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Plenary Session

TOWARDS AUTONOMOUS OBSTACLE DETECTION IN FREIGHT RAILWAY

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Abstract – *In order to increase the quality of rail freight, as well as its effectiveness and capacity, a level of automation of railway cargo haul at European railways needs to be increased. An important part of the autonomous operation of cargo haul at European railways shall be a 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 obstacle detection system shall be integrated into Autonomous Train Operation (ATO) module and it shall be a multi sensory system 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). In this paper, the state-of-the art in obstacle detection in railway as well as problems and lacks that should be overcome to achieve such autonomous obstacle detection are presented.*

Keywords – Rail Freight, Obstacle Detection, Machine Vision, Autonomous Train Operation

1. INTRODUCTION

One of the main goals of modern rail freight is to increase the quality, as well its effectiveness and capacity trough development of Autonomous Train Operation (ATO) module with autonomous obstacle detection as one of its key elements. Novel obstacle detection system should be capable to safely and reliably detect obstacles within existing mainline infrastructure at distance of 1000 m, which is sufficient to initiate forward-looking braking. In order to provide fail-safe and reliable obstacle detection, the obstacle detection system shall benefit from a fusion of signals received from multiple sensors such as thermal camera, radar, camera augmented with image intensifier, stereo vision system and lased range finder [Shift2Rail 2016]. Having in mind multi-sensor system, a novel software algorithms used for recognition of obstacles according to the railway demands and safety procedures need to be developed.

A novel fail safe and reliable system for obstacle detection on railway mainlines as well as short distance wagon/buffer recognition for shunting onto buffers, shall be integrated into planned Autonomous Train Operation (ATO) module over standardized interface. The system needs to include hardware and software solutions for obstacle detection at 1000 m in a rail-specific safety framework. Based on captured sensor data, software algorithms should recognize complex patterns ahead of locomotive relevant for rail applications in real-time.

Obstacle detection will significantly contribute to a Grade of Automation 4 (GoA 4) vision of cargo haul trains [Shift2Rail 2016], which will have an overall important impact on increase of quality of rail freight in terms of punctuality, reliability and flexibility, as well its effectiveness and capacity. Such change in rail cargo transport quality and capacity will make rail transport more competitive in regarding the road transport thus enabling the 60% cut in transport emissions by the middle of the century [Shift2Rail 2016].

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2. STATE OF THE ART

Several papers regarding the obstacle detection in railways with the purpose of improving the safety were published.. In majority of the literature, the main focus is on the existence of objects on the tracks in critical areas such as zones close to bridges, level crossings, and in the stations. However, the incidents on the railroad are not only limited only to those areas and they might happen in any spot along the track.

In general, there are two types of proposals to address this problem: a) sensory systems are stationary and placed in situ (on-site), and b) sensory systems are mobile and placed on-board trains. As it was claimed by many of the scholars in the past, in situ systems turned out to show more promising results as if a high speed train running at 350 km/h needs a distance of 2.5 km to come to a complete halt, the detection of an obstacle within this range used to be almost impossible so that multi-sensory systems placed on board trains were rejected [Garcia-Dominguez et.al. 2008]. Although it is easier to develop the in situ systems, which do not face complexity of the mobile sensors such as changing lighting, changing background, and process speed, they have their own drawbacks such as time-consuming installation and calibration, lack of the ability to detect small obstacles, etc. [Amaral et al. 2016]. By the advent of the autonomous vehicle era, making use of on-board systems seemed inevitable and taking advantage of a combination of sensors with advanced technology made their development even less challenging [Uribe et al. 2012].

Several works on detection of obstacles using in situ sensors were published. In the work of [Ohta 2005], the major aim is to detect pedestrians or small vehicles (like wheelchairs) so to avoid their collision with trains. For this purpose, two stereo camera sets (four cameras) were installed at level crossing. There are advantages in using stereo cameras such as their ability to deliver depth information or wide sensing area. Moreover, in comparison with methods such as ultrasonic or optical beam methods less number of sensors is needed. Image processing techniques are applied for obstacle detection. Since the cameras are stationary, background subtraction is successfully applied to detect obstacles. Nevertheless, the change in illumination affects the performance of the proposed system. Adverse weather conditions can also deteriorate the system's functioning.

In [Oh et al. 2007] the focus is on safety concerns in railway platforms, where many pedestrians commute. A big group of different types of sensors provides input data for the central data fusion unit. These sensors are stereo cameras, infrared sensors and thermal cameras, mounted in different points of the train station. Two main classes of hazardous situations are identified: fallen objects (which imply pedestrian falling on the railroad) and intense change in illumination (which may mean fire). Four tasks are defined in processing steps: train detection, object detection, object recognition and object tracking. The reference claims perfect train detection performance in practice. However, as in [Ohta 2005], illumination change is mentioned as a factor which affects stereo camera efficiency.

In [Garcia-Dominguez et al. 2008], the authors use a combination of infrared, ultrasonic, and vision, to overcome the weak points of each sensor with another one. With this configuration, the areas near the bridges are controlled for safety of railway and obstacle avoidance. The placement of sensors is so that a set of infrared and ultrasonic emitters and receivers are placed on both sides of the railway and form a "barrier" in controlled areas. Moreover, the vision sensor is based on a camera, mounted above the barrier. Principal Component Analysis (PCA) has been utilized in this system which has two tasks: to prevent false alarms by IR-US barrier, and to use a vision sensor for moving object detection.

The work of [Akpinarat et al. 2012] is quite similar to [Garcia-Dominguez et.al. 2008], in the sense that both use a barrier of IR-US sensors on two sides of the railroad to cover a rectangular area and to cover the drawbacks of each individual sensor. However, they take a step forward in applying fuzzy controller and Dempster–Shafer evidential theory [Kong et al. 2009] for fusion of information. These improvements are to achieve fewer false alarms in practical applications.

Using a tilting 2D laser scanner to provide a 3D point cloud and investigation of its application in railway level crossings is the subject of reference [Amaral et al. 2016]. The challenge to meet in this work is detection of small obstacles, which may remain hidden from former detection systems. As in [Ohta 2005], and using the fact that the sensory system is stationary, background subtraction is applied to detect moving objects. The hardware used for scanning is a LIDAR sensor from SICK, LMS 111 and the proposed setup is able to detect objects of size 10x10x10 cm. The paper reports high quality of object detection and zero false alarms in evaluation.

Unlike the mentioned works, the following studies have investigated the use of on board sensors. There are three sensor selection strategies for design and implementation of on-board systems, especially for autonomous train driving systems:

- Active: Emitting devices and associated sensors are placed on the train's head for scanning the near area which has the drawbacks of the short range of action and low accuracy on curve zones;
- Passive: Use less costly video cameras in front of the train and rely on image processing algorithms which have high computational requirements as

they need to process the acquired images in real-time or close to real-time but give more important data for object identification.

- Mixed strategy: Integrating the multiple sources of information to make up disadvantages of existing methods and split the working range to use both passive and active strategies.

In the autonomous driving for cars several related works are done by the combination of sensors. The most common approach to vehicle detection is using active sensors such as radar-based (i.e., millimeter-wave), laser-based (i.e., LIDAR), and acoustic-based, since they can measure certain quantities (e.g., distance) directly without requiring powerful computing resources and they can "see" at least 150 meters ahead in fog or rain, where average drivers can see through only 10 meters or less. In the literature, the majority of methods reported to detect the cars and obstacles follow two basic steps: 1) HG where the locations of possible object in an image are hypothesized which is done using a)knowledge-based methods employ a priori knowledge to hypothesize object locations in an image; b)stereo-based approaches take advantage of the Inverse Perspective Mapping (IPM) to estimate the locations of vehicles and obstacles in images; c) Motion-based methods detect vehicles and obstacles using optical flow; and 2) HV where tests are performed to verify the presence of object in an image. A comprehensive overview can be found in [Sun et al., 2006].

In Boss system [Urmson et al. 2008], the team preferred to use active sensors for obstacle detection in urban environment, since the direct measurement of range and target velocity was more important than getting richer, but more difficult to interpret, data from a vision system. They used a combination of several radar and scanning laser sensors with a variety of ranges up to 300 m. For each sensor type a specialized sensor layer is implemented, therefore the architecture enables new sensor types to be added to the system with minimal changes to the fusion layer. LIDAR scans are processed to building a 3D point cloud of curbs. Then by mitigation of false positives due to occlusions and sparse data, clustering the points initially based on distance between consecutive points, and using the dense/sparse labelling from preprocessing, sparse points are removed from the classification list, the resulting list represents the locations of the likely road and surrounding geometric cues.

The work of [Alessandretti et al. 2007] investigated how the results of different sensors could be fused together, benefiting from the best performance of each sensor, since different radar performances suggest different fusion levels. The methods differ mainly in the fusion level: Low-level fusion combines several sources of raw data to produce new raw data that are expected to be more informative and synthetic than the inputs. In intermediate-level fusion, various features such as edges, corners, lines, texture parameters, etc., are combined into a feature map that is then used by further processing stages. In the high-level fusion, each source of input yields a decision, and all the decisions are combined. They used vehicle detection algorithm based on symmetry and uses radar data in order to localize areas of interest. Data fusion operates at a high level: The vision system is used to validate radar data and to increase the accuracy of the information they provide. A long-range radar with a 77-GHz frequency that is not capable of data classification is used to detect non-vehicle objects (mainly guard rails). Two scanned radars with a 24-GHz frequency mounted above the front bumper and connected to a dedicated Electronic Control Unit (ECU) are used to detect obstacles up to 40 m with an accuracy of 0.25 m. Radar and camera calibration are performed separately, and then the two outputs are double-checked together using an obstacle in a known position.

The following works tried the mentioned strategies. [Piva et al. 2003] studies an image stabilization technique that can be used on board railway surveying systems. The general approach for image stabilization is motion estimation and compensation, proceeded by the image composition. The performance of the stabilizer is investigated on REOST (Railway Electro Optical System for Safe Transportation) system in which, a camera and a stabilizer have been mounted at the top of the locomotive and digital image stabilization. In this stabilization method, each image is characterized by two one-dimensional curves. Image instability is estimated and compensated by comparing two consecutive frames and the difference in their characteristic curves. Achieving real-time application with 14.2 frames per second is an advantage for the proposed solution.

[Uribe et al. 2012] focused on obstacle detection and tracking from the view of a camera mounted on the locomotive. This aim is achieved by rail detection and investigation of an area in the neighborhood of the rails for potential obstacles (constant or moving), as well as by detection of moving objects approaching far from the rails. Rail detection is achieved by the Hough transform, which is a well-known method for line detection. Detection of moving objects is done with Lucas-Kanade [Lucas et al. 1981] optical flow method. The image features for which optical flow is measured are obtained by Shi-Tomasi method [Shi et al. 1994]. This method chooses regions of the image, which have more chance to be repeated in consecutive frames. Nevertheless, some workarounds are needed to be able to discriminate between background and moving object pixels. The paper concurs the need of more sophisticated methods for practical application, although reports satisfactory results for evaluation of the proposed system.

In [Rüder et al. 2003], they used three progressive scan CCD video cameras as main sensors. Two are used in a stereo setup for monitoring the near range up to a distance of about 50 meters and one camera in the far range. For the far range a multi beam infrared radar senor originating from an adaptive highway cruise control system for cars is used with a detection range of 150 meters. The system receives measurements of velocity and position data along the track from the vehicle control computer as well as from a differential GPS receiver. A combination of several algorithms such as track gaps, properties of edge elements, grey value variance and correlation along the track, optical flow, statistics of textures and stereo by inverse perspective mapping were used to stabilize the results. The system detected objects of the size of 0.4 m2 up to a distance of 250 meters. A larger object would be detected from a greater distance.

