORKERS IN THE REPUBLIC OF SERBIA WITH SPECIAL REVIEW ON ENGINEER

Aleksandar BLAGOJEVIĆ[1]

Abstract *– The paper discusses the system and models of education and training railway workers in the Republic of Serbia since the release of the first railway line in 1886 to the latest proposals that the training of engineers in the future will be carried out in an informal manner outside the school centers.*

Keywords – education, railway workers, railway, training.

1. INTRODUCTION

According to the current model, education for occupations in rail transport is organized at school centers for vocational education founded by the competent ministry, and some forms of training are also carried out in railway companies. The new proposals envisage that the entire education and training of engineers and other railway workers can also be carried out in railway companies as non-formal education.

1.1. Building a resource base

When the first railway transport in Serbia was established in 1886, it was a great personnel challenge for the former state. In a poorly developed country, with a low technical base, the rail system was the first major step towards technical progress.. In particular, this was a challenge for the Ministry of Transport and the Ministry of Education." The railway has established a new, not only a technical-technological system, but also a new recruitment system, training, service, supervision and control of personnel according to a prerequisite hierarchical organization, which created a specific image of the society in the railways." At that time, the development of the human resources management system in "Serbian Railways" started, which is a condition and basis for the functioning of the railway as a large system.

Until the World War II, railway employees in Serbia acquired "solid education and training for specific occupations of the executive service (trainee trainer, engineer, etc.) in special railroad schools and types of education, according to special curricula, with specific examination. In defining the content and objectives of the curriculum and training programs, and staff training, the parameters were the obligation to know a lot of regulations by railway workers under which the operating rail transport is carried out with strict order, control, sanction and others.

After the end of World War II, forming and securing the necessary professional and specialized workers for the renewal of rail transport was the task of human resources services. To that end, four-year and three-year secondary schools were opened in Novi Sad, Maribor, Ljubljana, Nis, Sarajevo, Kraljevo, Subotica, Belgrade and Zagreb, in which railroad technicians, as well as qualified railway workers, masters for work in railway workshops and other workplaces on the railway. Also, one-year rail-traffic schools for trainees in Sarajevo, Skopje, and Sentvid, and special railway trainers for employees, have been established, where the internal secondary education for the needs of the railway has been acquired. Since all this was not enough, there were also courses lasting half a year for lower-level workplaces.. In this way, by the year 1950, a total of 54,782 workers acquired the necessary education and training for work in the railway activity in the country. From the middle of last century, an intensive process of qualitative and quantitative development of education, training and training for the needs of rail transport within the school network in the country took place. New railway traffic schools in Zemun, Kastvu, Srpske Moravice, Traffic Faculty and the Higher Railway School in Belgrade have been established and appropriate directions at higher technical schools in Nis and Subotica. Curricula and programs have been inaugurated, and periodic courses have been organized for employees from the working relationship for seniors, and there are still some professions of lower qualifications. Also, students of

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mechanical, construction, and electrical faculties have been awarded scholarships to provide highly qualified technical staff for railroad work throughout the country.. The intensive development of rail transport was accompanied by an adequate system of vocational education. Railway school centers in Ljubljana, Belgrade and Zagreb were created, from which a railway submarine came, human resources planning methodology was improved, new regulations on professional trainings were adopted, and a new nomenclature of occupations in railway transport activities was adopted in accordance with the new technique and rail technology, etc.

The seventies of the last century reformed the system of secondary education throughout the country. Two-year secondary schools for general education and two-year secondary vocational schools for the fourth degree in a chosen occupation were formed. According to this model, engineers, trainers, and other railway workers were also educated. After several years, this model was rated unsuccessful and abandoned, and independent four-year and three-year vocational schools and vocational training centers for relevant activities were re-formed. It is a model that is still in force today.