Dynamic programming is used by [Kaleli et al. 2009] in order to extract the train course and left and right rails simultaneously in front of the train using the Hough transform and compute the optimal path which gives the minimum cost to extract the railroad track space. Discarding background moving elements the algorithm finds candidate dangerous objects, tracks their trajectories and foresees their paths for determining if exist a course to collision. If an object could pose danger to the safety of the train a warning with anticipation is shown.

[Möckel et al. 2003] used look-ahead sensors such as Video cameras (optical passive), LIDAR (optical active) and RADAR (electromagnetic active) and acquired up to 400 m look-ahead range and with driving speed up to 120 km/h. To get maximum confidence in interpretation the concept of redundancy to choose a multi-sensor approach with stand-alone sensor units is used. The fusion of active and passive optical sensors and a railway track data base leads to very robust system performance. In small and medium distances, the detection probabilities of the technical system seem to be higher than those of the human being. However, for large distances the human driver's detection capabilities are better in comparison to the technical system.

[Inaba 2011] employed the millimeter wave high resolution radar for the range up to 300 meters. A high level of detection performance achieved by combining in a complementary way a radar sensor, offering long-distance detection performance, and an optical image sensor. A pan/tilt pan-head was developed with an automatic tracking function for the point of regard, and vibration isolation measures to minimize camera shake using Gyrostabilizer. Rail detection is performed by matching edge matching features extraction using the Chamfer distance and by pre-smoothing the input image with a 3x3 mean filter and using a symmetrical local. For long distance, the edges are extracted by pre-smoothing the input image with a 3x3 Gaussian filter and hysteresis thresholding the responses to a 7x7 Sobel operator. [Masato 2006] applied a passive detection method using a single-lens on-board camera (low-brightness CCD) to detect obstacles in front of the train in day and night. A telephoto lens is used to monitor long-distance perspectives and compensate the probable blur effects from vibration using optical flow. When an interruption in rail continuity was detected, system assumes the possibility of a stationary obstacle resting on or beside the rail(s), then it isolates the region in which the obstacle existed by analyzing the average and dispersion of brightness and the brightness profiles projected horizontally and vertically. Other characteristic points of the obstacle were extracted from the isolated region and analyzed on time-spatial photographic images.

[Berg et al. 2015] used a FLIR SC655 thermal camera to detect obstacles on or near the rails in front of the train at a limited range. The system acquires thermal images, computing the scene geometry (homography from pixel to ground coordinates using inverse perspective mapping), detecting the railway (possible rail locations), detecting foreground objects as well as anomalies, tracking possible obstacles, and giving alarms to the driver conditioned on certain criteria. In the study by [Kruse et al. 2003], it is claimed that there is no single sensor system available which has the capability to fulfil all given requirements, therefore, a low cost multi sensor system comprising a tele-camera, a far distance 24 GHz radar Sensor, a survey camera and a near distance radar network is designed. Two video cameras are situated behind the front windshield to be protected against weather impact. The acquired data from the sensors are combined using a Kalman-Filter based intelligent fusion method. The images of the cameras determine the track's curvature and boundaries. Using the gainful data fusion a precise estimation of the state (position and velocity) of the detected objects in front of the train is acquired. Then, if a detected object is in the driveway, target tracking is activated. On the basis of rail information now the decision is made whether one or more of the detected objects are situated in the rails. In this case, an alarm message is sent to the vehicle control unit and a corresponding reaction like whistling or braking follows. The measurement results show a high potential of the considered multi sensor system. In [Weichselbaum et al. 2013], stereo vision engine S3e with hybrid SW–HW dense stereo matching and Riegl laser scanner is used to precise 3D sensor data. The effective evaluation and fusion of their signals contributes to a useful recognition performance of obstacles inside the tracks clearance volume with at least a size of 0.3 m x 0.3 m x 0.3 m at a distance from 10 m up to 80 m ahead with a latency time less than 300 ms from capture time to obstacle report time. For the future work they suggested applying a stereo vision system with thermal infrared cameras to work reliably in all weather and light conditions.

When considering particularly stereo-vision based systems either in railways or in car driver assistance systems, two cameras, displaced horizontally from one another are used to obtain two differing views on a scene, in a manner similar to human binocular vision. In general, two types of methods are used to interpret the data obtained from stereo vision sensors in driver assistant systems: Disparity maps and Inverse Perspective Mapping (IPM).

Although computation of disparity map is time consuming, reference [Mandelbaum et al. 1998] shows that it can be done in real-time. A review on different methods of depth estimation using stereo camera system can be found in [Mohan et al. 2015]. In general, in disparity maps, position of pixels on both cameras that represent the same object are compared. The third component of pixel vector (z coordinate) can be calculated by comparing changes in pixels position, while inverse perspective mapping method is based on transforming the image and removing the perspective effect from it [Kovacic et al. 2013). An early example of applying inverse perspective mapping can be found in [Zhao et al. 1993], where the contours of the objects which stand above the ground are extracted from the images. Stereo cameras are mostly used for pedestrian and vehicle detection [Kovacic et al. 2013). Other tasks like lane detection and sign detection, though, can also be tackled with stereo cameras. But pedestrian detection and vehicle detection fully reflect the necessity for three dimensional understanding of the environment and the capabilities of utilization of stereo system to fulfill this need.

Since the advent of driver assistant systems, a great amount of work has been devoted to investigate the usefulness of stereo cameras in them. At Carnegie Mellon University’s NavLab, stereo vision is combined with neural network pattern classification of texture features [Zhao et al. 2000]. ARGO system, developed in the University of Pavia, combines stereo camera technology with template matching for detection of shoulders of pedestrians [Broggi et al. 2000]. In another example, and being developed almost at the same time with NavLab and ARGO, Daimlerchrysler applies chamfer matching (contour-based shape matching) on the data obtained from stereo camera to detect pedestrians [Gavrila 2001]. In 1999, Commission of the European Communities sponsors a joint work between some well-known companies which used to work on pedestrian safety systems to bring their work together. Some major car manufacturers like Daimlerchrysler and MAN, along with sensor providers like Siemens, were involved. The deadline of the project was defined to be in 2003 and the resulting work is documented in [Cicilloni 2003]. The work on obstacle and especially pedestrian detection systems continues till today. An example is reference [Nedevschi et al. 2009] in which, motion features and pattern matching based on chamfer distance are used for pedestrian detection. Reference [Kim et al. 2015] is one of the latest works that proves the popularity of stereo cameras in pedestrian detection. In this paper, the process of pedestrian detection is divided into three steps: First step is detection of region of interest using dense depth information. In this phase, using the size and the depth of each ROI, the system decides if the ROI can belong to a pedestrian or not. If the ROI is likely to belong to a human, Histogram of Oriented Gradients (HOG) features are extracted for it and are fed into a Support Vector Machine (SVM) classifier, which decides if the object is pedestrian or not.

Stereo cameras are used extensively in vehicle detection. Most of the applied methods are based on motion detection [Sivaraman et al. 2013], although there are examples of utilization of appearance-based approaches with stereo cameras as well. One is [Badino & Franke 2007], where appearance features are used for scene segmentation and obtaining an understanding of free space. Or in reference [Chang et al., 2005] features like size and height and width are employed to detect vehicles. In some more examples, like [Bak et al. 2010] and [van der Mark et al. 2007], Euclidean distance is measured to cluster point clouds into objects.

The use of occupancy grids [Moravec et al. 1985] for stereo vision object detection is another interesting field. Occupancy grids represent the environment by a grid and calculates the probability of each location in grid belonging to an obstacle. References [Perrollaz et al. 2010] and [Perrollaz et al. 2010] are two examples which use scene tracking and recursive Bayesian filtering to compose occupancy grid for each frame and then employing clustering methods for object detection.

Regarding the range of stereo-cameras reference [Okutomi et al. 1993] points out that there are disadvantages with using two cameras for stereo vision and suggests using a third camera. Nevertheless, according to [Sun et al., 2006] and [Kovacic et al. 2013], the system of only two cameras is preferred in future works due to the computational cost of trinocular-based system.

3. SOLUTIONS AND METHODOLOGY

State-of-the-art research has shown that significant work has been done in fusing different sensors to achieve more reliable object detection. Different combinations of sensors, such as stereo vision, mono cameras, radar and laser, were used. These combinations were mostly used for day vision; noticeable little work has been published on night vision for obstacle detection. Also, so far used combinations of sensors achieved relatively short range obstacle detection. To advance state-of-the-art, a system consisting of different sensors that would enable reliable object detection in short as well as in long range by 1000 meters is needed. Starting from the usual use of stereo-vision as preferable sensor for object detection in vehicle driver assistants systems, the required obstacle detection system shall be developed so that stereo vision system will be fused with other sensors like thermal camera, laser range finder, radar or camera augmented with image intensifier. Such system shall particularly advance state-of-the-art with respect to enabling short and long range obstacle detection in different conditions. Namely system shall be possible to use by day, night and difficult weather conditions. For that purpose, a multi-stereo system and laser shall be fused with a night vision system.

3.1. Night vision system

Night vision systems can use various types of technologies to allow users to see in low or no light scenarios. Each of these technologies has inherent advantages and disadvantages. Integrated night vision systems (INVSs) combine image output from two or more different types of night vision sensors into one composite (fused) image in order to take advantage of the strengths of each type of sensor [SAVER 2013]. The most common form of sensor fusion used for emergency responder applications is the coupling of an image intensifier (I2) with a thermal imaging sensor. Generally, I2 sensors provide an image of the surrounding environment under low-light scenarios, while thermal imaging sensors allow for the identification of objects and targets of interest by showing the thermal signatures of the objects in the environment [Couture & Plotsker 2005]. INVSs that combine these two technologies provide emergency responders with enhanced detection and recognition capabilities in fog, rain, and smog, as well as in poorly illuminated conditions. Those type of systems are very developed specially for military applications and have reasonable price.

Another fusion system with capability to produces true colour imagery is combination of a visible/near infrared (VNIR) colour EMCCD camera and thermal long-wave infrared (LWIR) microbolometer camera [Kriesel & Gat 2010]. The system can run in true color mode in day light down to quarter moon conditions, below this light level the system can functioning in monochrome mode. Those types of systems are relatively new on market and have still high price. Ultraviolet (UV), visible, and infrared (IR) light make up a portion of the electromagnetic spectrum. Only a narrow portion of the electromagnetic spectrum is visible to the unaided human eye. The ability to create an image using portions of the spectrum outside the visible range allows for the visualization and identification of objects that would be difficult or impossible using the unaided human eye [FLIR Systems 2016].

I2 night vision devices operate in the visible and near infrared (NIR) electromagnetic spectrums, while thermal imaging sensors operate in the mid- and long-wave infrared (MWIR and LWIR) spectrums. In addition to creating images from a broader portion of the electromagnetic spectrum, INVSs that utilize I2 sensors require a small amount of ambient illumination to operate effectively. Light entering an I2 sensor is amplified thousands of times to produce a visible image for the end-user. INVSs with thermal imaging sensors are capable of showing temperature differences as small as 2°–3° C between an object and its environment, thus allowing users to readily pick out objects with different heat signatures [Mitianoudis & Stathaki 2008]. Thermal sensors also provide the end user with improved visibility through many weather conditions that typically limit visibility such as fog and haze.

Fusion of images from each night vision sensor can be accomplished either optically or digitally. Optical fusion relies upon an optical combination of sensor images, while digital fusion employs digital signal processing to combine sensor images. Optical fusion in INVSs can be accomplished using a beam combiner to fuse images from two sensors into one image. Digital fusion INVSs uses digital signal processing to combine the images from each sensor into a single image.

Trend of night vision technologies in this moment is based on two actual opto-electronic technologies - image intensifiers and thermal vision. Every of those technology has own benefits and own limitations. The fusion system benefits are:

- redundancy, since we have two night vision channels
- fusion picture has an emphasized contour of the object detected from thermal image.