2. CURRENT MODEL

When considering the system of education, training and training of engineers, it is necessary to bear in mind that any education can be formal and informal. Formal education is an organized learning process based on accredited curricula and curriculum at primary, secondary and high level, and informally based on specific programs in order to acquire specific knowledge, skills, and abilities necessary for work and personal.

The existing legislation on education of railway workers in the Republic of Serbia has a significant impact on the existing laws and regulations, in particular the Law on the Foundations of the System of Education, the Law on Secondary Education and Education, the Law on Adult Education, the Law on Safety and Interoperability in the Railway, qualifications, Law on National Quailifikations Framework, as well as regulations issued by the Serbian Railways Directorate.

According to this system, formal education and training of engineers is organized according to curricula and curricula within the existing school network, over which the competent ministry has control.By this system, future trainee technicians must first complete a four-year rail transport school according to the curriculum prescribed by the National Education Council.Then follows a mandatory traineeship lasting six months under the supervision of a mentor, as well as taking a trainee, professional exam, from the theoretical and practical part. After the successful completion of the internship and passed exam, the trainees have been trained for independent work of the machine engineer, but it is prescribed that the first year of independent work the young engineers have to be followed by front passenger - a mentor, an experienced engineer with at least five years of work at the workplace engineer. At the end of a year of successful work, a young engineer becomes an independent worker, a trained technician.

3. INFORMAL EDUCATION

The Assembly of Serbia is in the process of initiating the adoption of novelties in education and training, and the manner of acquiring professional skills of railway workers, as well as engineers. Newspapers that are proposed, if adopted, will give greater opportunities to railway companies, including foreign companies that are preparing to enter Serbia's transport market, to train themselves, informal education of engineers and other railway workers, regardless of the official school system in Serbia in which formal education is acquired.

The following, most important inovations are proposed:

- establishment of training centers for trainers and railway infrastructure managers.
- the new way defines the type of previously completed secondary vocational school as a condition that the candidate be selected for theoretical and practical training at the center for professional development,
- the duration of the vocational training process is shortened,
- new way of checking the performance of the mortar,

in a new way,

- the provisions on the independent work of new engineers are defined, etc..

These proposals, if they are fully accepted, can have significant consequences for the safety of railroad traffic in Serbia. Therefore, it is necessary to critically consider and point out the limitations, risks and possible consequences that can arise in the practice of railway traffic on the railways in the Republic of Serbia.

The initial objection is that companies - the railway carrier or infrastructure manager - do not have material, personnel and organizational conditions for the required quality of training and professional training of engineers. It is justified that there are centers for so-called permanent education in these companies, but there are no conditions for the basic vocational education of engineers, as they exist in traffic technical schools, whose education is the main activity.

It is not a realistic expectation that they can successfully qualify for the job of engineers candidates who have previously completed high school for occupations bakery, butcher, carpenter, etc., instead of a completed four-year traffic rail school for the profession of towing technician - electrical engineer, or diesel tow. Practice has shown that in companies always the most successful employees who had continuity in one occupation, ranging from the lowest to the highest places in the hierarchy.

The proposed newsletter envisages training time in eight months training centers for theoretical training, and another four months of training for driving under the supervision of instructors for practical training.However, in order for the candidate to become trained for the independent work of a machine operator, more time is needed for training..4. The method of checking the success of the candidate's training on the proposal of the proposer is classical and usual, and it is not disputed. A pre-existing training system is controversial.

The proposal that a machine engineer qualified in the manner described immediately after passing the exam can independently carry out the work of the engineer without the obligation to have a mentor in charge of him in a year, carries a great risk for traffic safety.