This approach is very rational and not expensive solution compare for high level task of night vision recognition

4. CONCLUSION

The primary goal of increasing the quality of rail freight, as well its effectiveness and capacity, is in line with European transport strategy 2011-2021 (Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system). Initiatives proposed have a goal to shift 30% of road freight over 300 km to other transport modes such as rail or waterborne transport by 2030, and more than 50% by 2050. In order to achieve such vision, developing of new infrastructure will be necessary, as well as increasing of efficiency and throughput of the existing infrastructure.

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. Nevertheless, most of the innovation in autonomous vehicles is occurring on the road due to lack of innovation in railway automation as a consequence of railway heavy regulation and extreme focus on safety. Noted regulations and safety focus hampers the implementation of recent innovations in autonomous driving and pushes cargo transport to road with much higher risks and casualty levels.

Very important part of the autonomous train operation is the novel obstacle detection system for usage in automation of cargo haul. The developed obstacle detection system would make an important contribution to automated cargo haul trains necessary for implementation of EU transport strategy. Autonomous trains are significantly more efficient, safer, cheaper and have less downtime than human-operated trains. Shift2Rail Multi -annual Action Plan [Shift2Rail 2015] outlines numerous advantages of cargo haul automation which include the benefits for quality of service (due to better punctuality), increase of capacity (10 – 50%), reduced system costs (20% energy saving), reduction of operation costs (50% reduction of cost for drivers) and overall efficiency increase of 10 %. All of these benefits will result in a system cost reduction in the three-digit million Euro range, as well as great customer benefits [Shift2Rail 2015]. The cargo haul automation is of highest priority for the future of European rail freight and it is one of innovations which will lead to turnaround necessary for achievement of transport strategy goals.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '16

PRESENT STATE OF THE RAILWAY INDUSTRY IN SERBIA

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***Abstract** – Serbian industry has experienced great changes in the last few years. The social ownership of factories has transferred to the private ownership, and a great part of the national railway industry does not work any longer after this process. The transformation process of Serbian Railways has been being carried out recently while maintaining of infrastructure and vehicles has been neglected. The purchase of new vehicles has been carried out through international tenders, thus, because of severe commercial conditions, the national industry could not be employed. Serbian Railways, preoccupied with its own reorganization, has neglected the relationship to the national industry. This condition has accelerated the deterioration of national enterprises addressed to the Serbian Railways. Considering the bankruptcy of many national enterprises and real possibility for their closing, this paper reminds us of their significant participation in the development of Serbian Railways.*

Keywords – Railway industry, Serbian Railways, transformation process, privatization, RAILCON.

1. INTRODUCTION

The railways and supporting industry had their beginnings in Serbia as early as 1884. In the course of 132 year long history there have been the periods of development and progress as well as those of destruction and decline of the railway industry. In fact, it can be seen a great difference between the level of infrastructure and quality of vehicles nowadays and in the past - from the former steam traction to today's electrical and diesel-electrical traction. Likewise, signalling and transport management have reached a high level of automation. During the two world wars the railways and supporting industry suffered considerable devastation together with the loss of a large number of workers. After the war the destroyed infrastructure was renewed and there was a rapid development with the help of great enthusiasm of people.

However, in the last decade of the twentieth century, Serbian economy experienced a lot of difficulties: there was a break-up of Yugoslavia, economic sanctions, NATO bombing. Since then there has been a period of continuous overall economic decline in the country, which influenced the rail transport as well. In recent years, a particularly difficult period has been appeared. Serbian Railways has been experiencing significant changes during the process of restructuring with the steady decline in business indicators and the national industry mainly disappears after the unsuccessful privatization.

This paper contains quotations from papers presented at the Scientific-Expert Conferences on the Railways RAILCON in the period between 2002 and 2014 and aims at indicating the events and processes that have led to the present state of the railways and national supporting industry.

2. SERBIAN RAILWAYS IN THE PERIOD BETWEEN 2000 AND 2015

The transformation of European railways began in the early nineties of the last century. The main objective of the transformation was to stop the decline in the share of railways in the transport market and to increase its competitiveness. The state railways was supposed to be transformed into an independent transport company with market orientation [1].

2.1. Restructuring of Serbian Railways

The first concrete activities in restructuring of Serbian Railways were launched after 2000, however, the process of transformation continues today. Brief overview of the restructuring process, from the initial activity to present days is given using the quotes from the papers presented in plenary sessions of RAILCON conferences.

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At the Conference RAILCON 2002, Rosić announced a radical reform of Serbian Railways both in organizational and essential terms in his paper [2]. "These changes will be reflected not only in a good part of the economy related to the railway program, but also in regional terms in a completely different approach to solving local traffic, and even in the survival of regional railways. For the successful implementation of the restructuring program and finding the optimal solution it is necessary to ensure a broad cooperation, support and coordination with local industry, local government structures, as well as with all professional and other organizations." He also pointed out that "there is no much time, and even more it will be a missed opportunity for recovery of both railways and national industries related to rail program if there is no coordinated activity."

At 2004 RAILCON Conference, Bošković and Lasica [3] pointed out that the key parts of the restructuring of the railways are: the restructuring of railway companies, governmental management and the relations between the state and railway companies. "No restructuring of the railway system is possible without changing the regulations in this area as well as the relationship between the state and the railway company. This is the basis and precondition for the start of any changes." At the same Conference, in his work [4] Bečejac presented the basic assumptions of the restructuring of the company ŽTP Beograd, key strategies and legal and institutional framework. The obligations that were supposed to have been implemented by 2007 by Railways and the State as well as the expected effects of the restructuring process were given in the paper.

Authors Bošković and Pop-Lazić, at the Conference RAILCON 2006, described the experiences of European rail companies privatization and structural organization of infrastructure management and transport. The same year, Lasica [7] made a recollection of activities on the restructuring of the public enterprise Serbian Railways, pointing out that the transformation process started in 2003 and could last for 5-7 years according to the experiences of railway companies from Western Europe. The Law on Railway, passed on March 1st, 2005 regulates the management of infrastructure and transport in the railway traffic. In his paper [7] the author also indicates: "The greatest problems that now threaten the continuation of the restructuring are: insufficient coverage of the costs by their own income, insufficient budget subventions for maintenance of infrastructure, lack of readiness of all management structures for the implementation of necessary reforms, high level of debts arising from international loans, lack of proper railway traction vehicles, poor state of infrastructure which causes a large number of slow driving on certain routes and the like. "

At the Conference RAILCON 2008, the authors Bošković and Janković analyse the dynamics of the process of restructuring of railways in the countries of Southeast Europe in their paper [8]. They indicate that in 2007, apart from Romania and Bulgaria, all other countries in the Balkans are at a low level of restructuring, and that they have a low level of development of railway market.

At the Conference RAILCON 2010, in their paper [10], authors Lasica et al emphasized the urgent need for changes and amendments to the Law on Railways to help Serbia align with the EU. At the same conference, Mandić in his work [11] showed that the restructuring of the railway sector in Serbia was being carried out very slowly and said: "They must promote smaller, technologically rounded, profitable projects rather than megalomaniac. It is very important to define and implement new technology in freight traffic and to leave classic technology with several processing of freight trains in the technical stations on an average transport of goods. The introduction of Obligations of public transport and the resolution (funding) of the organization of passenger traffic between the central and regional governments in passenger traffic will be very important."

At the Conference RAILCON 2012 authors Stamenković and Milošević in their paper [12], in addition to presenting the history of the development of the conferences RAILCON, provided comparative data of the work of Serbian Railways in the business years of 1984 and 2011 which showed a significant decline in the parameters of the transport performed. At the same Conference in his paper [13] Cadet pointed out that the railways can increase their competitiveness only through innovation, and this can be implemented only in the cooperation of the academic community and the railway industry. He describes examples of innovation in the company ALSTOM regarding high-speed trains, vehicles with tilting (Pendolino) system for controlling trains and the like. The same year, Rosić and Mandić, in their paper [14] said: "It is necessary to create a sustainable economic situation in the Serbian Railways as soon as possible. In order to realize this objective, it is necessary to increase the income and decrease the expenditure, and not to increase budget funds. This objective cannot be achieved unless there structuring of the company has been completed. It shall be kept in mind that during economic crisis, it is very difficult to increase the revenues and that the main task will be to reduce the expenditures as much as possible"

In the paper [15], which was exposed in 2014 at the Conference RAILCON authors Tomović and Pejčić-Tarle described the basic lines of strategy and policy options for the improvement of Serbian Railways in the period 2014-2018. They point out: "Unfortunately, the time is passing and differences between developed railway governments and Serbian railways are becoming more dramatic. The most difficult issue for management is how to find the best way to align with developed railway governments. Such burden is the largest in these complex processes. These processes demand great expert knowledge and capabilities".

Since August 2015 Serbian Railways have been organized into four stock companies: Company "Serbian Railways" JSC, the joint stock company for management of railway infrastructure "Infrastructure Railways of Serbia", the joint stock company for rail transport of goods "Serbia Cargo" and the joint stock company for passenger railway transport "Srbija Voz".

The company "Railway Infrastructure of Serbia" JSC has 9645 employees and the company "Serbian Railways" JSC has 130 employees.

Company "Serbian Voz" JSC has 2873 employees and the rolling stock of 38 electric locomotives, 11 diesel locomotives, 21 electric multiple units Series 413, 38 electric multiple units Series 412/416, 33 diesel multiple units, 22 rail buses and 171 passenger carriages.

The company "Serbia Cargo" JSC has 3963 employees and the available rolling stock of 79 electric locomotives (15 locomotives of 441 Series, 30 locomotives of 444 Series, 34 locomotives of 461 Series), 74 diesel locomotive (12 locomotives of 621 Series, 16 locomotives of 641 Series, 7 locomotives of 642 Series and 7 locomotives of 643 Series, 6 locomotives of Series 644, 25 locomotives of 661 Series and 1 locomotive of 732 Series) and 4666 freight wagons.

The following years present a special challenge because it is necessary for newly formed companies for infrastructure management, for passenger and goods transport to become independent and compatible so as to survive on the transport market.

These quotations from papers presented at the Scientific-Expert Conferences on the Railways RAILCON in the period between 2002 to 2014, prove that the experts have been engaged in research/analyses in the field of transformation of the railways and pointed out priority areas of action. However, the process of restructuring of Serbian Railways has taken place very slowly which caused the decline in operating business results, the deterioration of national supporting industries and the reduction of perspective rail transport in Serbia.

2.2. Performance of Serbian Railways

Although the period from 1980 to 1990 was characterized by stagnation as well as by a slight decline of the gross national product, the period of extremely difficult situation of Serbian society and economy, including the railway and supporting industry, started in the last decade of the twentieth century. The break-down of Yugoslavia, wrong economic policies with hyperinflation, the absence of necessary reforms, sanctions and NATO bombing made great damage and caused a deep disturbance in trade flows and developments in rail transport.

Passenger transport has performed steady decline since 1990. The range of passenger transport fell from $4{,}45x10^9$ pkm in 1990 to $1{,}24x10^9$ pkm in 2000. The unreliability of services, the poor state of carriages and insufficient investment in infrastructure have been the main factors that led to a bad situation. Transportation of goods was declining from 1990 to 1999, but after that there was a certain growth. The scope of freight transport fell from $7{,}22\ x10^9$ ntkm in 1990 to $3{,}64x10^9$ ntkm in 2000. The large decline in the national economy is the biggest reason for the decline in the transport of goods. In this period the number of employees was reduced in Serbian Railways from 43668 in 1990 to 33832 in 2000 [5].

In order to evaluate the business efficiency of Serbian Railways during the period of transformation Fig. 1 provides an overview of the range of passenger transport in pkm, and the scope of freight transport in ntkm in the period 2000-2014.

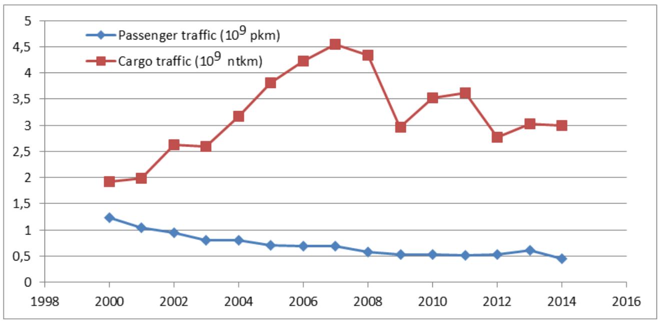

Fig. 1. The scope of passenger and freight transport between 2000-2014

In the period between 2000-2014, passenger transport was in steady decline, while cargo transport had a significant increase from 2000 to 2007, and then it started to oscillate with decreasing intensity.

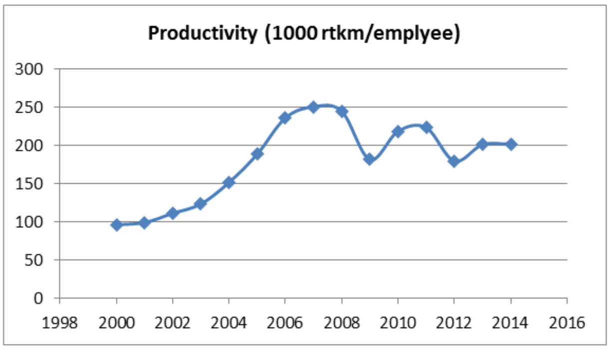

Fig. 2. Productivity in reduced ton kilometres per employee between 2000-2014

Productivity expressed in reduced ton-kilometres (pkm + ntkm) per employee for the same period is shown in Fig. 2. As the number of employees decreased significantly, from 33832 in 2000 to 17078 in 2014, the productivity of transport per employee has risen.

Every year Serbian Railways received subsidies from the state to cover its operations. The subsidy in 2014 was 12.5 billion dinars. Meanwhile, foreign debt increased because of infrastructure investments and the purchase of new rolling stock that had been realized with the help of international loans.

3. SERBIAN RAILWAY INDUSTRY

The railway industry in Serbia has a long tradition of over 130 years. During this period, the companies have experienced success, crisis, progress and war devastation. National railway industry developed its capacity primarily considering the needs of local railways and major mining and metallurgical companies in the country. These include companies engaged in production and servicing of railway traction vehicles MIN Lokomotiva Niš and ŠINVOZ Zrenjanin, then the factories engaged in the manufacture and overhaul of freight wagons Bratstvo Subotica, MIN Vagonka Niš, FVK Kraljevo as well as GOŠA Rolling Stock Company Smederevska Palanka dealing with production and servicing of passenger and freight wagons and ŽELVOZ Smederevo dealing with overhauling of passenger/freight wagons, electric and diesel trains. Beside them, a lot of mechanical, electric, metallurgical enterprises and other industries were producing parts for rolling stock and rail infrastructure. These include MINEL Beograd, EI Nis, Tigar Pirot, PPT Trstenik, Foundry "Požega" Foundry "Kikinda", FIAZ Prokuplje, Krušik Valjevo, Sever Subotica, Novkabel Novi Sad, FASO Vladimirci, MIN Skretnice, MIN Svrljig, ZGOP Novi Sad and other. It was estimated that the companies which had been linked directly or indirectly to railway vehicles in Serbia in the early eighties had about 25,000 employees [9]. The long tradition of successful business is an advantage of the national industry, but it is not enough for survival in today's market.

During the initial construction of the railway network in Serbia, at the end of 19^{th} century and early 20^{th}, qualified professional staff was obtained and the necessary institutions and companies that were able to perform almost all activities in the field of railway infrastructure were formed, while in the mechanical field everything was kept at the level required necessary for the basic maintenance of the stock [9].

In the period between the two world wars the industry of rail vehicles was practically created in Serbia. All factories were private. Railway companies decided to maintain vehicles in their facilities, and to leave new construction and modernization of vehicles to industry. During 6 years before the Second World War, the national industry produced 32 steam locomotives (independently and by license), 7 diesel multiple units (in cooperation), 20 trams (in cooperation), 33 tram trailers (independently), 112 passenger wagon (independently and by license), 3 lounge and a restaurant car (independently), a large number of freight wagons and other vehicles for railway purposes [9].

Significant capacities of railway industry were developed between 1950 and 1980. So beside the pre-war private factories, "Wagon Factory" in Kraljevo, "Stanko Paunovic (MIN)" in Niš, "Banat (Šinvoz)" in Zrenjanin,"Heroj Srba (Želvoz)" in Smederevo and "MIP" in Ćuprija joined the industry of rail vehicles.

3.1. Privatization of national industry of railway vehicles

In the period from 1980 to 1990 there was a great reduction of transport services market and the economic weakening of the railway. There was a great immobilisation of transport capacity due to the lack of maintenance. This state of the economy in the country, especially the situation in the national rail market had an impact on the activity and status of the railway industry. The range of production declines rapidly and unengaged capacity were partially used for overhaul operations, reconstruction and production of spare parts or other activities.

Serbia Railways has been preoccupied by its own reorganization and neglected the relationships with national industries. The purchase of new vehicles, the reconstruction of old ones and investment repairs have been realized through international tenders. During the last four decades world railway have experienced the process of concentration so several large international industrial systems became the leading global service providers in railway infrastructure and transport vehicles. National industry cannot get contracts in the production of new products due to strict commercial conditions except as subcontractor. Because of that, larger investments in railway industry have bypassed Serbian economy.

In such circumstances, the process of privatization has begun and brought new uncertainties and challenges. The state has claimed responsibility and started the implementation of privatization process but it has not taken any incentives in order to facilitate this process as it was the case in other branches of production whose size and prospects are considerably smaller than the industry of railway vehicles [9]. In some cases of privatization the new owners have shown impatience to achieve earnings and thus worsened already deteriorated situation in enterprises. The employees in factories have turned to social demands, not to the initiative of improving the quality of their products and finding new markets. So there was a significant reduction in production capacity, and some factories have gone bankrupt.

Unsuccessful privatizations was conducted in factories for overhaul and production of rail vehicles. Tab. 1 shows the number of employees and status of enterprises for overhaul and production of rail vehicles in Serbia in the privatization process.

Tab. 1. Factories for production and overhaul of rail vehicles in Serbia

Firm	Year of foundation	Number of employees			Status	
		2008.	2012.	2016.		
MIN Lokomotiva Niš	1884.	430	296	0	Privatized in 2007. Privatization contract cancelled in 2009.	In bankruptcy since 2015.
ŠINVOZ Zrenjanin	1887.	600	100	150	Privatized in 2004. Privatization contract cancelled. Conducted bankruptcy and reorganization of the company	Active
GOŠA – Rolling Stock Company Smederevska Palanka	1923.	750	445	370	Privatized in 2007 ŽOS Trnava	Active
BRATSTO Subotica	1886.	400	246	270	Privatized in 2004 TATRA VAGONKA	Active
MIN Vagonka Niš	1884.	440	275	0	Privatized in 2007. Privatization contract cancelled in 2009.	In bankruptcy since 2015.
ŽELVOZ Smederevo	1916.	1600	1240	0	Privatized in 2007. Privatization contract cancelled in 2011.	In bankruptcy since 2015.
FVK Kraljevo	1936.	850	750	0	Privatized in 2006. Privatization contract cancelled in 2010.	In bankruptcy since 2015.

Beside above stated, in present days several smaller enterprises such as MIP Ćuprija, Intermehanika Smederevo, Elektroremont Subotica and others deal with maintenance /overhaul of railway vehicles, i.e. their components.

The fact that national enterprises for the production and overhaul of railway vehicles are not engaged in any projects for Serbian Railways is one of the major causes of their deterioration. The remaining three factories Šinnoz, Gosa šinska vozila i Bratstvo still do not do any significant work for Serbian Railways.

Factories MIN Lokomotiva and MIN Vagonka date from the first state railway workshop founded in 1884 in Nis. Further on, the paper gives a brief historical review of operations of the two plants from its beginning until today.

3.2. From State Railway Workshop of 1884 to unsuccessful privatisation in 21st century.

During construction of the railway Belgrade - Niš - Vranje, Ministry of Construction decided to build a workshop for repairing locomotives and wagons built in Niš, in the geographical center of the future railway network of Serbia. Railway Workshop in Niš began operating in the first months of functioning of railway traffic on the Belgrade – Niš railway, in the fourth quarter of 1884. The workshop was employing about 100 workers, craftsmen and officials, mostly French [16].

In 1889 Serbian government took over the exploration of state railways. The number of workers in the workshop increased from year to year following the increase in the number of locomotives and wagons in the stock of Serbian State Railways (SDŽ). In the period between 1890. and 1912. three new departments were established.

At the beginning of World War One, Railway Workshop was placed under the direct control of the Supreme Command of Serbian army by the Military minister act from October 4th, 1914. In these extraordinary conditions, in 1914 30 locomotives, 59 passenger and 130 freight wagons were overhauled. By the order of the military authorities in the autumn of 1915 the workshop was evacuated. Over 200 most skilled workers, with tools and equipment were evacuated to Greece. This group established a railway workshop in Zejtinlik near Thessaloniki.

Niš was freed on October 12th, 1918. Bringing back to life of Railway Workshop in Niš was of great importance to the revival of Serbian State Railways and therefore Borivoje Djurić, former Assistant Minister of Transport, was awarded to be the director of the Workshop by Directorate of SDŽ. A large number of the workshop facilities was damaged and some were completely destroyed. Despite the difficult conditions and shortages of spare parts and other materials, in the first year after the liberation (1919) Railway Workshop repaired 15 locomotives, 210 passenger carriages and 475 freight wagons [16].

In the eve of the Second World War Railway Workshop in Niš was organisationally and technologically fully completed for the needs of the entire maintenance and repair of all types of locomotives and wagons in the stock of public and private (mining and manufacturing) railways. In 1940

150 steam locomotives, 1136 passenger, service and postal wagons and 3100 cargo wagons were repaired and overhauled. At that time, in 1940 Railway Workshop in Niš employed around 2,240 workers and civil servants, and Railway Craftsmen School had 151 students [16].

Railway Workshop in Niš was completely destroyed in the closing days of World War II. Immediately after the liberation of Niš on October 14th, 1944 all available measures were taken to empower the workshop as soon as possible, in order to restore the railway traffic quickly in the liberated part of the country. By outstanding efforts of workers in very difficult conditions, Railway Workshop in Niš succeeded to repair 53 train steam locomotive in the first half of 1945. There were 169 skilled, 15 semi-skilled and 49 unskilled workers, 7 wardens and 27 students. In the second half of 1945 64 locomotives were completed. The number of workers gradually increased - demobilized workers were returning from the railway brigades and the army.

Fig. 3. Workers going out of Factory Stanko Paunović in 1949

Railway Workshop in Niš was part of the JDŽ (Yugoslav National Railways) until 1952, when it became an independent organization with 2276 employees and clerks. The workers' council of Railway workshop made the decision on November 29th, 1953 that the workshop should be constituted as the Factory of machine and rail vehicles "Stanko Paunović" - Niš. Following organizational units were parts of the factory:

- Factory of switches and rail accessories
- Factory of freight wagons
- Factory of propelled means of transport
- Factory of machines and devices
- Factory of cranes and steel construction
- Factory of casting iron and nonferrous metals
- The overhaul of means of transport
- Engineering organization

The scope of repairs of railway vehicles was growing from year to year. Even the locomotives of narrow-gauge (0.6 to 0.76 m) with a variety of mining and industrial trails were brought for repair. In 1955 168 steam locomotives, 416 passenger carriages and 3173 freight wagons were repaired, and in 1958 the number increased to 268 locomotives, 570 passenger carriages and 4837 freight wagons. In 1955 there were 5098 employees in the factory and in 1957 there were 5353 [16].