4. TAYLOR'S SCIENTIFIC MANAGEMENT AND MODERN HRM

When looking for answers to the current issues of effective education and training for the profession of engineer and the challenge of the present time, two important determinants important for the selection of the optimal model of vocational training and employee training, especially in industrial activities, should be taken into account. One is Taylor's scientific management, and another modern human resource management in modern companies.P.Draker has found that "in decades after the Second World War, training based on Taylor's teachings has become the only truly efficient driving machine of economic development." He states that the US industry, by applying Taylor's scientific management, during the World War II, trained fully unskilled workers in first-class welders, shipbuilders, and masters for the production of precision optical instruments (now the principle of "training and commandments") for sixty to ninety days. Thanks to that, the United States built a powerful navy and managed to defeat Japan in the Pacific. In the United States, you also have the "You are overqualified" principle - you have too many qualifications. The concept does not need the most qualified and educated, but uneducated, cheap labor.

The second determinant is modern HRM in large multinational companies These companies have a developed staffing system, which includes all human resource management activities, including an assessment of the candidate's suitability for the job and the company, and the company for the candidate. On receipt of new employees the company is not a priority formal educational attainment and the knowledge acquired in previous education, but the willingness and ability of the applicant..These guidelines are important for large companies in industrial and some other activities, but they, however, although they should not be overlooked, are less relevant for the concrete situation in railway transport companies in Serbia. In some other circumstances and conditions of this heading, it will be significant for rail traffic in Serbia, but not now for the training of engineers. The training and training of engineers must only be in school centers.

5. CONCLUSION

Although today's schools have serious shortcomings, they acquire the necessary general and vocational education, education, personality, socialization, the basis for further education, and there is a possibility that curricula and programs can be supplemented, modernized and adapted to the needs of companies as needed. On the other hand, companies in the field of rail transport in Serbia do not have the necessary capacity to undertake complete professional training and training of engineers for their needs. However, they can, and should, organize in their centers the so-called permanent education, education, innovating existing knowledge, familiarizing employees with newspapers in railroad traffic, and the like. In conclusion, there is a need for permanent and maximum cooperation between accredited vocational schools and companies in the traffic area, in order to synchronize all activities in the direction of quality education and training of engineers for the needs of railway transport in Serbia.

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The Graduates and the Future of Railway

XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

HOW TO MANAGE PUBLIC SERVICE OBLIGATION CONTRACTS

Student: Uroš STANIMIROVIĆ [1]
Mentor: Branislav BOŠKOVIĆ [2]

Abstract – *The restructuring of railway sector includes not only changes in newly created railway companies, but also changes in relationship on relation state - railway company. One of the key changes is the introduction of a contractual relationship between the government and the railway company in passenger transport that replaces conventional subsidies. The primary objective of introducing a contractual relationship is to increase the efficiency of the railway undertaking, to obtain value for the money invested, to increase the quality of service for the user and the efficiency of the railway lines. However, in practice, these contracts are not managed in all countries in the initial period of its introduction due to insufficient knowledge and appropriate skills primarily at government level, and then on the side of the company for the transport of passengers. Paper presents an analysis of the problems in the management of these contracts and the basic principles and leverage for management. The approach in contract management is based on the CMMI contract management model.*

Keywords – Railway, Public service obligation, Contract.

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XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '18

COMPARATIVE ANALISYS OF THE TRACTION CURRENT ACCESS CHARGES

Student: Miloš STANOJEVIĆ [1]
Mentor: Branislav BOŠKOVIĆ [2]

Abstract – *The subject of this paper is to explore and analyze the existing models of organization of the systems in which the processes such as delivery of the traction current, calculation and collection of consumption data, structuring and leveling of access charges for the traction current itself all takes place. At roughly the same time as railway sector, the energy sector of EU also went through the process of restructuring according to EU market policy, and it had as a consequence a segmentation of the electricity market, namely, the separation of the activities of generation, transfer, distribution and the supply of electricity. If this market segmentaion is being taken into consideration altogether with the idea of free choice of the supplier of electricity, applied for all final users, the railway sector has found itself in a complicated situation to organize its system and way of consumption calculation, and still to remain in line with demands of both, railway and energy regulation. The paper's main goal is to explore this very up-to-date field and eventually to offer possible solution(s) for the railway sector of the Republic of Serbia in context of system organization, model of consumption calculation and collection of charges for consumed traction current.*

Keywords – traction current, access charges, electricity, mobile measuring devices.