In 1962 the factory "Stanko Paunović" formed the Department for the repair of diesel locomotives. A group of mechanical and electrical engineers intensively prepared the organization and technology for overhauling of diesel locomotives. The first diesel locomotive (JŽ 661-111 locomotive produced by General Motors Company - USA) entered the factory "Stanko Paunović" on emergency repair after the accident at Medjurovo in summer of 1962 [16].

In 1963 two biggest enterprises for metal processing in Niš – Factory of Machinery and railway vehicles "Stanko Paunović" and Factory of bridges and switches - were integrated into a new company - Mechanical industry Niš (MIN). Both companies originated from railway workshops. In the new integrated company, the Workshop tradition was followed by the Factory for production of railway freight wagons, the Factory for self-propelled means of transportation (locomotives) and General overhauling of transport means (locomotives and wagons). Independent factories were formed out of some support departments of the former Railway Workshop. Thus, Factory of iron and non-ferrous metals castings was established from the former foundry department, the Factory of castings and forgings was established from forges and pressed parts. Factories for production and overhaul of locomotives and wagons survived various reorganization and transformation, until finally, at the beginning of the seventies of the last century, rail program was concentrated on just two factories i.e. two enterprises MIN Lokomotiva and MIN Vagonka.

From 1963 to 1990 over 9000 wagons were produced for the needs of the national and foreign markets in the factory for freight wagons MIN Vagonka. Some of the major types of railway vehicles which are manufactured in MIN Vagonka for mining and metallurgical plants and railway organizations are:

- wagons for Mining and Metallurgy
- carriages for public rail transport for domestic railway, as well as for various foreign railway managements and companies
- low and high sided open freight wagons
- flat wagons for transport of containers
- flat wagons for transporting heavy loads

- closed freight wagons, and wagons with sliding roof and sides
- kipper wagons with pneumatic-hydraulic installations for kipping on both sides
- wagon tanker for transport of powder and granular materials (cement, calcined soda, coal dust, etc.)
- wagon tankers for various chemical materials (oil, gasoline, fuel oil, bitumen, sulfuric acid, hydrochloric acid, etc.)
- special car carrier wagons
- wagons for the transport of long rails and other.

The highest annual production was achieved in 1984/85 with the production of 845 wagons of type Hais for Iraqi Railways. In the period from 1993 to 2001, about 4000 wagons were repaired for the needs of Serbian Railways and the national industry. Fig. 4 shows the amount of completed repairs of freight cars in the period 1993 to 2001 [17].

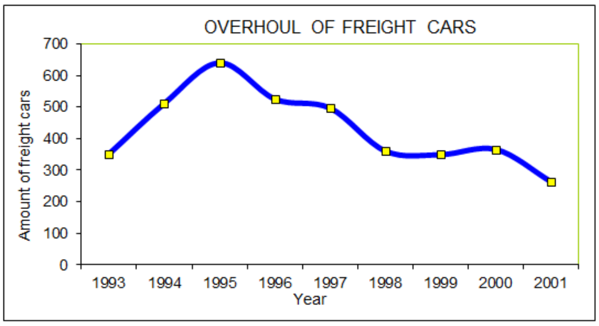

Fig. 4. Maintenance of freight cars between 1993-2001 [17]

The factory MIN Lokomotiva performed the overhaul of diesel-electric locomotives series 661, 645, 664, 666 electric locomotives series 441, 444 and 461, the production of diesel-hydraulic locomotives and track car with powers from 22 kW to 1200 kW, overhauls of trams and trollies, etc. Tab. 2 provides an overview of the vehicles produced at the factory MIN Lokomotiva.

Fig. 5. Locomotives being overhauled in the factory MIN Lokomotiva in 1992

In the period from 1985 to 2005 the factory MIN Lokomotiva performed overhaul of 190 locomotives series 441, 138 locomotives series 461, 263 locomotives series 661, and over 1200 locomotives of those series were repaired (larger or smaller faults). Fig. 5 presents a part of the factory MIN Lokomotiva with locomotives being overhauled in 1992.

Tab. 2. Overview of the vehicles produced at the factory MIN Lokomotiva

Product	Type label	Power [kW]	Amount	Product
Diesel-hydraulic locomotive	DHL-650	442-478	68	1969 -2005
Diesel-hydraulic locomotive	DHL-735	540	2	2005
Diesel-hydraulic locomotive	DHL-200	147-165	20	1977 -2000
Diesel-hydrostatic locomotive	DHSL-30	24	5	1980 -1988
Diesel-hydraulic locomotive	DHL-450	2x165	2	1987
Heavy track car	TMD-22	103	141	1957 -2005
Railcar	TMD-22KM	103	1	1992
Light track car	LMD-9	6,6	42	1977 -1988
Heavy track car	TMD-25	118	18	1980 -1984
Diesel-hydraulic track car	DHD-200	165	17	1984 -2007

Fig. 6 presents the total production, i.e. the total number of vehicles delivered from major/medium repairs, reconstruction and new construction, not taking into account the less emergency repairs in the period 2001-2010.

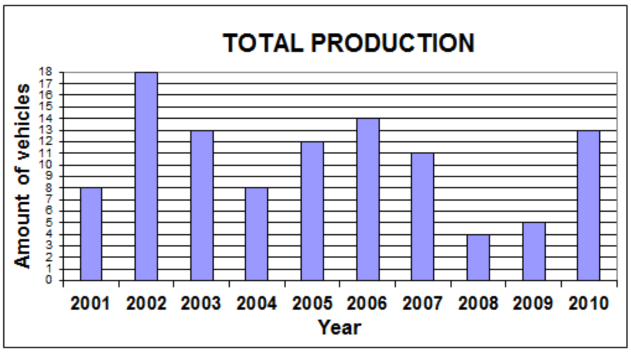

Fig. 6. Overview of the delivered vehicles (new and reconstructed) in the period 2001-2010.

In 2007. these two companies were privatized, and the new owner made huge debts and permanently disabled their recovery. This privatization was terminated in 2009. Because the new owner did not respect contract obligations, and the state declared bankruptcy in 2015. That is how ended turbulent and long history of Niš factories for production and repair of railway vehicles descended from the first Serbian Railway Workshops in 1884.

4. CONCLUSION

The process of transformation of the railways in

Serbia has been carried out very slowly and insufficiently thoroughly resulting in a decrease of transport and business indicators. The decrease in revenue from transport services has been covered by state subsidies. However, in addition to operating losses, the position of Serbian Railway is significantly getting worse in the transport market. The maintenance of infrastructure and rolling stock has been neglected. In addition, supporting industry has not been engaged in the railway program and was forced to develop alternative programs as well as to reduce the workforce that has caused constant deteriorating. The process of transformation of state property into private is being implemented under these difficult circumstances which make the situation in most factories worse.

The main causes of the deterioration of the national rail industry are:

- Unsuccessful privatization
- Lack of support of Serbian Railways in the process of restructuring of national companies
- Failure of national industry to adapt to the new market conditions (globalization and market liberalization)
- Relying on old previously adopted programs without the development of new products and services.

The academic community (university) has the task of indicating the directions for further development. By analysing the papers from previous RAILCON conferences dealing with restructuring of railways and transformation (privatization) of industrial enterprises it can be concluded that the plans and goals were set on time. However, the plans and objectives differ from the results (realization). Politicians who have "no time" for long-term reforms but only for short-term actions and their own promotions mostly contribute to this situation. But the progress requires the change of entrenched habits, the persistence in the realization of the objectives, often opposing opinions, or loss of popularity.

It is difficult to understand the fact that the railway industry has recovered after the massive destruction in two world wars, and that it cannot survive the process of globalization and market liberalization, as well as the process of transformation of the state property into private one.

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ASSISTED, AUTOMATED AND AUTONOMOUS DRIVING ("TRIPLE A") FOR RAILWAY TRAFFIC

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Abstract *– Assisted, Automated and Autonomous driving are the terms that dominate discussions not only in the automotive sector but increasingly also in the railway industry. At the Institute of Rail Vehicles and Transport Systems (IFS) of RWTH Aachen University these expressions are summarised with the catch phrase "Triple A". Although these expressions describe similar things, namely the possibilities of using modern communication and information technology to relieve drivers and finally replace them, their precise meaning is different. In this paper an overview on the definitions of the three mentioned expressions is given. Based on that, potential applications and strategies – autonomous, automatic or just assisted – for different areas of rail transport are discussed. In particular the different braking abilities and the different interfaces to other traffic participants lead to diverse proposals on how to achieve driverless or driver assisted operation.*

Keywords – Driver Assistance, Automation, Driverless Operation, Triple-A, Future prospects

1 INTRODUCTION

The International Association of Public Transport (UITP) defines four grades of automation (GoA) for railway traffic [1]. In Fig. 1 they are compared with the SAE definitions that are used by the automotive sector for the automation of cars [2]. The UITP definitions start with GoA 0, meaning driving on sight without any technical train protection, e.g. like a tram running in street traffic. They go up to level GoA 4, meaning fully automatic, unmanned train operation.

At RWTH Aachen University's Institute of Rail Vehicles and Transport Systems (IFS), the term "Triple A" is used to summarise three kinds of digital vehicle operation support:

1.1 Assisted driving

The first A stands for "Assisted Driving", the usage of digital systems to give additional support to the driver of a vehicle. Driver assistance systems are well known within the automotive industry. They help the driver by providing information e.g. about the route (navigation) or about near objects (collision warning). Some assistance systems are also capable of actively interfering with the driver's actions, like parking, lane-keeping or distance control assistance. Although the assistance takes over some actions, the responsibility and final authority is still always up to the driver.

In railway traffic, nearly all European main lines nowadays operate with at least with GoA 1, i.e. signal based and equipped with an automatic train protection system, for example the PZB Indusi system used – amongst others – in Germany, Austria and Serbia. The responsibilities for accelerating and stopping the train as well as control of the passenger doors (which are considered as safety-relevant for trains) lie still with the train driver. Automatic train protection systems are widely used since the first half of the 20th century and are mandatory in most national railway systems.

In GoA 2, or semi-automated driving, the driver only gives the starting signal and supervises the doors. This level is used today in several metro and urban commuter trains with short distances between stops.

1.2 Automated driving

The second A stands for "Automated Driving". From the vehicle's perspective this is still mostly a passive technology. The vehicle is not acting solely by itself but is in most cases controlled extraneous, usually from a central control room. In rail transportation the term "Automated Train Operation ATO" is used.

Driverless operation according to the UITP definition starts with GoA 3, where starting, driving and stopping the train all is done fully automatic. Only the doors still have to be supervised by a human train attendant. This train attendant does not need to be a fully trained driver; however he is still responsible for handling basic train operation in the event of a

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disruption of the automatic systems. The last level, GoA 4, refers to a system without any operational staff on board of the train. Vehicles run fully automatic, operate the passenger doors and are able to react in a safe way in case of disruptions.

Mixed forms of GoA 3 and GoA 4 are implemented in a number of driverless automated metro systems world-wide [3]. While in most cases safe operation is ensured by automatic platform doors that prevent unauthorised access to the tracks, some solutions (e.g. the Nuremberg U-Bahn in Germany) rely on open station platforms with dedicated track bed surveillance systems instead.

1.3 Autonomous driving

The third A finally stands for "Autonomous Driving". In contrast to automated driving this means that a vehicle has to be able to operate without any extraneous control and get all information required for safe operation from its on-board sensors. If necessary, an autonomous vehicle should be able to find its way without external influences and without endangering other traffic participants. While in case of unforeseen disturbances an automated system tends to assume a safe fall-back state (usually standstill in railway systems) until the disturbance is resolved from the outside, an autonomous system – like a human – tries to reach its goals by applying a solution strategy by itself. Therefore for an autonomous system the "intelligence" is on-board, while for an automated system it is centred in a central control entity.

2 DIFFERENCES BETWEEN ROAD AND RAILWAY TRAFFIC

For the automotive industry self-driving, completely autonomous cars are the ultimate goal of current automation development efforts. As this decades-old vision is making huge steps towards becoming reality with today's technology, railway operators like Deutsche Bahn (DB) start to realise the potential of driverless operation for the railway system too and are officially aiming for driverless train operation on main lines in the near future [4].

However, in the opinion of the authors, fully autonomous operation in terms of above definitions, like it would be the case with self-driving cars, is neither reasonable nor necessary for most areas of railway traffic. While the railway industry can gain huge profits by adapting technologies developed by the – much larger – automotive industry in that area, the systematic constraints (and advantages) of guided transport have to be considered.

With regard to "Triple A" the main technical difference between road and rail vehicles is the much longer overall stopping distance of the latter. The overall stopping distance consists of the distance a vehicle covers unbraked during the driver's reaction time and the braking distance that is covered between brake triggering and standstill.

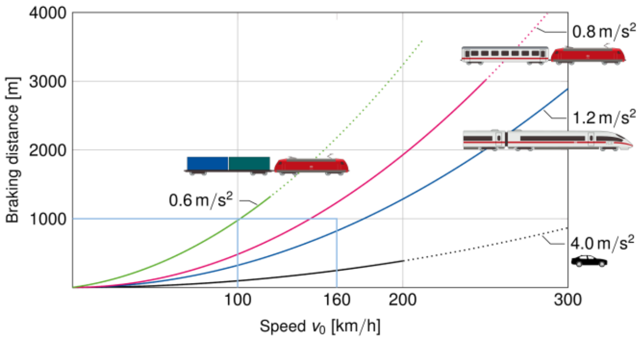

Fig.2. Braking distances for different train categories

While the driver reaction time is vehicle-independent, the physical conditions influencing the braking distance are much more unfavourable for the rail vehicle. One reason is the much lower adhesion coefficient – the relation of normal force and traction/breaking force – between (steel) rail and (steel) wheel compared to a rubber tyre on asphalt road. For brake design usually a rail/wheel adhesion coefficient between 0.1 and 0.15 is assumed, resulting in maximum deceleration values between 1.0 m/s² and 1.5 m/s². For road vehicles, much larger values of 0.4 resp. 4 m/s² can be used. Furthermore the build-up time t_1 between trigger and reaching full braking force can take several seconds on a long freight train with pneumatic brakes.

As an example, in the German railway system a safe stopping distance of 1000 m is assumed for passenger trains travelling at 160 km/h, corresponding to the distance between pre- and main signal. For freight trains, depending on brake equipment and train length, this stopping distance can only be guaranteed for travelling speeds up to 100 km/h or less. High-speed trains can have braking distances up to several

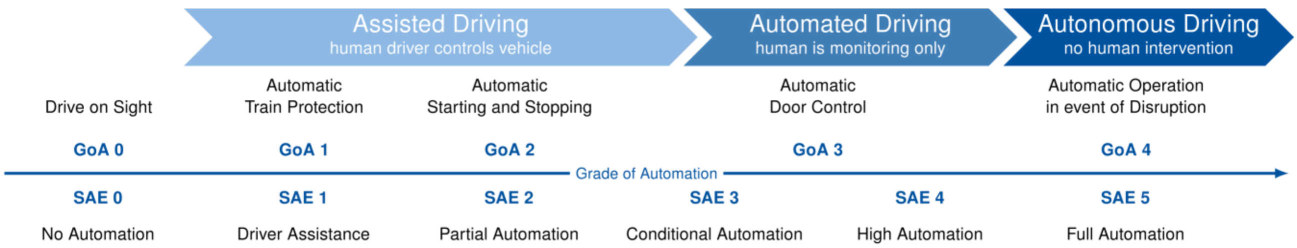

Fig.1. Grades of Automation in railway traffic compared to automotive terms

kilometres. Fig. 2 shows a comparison of overall stopping distances for different train categories, compared to road vehicles.

For “Triple A”, this especially means that safe autonomous driving of main-line trains – in the definition of relying only on vehicle-born sensors – is simply not possible with present-day technology due to braking distances far exceeding the line of sight, especially in curves or on crests. This corresponds to the fact that even human driven trains are not “autonomous” like a human driven car, but have to rely on signals and a central interlocking infrastructure to assure a free track ahead. However, the existence of this centralised infrastructure, that already contains information about the whereabouts of all traffic participants, means that – in contrast to road traffic – the goal of driverless operation can already be reached by “merely” automated driving.

3 APPLICATIONS OF “TRIPLE A” FOR RAILWAY TRAFFIC

Depending on the sector of railway operation, several potential applications for different grades of automation arise.

3.1 Main lines

On main lines, assisted driving is already state of the art. Driver assistance systems like the electronic working timetable “EBuLa” used by Deutsche Bahn to continuously display information about the track ahead based on GPS localisation are in common use. Driver assistance systems to support energy optimised driving are also tested successfully and are implemented by several railway operators [5].

Modern systems for automated train protection like the German “Linienzugbeeinflussung” LZB or the European Train Control System ERTMS/ETCS in levels 2 and 3 allow for continuous train control and monitoring of permitted speed. Especially on high-speed lines, when travelling at speeds up to 300 km/h, the danger of missing a conventional track-side signal is too high, so a continuous train protection and speed monitoring system is mandatory. Combined with a cruise control driver assistance system like the German “Automatische Fahr- und Bremssteuerung” AFB, this enables use cases of automated driving. On the predominantly LZB-equipped German main line network it is already common practice that drivers let the AFB system control the speed of the train and – while still responsible for safe operation – confine to monitor the automated systems and the track ahead.

Taking the step towards fully driverless operation on those systems is – from a technical perspective – a very small one. Due to the mentioned braking distances far exceeding the line of sight in most cases, collisions with other trains or objects on the track could not be avoided even by a human driver, so a reliable and trustworthy infrastructure system to ensure collision-free train traffic is already in place. Operating fully automated trains without any on-board track surveillance sensors would therefore – in an undisturbed system – not decrease objective safety. However, such a system would hardly gain acceptance from passengers for whom subjective safety is also very important. The main problem from the technical side is that safe operation in case of disruptions or external influences (e.g. fallen trees on the track) cannot be guaranteed by an automated system.

For the same reasons, fully autonomous train operation on main lines with trains relying only on their own on-board sensors is not feasible with today’s infrastructure and technology. The major expected advantages of driverless train operation – less staff cost, improved punctuality and increased safety – can already be reached with automated driving without the need to go autonomous.

For solving the problem of continuous monitoring of hundreds of track kilometres for objects like trees and rocks as well as human or animal intrusion, technologies like “Fibre Optic Sensing” [6], using optical fibres to detect acoustic signatures of those events along the track, are currently tested by railway operators [7].

3.2 Metro and commuter trains

Similar to main line operation, long braking distances combined with very short succession of trains make autonomous commuter trains not feasible. However, due to the mostly closed systems of urban metro subway lines, the technical problem of track surveillance for automated driving is simplified significantly. A growing number of driverless metro systems operating in Grade of Automation 4 already are in operation worldwide [3].

3.3 Marshalling yards

While technically being part of the mainline network, marshalling yards fill a special role. Marshalling yards are places where freight trains are assembled, disassembled or reorganised. While there are some central large “hump yards” with large shunting capacity relying mostly on gravity to move the freight cars, many smaller decentral “flat yards” require dedicated shunting locomotives and a lot of manual work to reorganise trains, making them economically unattractive. Increased personnel costs and dangerous working conditions lead to high potential for automation of marshalling yards.

Since shunting locomotives operate on low speeds and are usually driven on sight, in case of marshalling yards autonomous driving is an interesting option. The fact that shunting locomotives usually stay in the very limited area of the yard can additionally support localised development or testing of an automated or autonomous system. RWTH Aachen University already successfully demonstrated an experimental GPS/Galileo-equipped shunting locomotive that autonomously approached and moved freight wagons ready for coupling [8].

A major obstacle for fully automated marshalling yards is the standard UIC screw coupling used in the European railway system that has to be coupled manually. Currently, no market-ready solution exists to automate the process of splitting and coupling freight wagons. Research on automated coupling robots able to handle standard UIC couplings is still ongoing [9][10].

3.4 Industrial railways

Industrial railways are short, private owned feeder lines for material transport connecting public main lines with factories as well as different loading sites within larger factories. On the factory ground, incoming trains from the main line are usually disassembled and a dedicated locomotive is used to haul single or very few wagons to and from the loading sites, before finally reassembling them to an outgoing train again.

For several reasons, the special conditions of private owned industry railways in combination with high personnel cost and comparatively low throughput in terms of wagon count lead to high automation potential in this area of application. When moving single wagons only between loading sites, the problem of operating couplings between wagons can be circumvented. For locomotives, automated couplings to grab the hook of a single wagon already exist on the market. Low speeds, short distances and a limited rail topology favour autonomous solutions with sensor-based collision avoidance. Finally, legal approval of such systems will be much easier on a confined private rail network than in public.

3.5 Trams

As a special case of rail traffic, trams operate in city centres and mostly run on tracks embedded in the street. They have to share space with other traffic participants like road vehicles and thus are driven on sight.

With increasingly available off-the-shelf solutions for road user assistance systems from the automotive industry, first public transport companies have already started adapting those technologies for trams [11]. As the stated goal of the automotive industry is to develop autonomous and V2X-connected cars able to handle even crowded urban traffic situations, the logical development will be to embed trams into that ecosystem, too.

4 CONCLUSION

The prospects of digitalisation will not spare railway traffic. Completely driverless metro systems are already a reality. On main lines, many things can be done automatically, but not autonomous. However, much still has to be done to increase the acceptance of driverless trains. Only in marshalling yards, industrial railways and tramway systems autonomous driving is feasible. In all cases (further) assistance systems can increase safety, reliability and efficiency of railway traffic.

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Rolling stock

XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '16

REVIEW OF PROPERTIES OF COLLISION ENERGY ABSORBERS - EXPERIMENTAL AND NUMERICAL RESEARCHES

Jovan TANASKOVIĆ [1]
Vojkan LUČANIN [2]
Dragan MILKOVIĆ [3]
Aleksandar ŽIVKOVIĆ [4]

Abstract *– One of the main assemblies in the front part of the rail vehicle structures are passive safety elements. Perennial researches in the field of passive safety produced several different types of collision energy absorbers. Subject of this paper is review of experimental characteristics of a few different types of energy absorbers that works on the principle of folding, shrinking, expanding, shrinking-folding and shrinking-splitting of the tube. Using these types of absorbers, the energy absorption occurs by elastic-plastic deformations of the tube and friction between the tube and the special tools. Experimental researches were realized via quasi-static tests in a laboratory conditions and via collision of two passenger wagons. These absorbers can be installed in a line with standard buffer or separately in a front part of the rail vehicles structure. Numerical simulations of different shapes of deformation were realized using finite elements method (FEM) while the numerical models were verified using experimental results. Main target of development was to design collision energy absorber of compact (acceptable) dimensions that has gradual increase of the force and requested absorption power. Using results of experimental investigations and numerical simulations, the main advantages and disadvantages of described types of collision energy absorbers were presented.*

Keywords – Passive safety, Collision Energy Absorbers, Numerical simulations, Experimental researches.