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CONDITION MONITORING OF RAILWAY TRACK

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Abstract *– Main characteristics of railroad traffic are listed in this work. Railway infrastructure and railway vehicles are the basic technical means for performing rail transport. The level of development of rail transport in one country depends directly on the development of the railway infrastructure in which the track has the greatest importance. The safety of rail transport is directly dependent on the state of the track, and because of that the monitoring of railway track is a very important activity of the railway enterprises. In this work is presented classification of malfunctions on the track and description of diagnostic procedures which are used in track monitoring process in order to perform efficient of maintenance. The diagnostic procedures for track inspection are given through examples of good practice in Germany and Hungary. The track-maintenance efficiency, among other things, is based on timely diagnostics of failures. A significant improvement in the condition-based maintenance of the railway track would be achieved if the track inspection is carried out by locomotives that are in service ie. regular traffic.*

Keywords – Railway infrastructure, track, condition monitoring, maintenance, safety.

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DEVELOPMENT OF NEW RAILWAY TECHNOLOGIES ACCORDING TO RESEARCH IN THE PROGRAM "S2R - SHIFT 2 RAIL"

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Abstract – *Increasing the competitiveness of rail transport takes place in several directions: restructuring of the railway sector in order to increase liberalization and competition in the infrastructure, better linkage between railway and other modes of transport, introduction of new technologies and business models, etc. The EU`s efforts in this direction are supported by the funding of numerous research into the application of modern rail technologies in the original rail technologies. All projects are public with obligation to publish content and research results on EU portals and project website. Special attention in this paper is dedicated to defining the concept of technology, and the presentation of European funds that finance research of importance for transport, in particular the program "S2R - Shift 2 Rail" as well as the method of access to research and project presentation (template). There is also descriptive statistical analysis of presented projects.*

Keywords - railway, technology, Shift 2 Rail.

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TAXONOMY OF NEW TRANSPORT TECHNOLOGIES OF IMPORTANCE FOR THE DEVELOPMENT OF RAILWAY

Student: Teodora MILENKOVIĆ [1]
Mentor: Branislav BOŠKOVIĆ [2]

Abstract – *Increasing the competitiveness of rail transport takes place in several directions: restructuring of the railway sector in order to increase liberalization and competition in the infrastructure, better linkage between railway and other modes of transport, introduction of new technologies and business models, etc. The EU`s efforts in this direction are supported by the funding of numerous research into the application of modern rail technologies in the original rail technologies. All projects are public with obligation to publish content and research results on EU portals and project website. Special attention in this paper is dedicated to defining the concepts of technologies and innovations, then presenting European funds that fund research of importance for transport and railways, as well as the method of approach to research and project presentation. There is also descriptive statistical analysis of presented projects.*

Keywords - railway, technology, innovation, EU fund.

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INNOVATION IN TECHNOLOGIES OF TRANSPORT OF GOODS

Student: Stefan STANKOVIĆ [1]
Mentor: Branislav BOŠKOVIĆ [2]

Abstract - *In the last twenty years there have been numerous innovations in the transport of goods, which have a significant effect on the rail transport of goods. With the globalization of the market and business, the implementation of innovations in all modes of transport and even in the railways has been accelerated. Particularly important is the aspect of intermodality in transport, which is a great opportunity for railways to increase its participation in the transport market. In this paper, special attention is devoted to defining terms concept, technology and innovation as well as defining a unique system for presenting innovations in intermodal transport. Considering the diversity of different innovations in this paper, seven innovations that are applied or will be implemented in the near future are described.*

Key words - technology, innovation, intermodal transport, concept.