1. INTRODUCTION

The subject of this paper is a review of characteristics of several types of collision kinetic energy absorbers. These absorbers were developed and investigated in the previous twelve years within research projects financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia. Development of the energy absorber started with the elements using folding deformation process [1]. This type of energy absorber gives the peak of the force at the start of deformation process. These peaks can cause undesired deformations of the vehicle structure behind the absorber, before the full utilization of its material. Disadvantages of this type of absorber redirected further research on the expanding tube absorbers type [1]. Expanding of the seamless tube results in much better characteristics in comparison with folding absorber, but this type of absorber needs larger mounting space for absorption of requested amount of collision energy. In order to improve force vs. stroke characteristics as well as absorption power, quasi-static test of shrinking absorber was performed [2, 3]. In comparison with the previous two types of absorbers, shrinking process has most acceptable force vs. stroke characteristic and requires significantly less mounting space. Considering previous conclusions, further research was focused to additional reduce in dimensions of absorber and increasing of absorption power. This problem has been resolved using different combination of deformation processes. Characteristics of two types of combined energy absorbers were investigated: a) shrinking-folding and b) shrinking-splitting absorber,

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[4, 5]. Force vs. stroke characteristic of shrinking-splitting absorber has gradual increase of force during absorption process, while the shrinking-folding absorber characterizes jagged flow of the force in the phase of deformation when starts folding process. Both combined absorbers have compact dimensions and satisfactory absorption powers. Using expanding, shrinking and combined collision energy absorbers, energy absorption occurs by elastic-plastic deformation of the tube and friction between the tube and the special tools. Experimental investigations were realized using quasi-static tests and crash test via collision of two passenger coaches. Numerical simulations of only shrinking, shrinking-folding and shrinking-splitting deformation processes were done using finite elements method. Numerical models were verified using experimental results. Using experimental and numerical results, the main advantages and disadvantages of described types of collision energy absorber were presented.

2. EXPERIMENTAL INVESTIGATIONS

Experimental investigations were realized in the laboratory conditions using Servo-hydraulic machines LITOSTROJ 2500kN (GOSA Rolling Stock Company) and Zwick Roell HB250 (University of Belgrade Faculty of Mechanical Engineering), Fig. 1., as well as via collision of two passenger coaches (for only shrinking process).

Fig. 1. Test machines

Initial research of passive safety elements started with absorbers which work on the principle of folding the square tube under axial compressive loading.

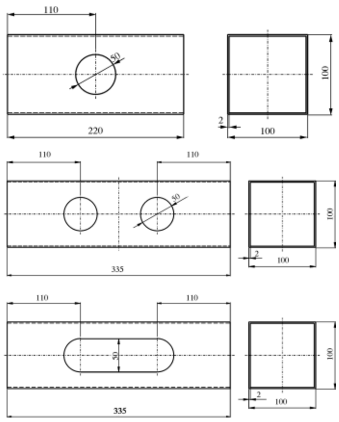


Fig. 2. Samples – folding absorber

Fig. 2 shows characteristic dimensions of three types of the tubes. Differences between the tubes presents shape of initial places where buckling starts. Initial places were designed as one circular hole, two circular holes and groove on the opposite walls of the tube. Tubes were made from steel grade S355J2G3 by bending and welding from 2mm thickness steel plates. Deformed samples are presented in Fig. 3. Experimental investigations of the folding absorber were realized in the laboratory conditions. This absorber type characterizes relatively low level of material utilization.

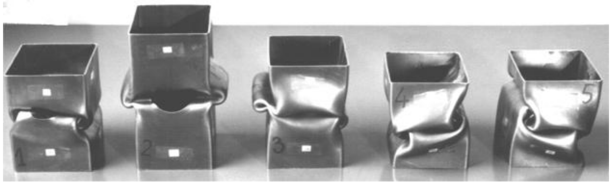


Fig. 3. Deformed samples – folding absorber

Disadvantages of folding absorber focused further research to other deformation process, expanding the seamless tube. Circular seamless tube was made from low carbon steel P235T1. Diameter of the tube was ∅88,9 mm and wall thickness 4 mm. This type of absorber works on the principle of expanding the tube using special cone tool, Fig. 4.

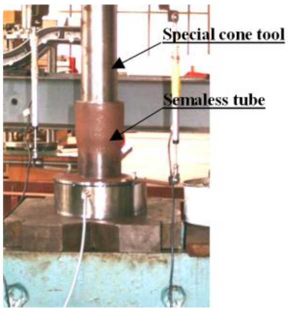


Fig. 4. Working principles – expanding absorber

This absorber has better force vs. stroke characteristics with gradual increase of the force in comparison with folding absorber. Disadvantage of expanding absorber is length of cone tool that requires a larger mounting space. This problem initiated new idea for energy absorption. It was the shrinking of the tube.

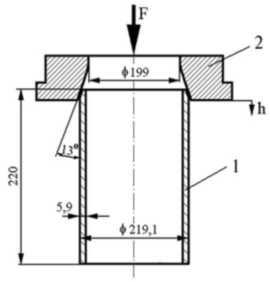


Fig. 5. Working principles – shrinking absorber

Shrinking absorber works on the principle of compressing the seamless tube (Item 1) through cone bush (Item 2), Fig. 5. Experimental investigations of this type of absorber were realized on a Hydraulic press and via collision of two passenger coaches (first Rail Vehicle Crash Test in Serbia and ex-Yugoslavia). Seamless tube was made from low carbon steel P235T1 with dimensions Ø219,1/6,7x205 mm, while the cone bush was made from quench and tempered carbon steel C45E with dimensions Ø219,1/Ø199/13°. Deformed shrinking absorber is shown in Fig. 6. During these research were analyzed strain rate dependence on deformation resistance, which is very important for further design and dimensioning of absorbers for different types of rail vehicles.

Fig. 6. Deformed sample – shrinking absorber

With the aim to increase absorption power and reduce dimensions as much as possible, further research was focused to combined energy absorber. This type of absorber using two different types of deformation processes to energy absorption, as follows: a) shrinking-folding and b) shrinking-splitting the seamless tube. Experimental investigations of these types of absorbers were realized on a scale samples, Fig. 7.

Shrinking-folding absorber Shrinking-splitting absorber

Fig. 7. Samples – combined absorbers

The following elements were used for this investigation: seamless tubes from low carbon steel with outer diameter of ø75 mm and length of 70 and 110 mm (material P235T1), cone bush with dimensions ø75/68x13° and die (splitting process) with dimensions ø61/r8 from quenched and tempered carbon steel grade C45E. Working with scaled samples in a large degree reduces development costs and gives very good image about behavior of material as well as about the shapes of deformations.

Thus, it is possible to precisely determine the amount of increasing the absorption power and desired shape of deformation, i.e. flow of the force during whole process of energy absorption. Fig. 8 shows deformed combined absorbers. As expected shrinking-splitting absorber gives more favorable force vs. stroke diagram in comparison with shrinking-folding absorber, which has jagged effect in the second phase of deformation, when the shrinking and folding deformation processes work together in parallel mode.

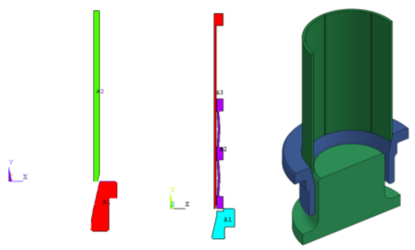
Shrinking-folding absorber Shrinking-splitting absorber

Fig. 8. Deformed combined absorbers

In addition, shrinking-splitting absorber requires less mounting space for the same amount of absorption power in comparison with shrinking-folding absorber.

3. NUMERICAL SIMULATIONS

Numerical simulations were performed using software package ANSYS (for only shrinking and shrinking-folding absorbers) and LS-Dyna (shrinking-splitting absorber). Using ANSYS software package and the finite elements method, the nonlinear numerical simulation on the plane axisymmetric model (shrinking and shrinking-folding) was performed using Perzyna model with rate dependent option, Fig. 9.



Shrinking absorber Shrinking-folding absorber Shrinking-splitting absorber

Fig. 9. Numerical models

Perzyna model requires defining key parameters which characterize rate dependent option, [6]. Using LS-Dyna software package and finite elements method, the nonlinear numerical simulation with fracture criteria on the 3D model (first from right in Fig. 9) was performed.

4. RESULTS

The following figures show characteristics force vs. stroke diagrams obtained by experimental investigations of described types of collision energy absorber. Fig. 10 shows F(h) diagram obtained by experimental investigations of folding absorber. This absorber produces undesired peak of the force at the start of folding (buckling) process. Force vs. stroke diagram recorded during quasi-static and dynamic tests of only shrinking process is shown in Fig. 11.

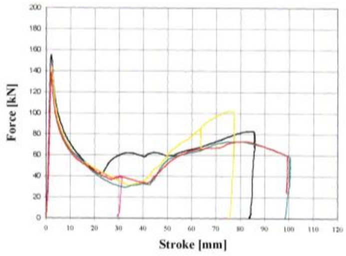


Fig. 10. F(h)diagram – folding absorber

This type of absorber characterizes gradual increase of the force until reached maximal value when remain at this level, with minor deviations, to the end of the quasi-static test (Fig. 11 left). Dynamic test gives higher values of the force, as expected, having in mind high sensitivity to strain rate.

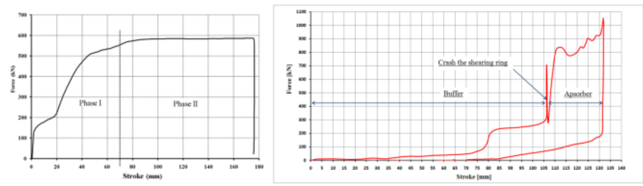


Fig. 11. F(h) diagram – shrinking absorber

Force vs. stroke diagrams, shown in Fig 12., obtained by experimental investigations of combined absorber. Left diagram presents characteristic curve F(h) with expected jagged effect in the second phase of deformation obtained by testing of shrinking-folding absorber, while the right diagram shows characteristic curve F(h) obtained by testing of shrinking-splitting absorber. It can be seen that the shrinking-splitting absorber has gradual increase of the force from the start to the end of deformation process, what is preferable in comparison with flow of the force using shrinking-folding absorber.

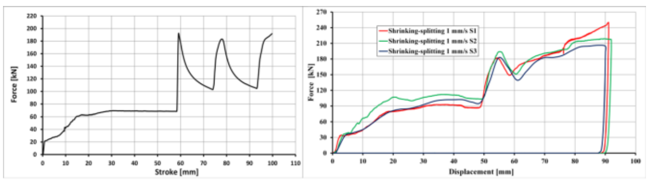


Fig. 12. F(h) diagram – combined absorbers

Fig. 13 shows shapes of deformations obtained by numerical simulations of only shrinking, shrinking-folding and shrinking-splitting absorber.

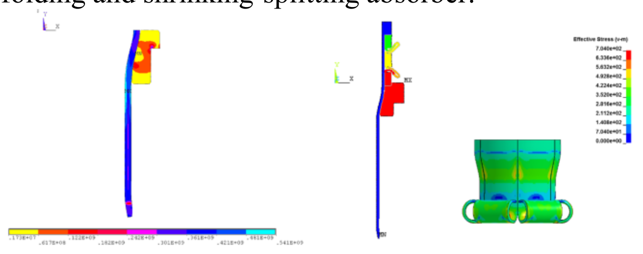


Fig. 13. Shapes of deformation – numerical simulations

Developed numerical models in ANSYS and LS-Dyna software packages are verified by experimental results and they serve for further research and modification of these types of absorbers whether for reducing dimensions or increasing absorption power.

5. CONCLUSION

Development of presented types of absorbers has significant role in future modernization of Serbian Railways, considering that majority of existing rolling stock, passenger coaches and freight cars, are not equipped with elements of passive safety. Results of experimental investigations show that combined shrinking-splitting absorber has the best F(h) characteristic, so it is most favorable for application on the rail vehicles. Developed numerical models reduce research costs and give great opportunity for modification of dimensions and absorption power without intermediate tests.