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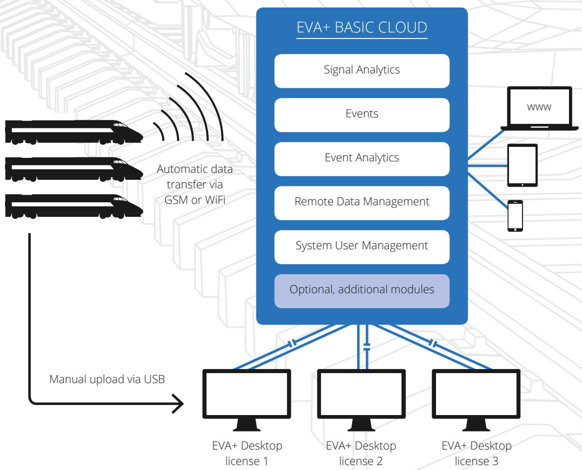

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PRODUCTS & SOLUTIONS

DATA AQUISITION & RECORDING
- Data / Event recorders - Juridical Recording Unit (JRU)
- Safety functions
- Badge readers
- Voice & video

RAIL DATA MANAGEMENT
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- Incident investigation
- Fleet location

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- Protocol converters
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- Outdoor integrated voltage & current sensors for AC or DC
- Indoor integrated DC voltage & current sensors
- Indoor DC sensors voltage or current

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- Hall effect speed sensors
- Odometry solutions

DISPLAY & VISUALIZATION SOLUTIONS

SPEED INDICATORS

CONTROL, PROTECTION & I/O
- Vehicle Control Units (VCU)
- Remote I/O units
- Traction protection relay solutions
- Cold movement detection SIL4

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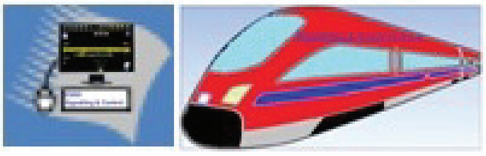

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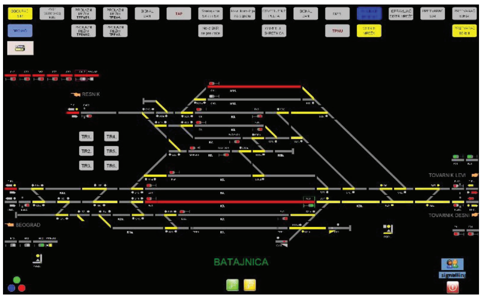
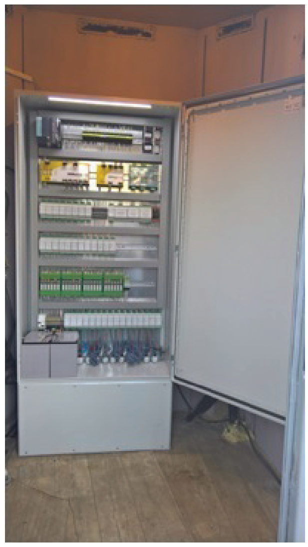
MAIN PRODUCTS:

EMMI - ELECTRONIC MAN MACHINE INTERFACE



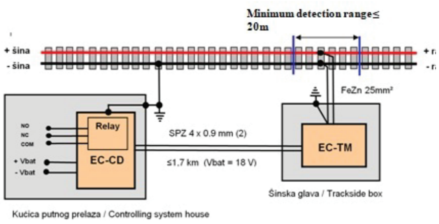
EI - ELECTRONIC INTERLOCKING (SIL4)

ELC - ELECTRONIC LEVEL CROSSING (SIL4)



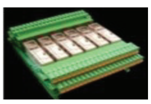
EAC - ELECTRONIC AXLE COUNTER (SIL4) with rails continuity detection

ERC - ELECTRONIC RAIL CONTACT



Detector Trackside Module Trackside Box.

VARIOUS MODULES FOR SIGNALLING SYSTEMS



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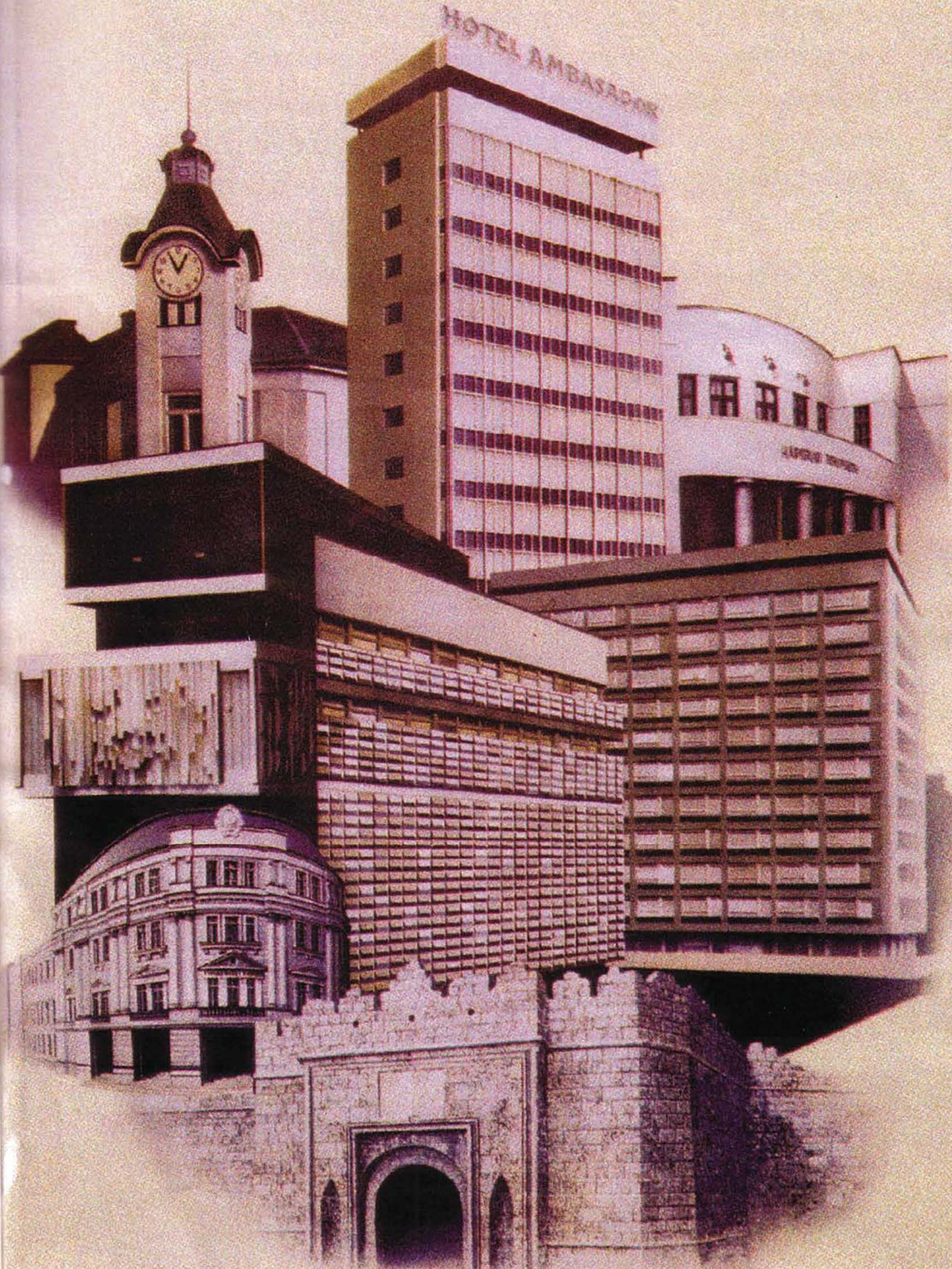
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