ACKNOWLEDGEMENT

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BASIC ASPECTS OF PROBLEM OF CONTINUOUS MEASUREMENT OF WHEEL-RAIL CONTACT FORCES

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Abstract *– The wheel-rail contact forces are the main influential parameters and indicators of quality of dynamic behaviour of railway vehicles. Their exact determination has great practical importance in development and testing of railway vehicles. Past experiences have shown that the best way for determination of wheel-rail contact forces is experimental testing or measurement, that can be stationary (measurement from the track side) and continuous (measurement from the vehicle side). When it comes to the continuous measuring systems which are obligatory in many cases of certification of railway vehicles according to the international standards, there is no universally and prescribed technical solution of measuring system. Consequently, today there are a number of solutions of these measuring systems which are mainly based on using of instrumented wheelsets. The aim of this paper is to identify the basic aspects of the problem of continuous measurement of wheel-rail contact forces, and to point out the basic problems that occur in the initial stage of development of instrumented wheelsets. In addition, the aim of paper is to define the main guidelines for solving these problems, which should be an important source of information for scientists and engineers, considering the deficient of literature and publications in this field.*

Keywords – Continuous measurement, wheel-rail contact forces, instrumented wheelset.

1. INTRODUCTION

The wheel-rail contact forces are the main influential parameters on the running stability of railway vehicles. In addition that can lead to the derailment, these forces cause wear, thermal effects, noise, fatigue, etc. Consequently, finding ways for more accurately and reliably analytical and experimental determination of these forces is one of the most important tasks in research of dynamic behaviour of railway vehicles [1, 2]. The most reliable way for determining parameters for assessment of quality of dynamic behaviour of railway vehicles, particularly wheel-rail contact forces, is experimental testing or measurement, which is required by international standards UIC 518 and EN14363 [3, 4]. This measurement is based on the use of instrumented wheelsets equipped with sensors (typically strain gauges) (Fig. 1), which are mounted on the railway vehicles to be tested [5]. The main objective in the development of instrumented wheelsets is to achieve the highest possible measurement accuracy. The degree of fulfilment of this goal depends on the success of solving of more mutually coupled problems [6]. Over the years, many researchers are dealt with solving of these problems, which are still in trend in scientific and professional public.

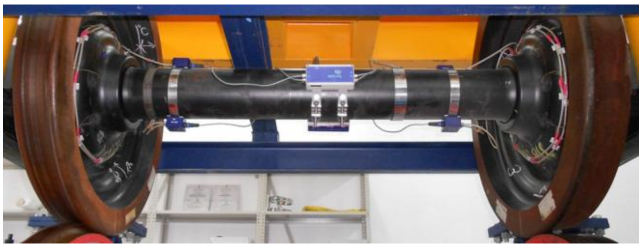

Fig.1. The instrumented wheelset

It is very important to note the fact that today there is no universal method for the experimental determination of wheel-rail contact forces using the instrumented wheelset. Although the mentioned international standards prescribe using the instrumented wheelsets in certain phases of certification of railway vehicles, they do not define

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the technical solution and the required accuracy of the measurement system. That is why there are many different approaches and methods, while each of them has certain advantages and disadvantages compared to the other [5, 6]. In this sense, the main objective of this paper is to identify the basic aspects of the problem of measurement of wheel-rail contact forces and contact point position using the instrumented wheelsets.

2. PROBLEM FORMULATION

The basic problem in measuring of wheel-rail contact forces consists in the fact that these forces cannot be measured directly in the contact surface between wheel and rail. Consequently, these forces are determined indirectly based on the measurement of strains of structures which are located in the vicinity of the contact surface. In the measuring systems from the vehicle side, the measurement is usually carried out through the wheel as an element of railway vehicles that is exposed to the greatest loads due to the effect of given forces. Measurement of wheel strains using strain gauges enables indirectly determination of wheel-rail contact forces using an algorithm. The main problem of all indirect methods comes from the fact that the wheel strains are not arise only as a result of actions of lateral and vertical forces to be measured, but they are at the same time affected by the various other parameters. Taking into account and the proper understanding of the effects of these parameters is a key prerequisite for development of high-quality method for experimental determination of wheel-rail contact forces and achieving a high measurement accuracy.

The wheel strains during running are caused by the following forces in the wheel-rail contact: vertical force Q, lateral force Y and longitudinal force X. In addition, these strains are affected with: contact point position y_{cp}, wear of wheel profile w, angular velocity of the wheel ω and temperature field T. The dependence of wheel strain in point j from the mentioned parameters can be expressed as follows:

$$\varepsilon_j = f\left(Q, Y, X, y_{cp}, w, \omega, T\right) \tag{1}$$

Thus, on the basis of wheel strains or signals from Wheatstone bridges which are mixed due to the influence of all mentioned parameters it is necessary to determine indirectly the values of unknown parameters Q, Y and y_{cp}. This problem belongs to the group of inverse identification problems and its solution is in this case very complex. It can be schematically represented as shown in Fig. 2.

Due to the high stiffness of the wheel, strains which are registered by strain gauges have very low values, particularly at the effect of the vertical force Q. There is another very important problem how to obtain the highest possible values of the signals from Wheatstone bridges and increase signal-to-noise ratio. Bearing in mind that strains are changeable along the wheel body, it is extremely important to determine locations or radial distances with highest sensitivity to the effects of parameters to be measured. Placing the strain gauges on such locations provides greater sensitivity of the measuring system or higher values of output signals from Wheatstone bridges. If the strain gauges are placed at locations with insufficient sensitivity, small values of the output signals will be obtained, which will lead to the great signal-to-noise ratio and large measurement error.

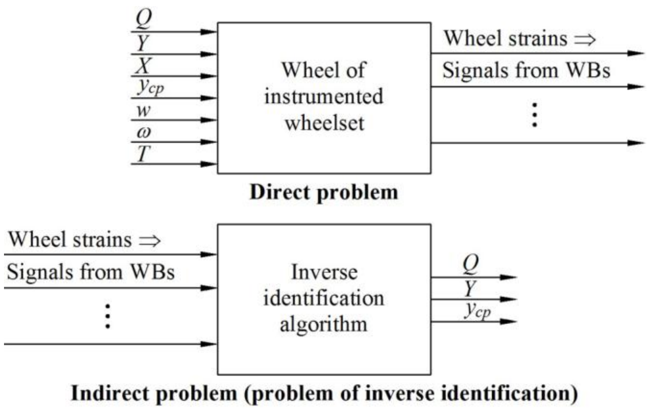

Fig.2. The inverse identification problem in measurement of wheel-rail contact forces

In addition, very important problem is determination of optimal layout, number and way of connection of strain gauges, also in order to obtain the highest possible values of output signals, or with the aim of compensating of influence of the certain parameters from expression (1). So, the main prerequisite for obtaining the high measurement accuracy is interactive and quality solving of defined problems as well as the problem of development of inverse identification algorithm.

3. GUIDELINES FOR PROBLEM SOLVING

The basis for solving of formulated problems should be the FEM model of wheel of wheelset which is selected as platform for development of the instrumented wheelset (Fig. 3). A key task of the model is to provide accurate determination of the stress-strain state of the wheel at actions of given parameters defined in expression (1). This allows the identification of influence of given parameters on the wheel strains or signals from Wheatstone bridges, which is of crucial importance for quality solution of the problem and obtaining high measurement accuracy. The model should enable accurate identification of optimal locations of strain gauges, as well as their optimal layout, number and way of connection. In addition, it should enable testing and verification of developed algorithm of inverse identification. In this way, the costs of development of instrumented wheelset are significantly reduced.

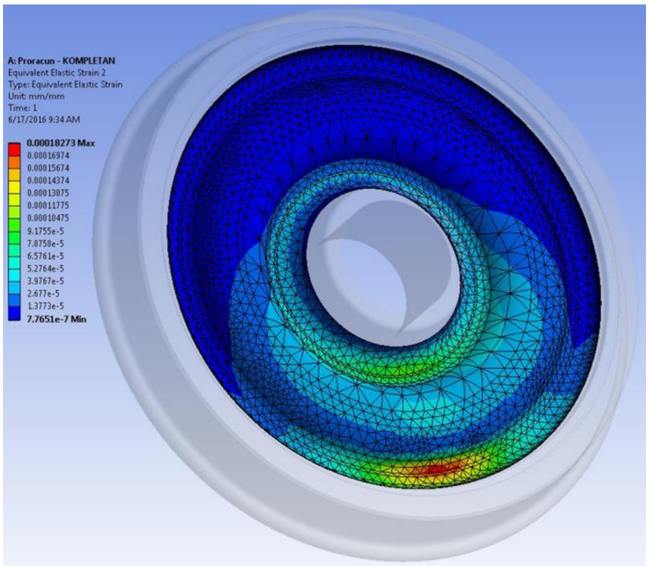

Fig.3. The FEM model of the wheel

Of all mentioned influential parameters on wheel strains in expression (1), only the influence of longitudinal force *X* can be neglected. The reasons lie in the facts that instrumented wheelsets are primarily intended for testing of hauled railway vehicles in which force *X* has no significant values, and that the measurement of this force is not prescribed in the certification process according to the mentioned international standards.

It is significant to point out that international standards UIC 518 and EN 14363 do not require the experimental determination of the contact point position y_{cp} in certification process of railway vehicles. However, this parameter has a certain influence on wheel strains and must be taken into account in order to achieve high accuracy of experimental determination of *Q* and *Y* forces.

The influence of parameter *w* is manifested by changing of wheel profile during a certain period of exploitation of instrumented wheelset. In order to achieve a high measurement accuracy, influence of this parameter should be taken into account in inverse identification algorithm.

Finally, influences of parameters ω and *T* on output signals from Wheatstone bridges should be compensated via appropriate way of connection of strain gauges.

In this way, the signal from Wheatstone bridge which is placed at certain radial distance becomes the following function:

$$S_m = f\left(Q, Y, y_{cp}\right) \tag{2}$$

Therefore, based on the output signals from Wheatstone bridges, the three unknown parameters *Q*, *Y* and y_{cp} should be determined. Bearing in mind that each strain gauge registers the relative strain ε, and the fact that the wheel is in zone of elasticity, according to the Hooke's law there will be a linear relationship between stress or wheel-rail contact force and the registered strain. The same is true for Wheatstone bridge that is composed of multiple strain gauges. Since the relationship between registered strain of every individual strain gauge and applied force is linear, correlation between the signal from Wheatstone bridge and applied wheel-rail contact force will be also linear. On this basis, the dependence of signal S_m from *Q* force and *Y* force is linear in expression (2). However, the key problem arise from the fact that, due to the complex non-linear geometry of the wheel profile, the dependence of the measuring signal S_m from the contact point position y_{cp} is nonlinear. This non-linear relationship can be transformed into linear by introduction of moment *M* of *Q* and *Y* forces with respect to the nominal contact point position on the wheel (Fig. 4). Moment *M* is in fact a non-linear function of parameters *Q*, *Y* and y_{cp}:

$$M = -Q \cdot y_{tk} - Y \cdot z_{tk} \tag{3}$$

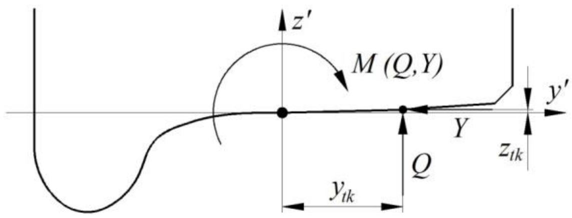

Fig.4. The moment M of Q and Y forces with respect to the nominal contact point position

In the initial phase of the research, for development of model and stress-strain analysis of the wheel, of crucial importance is the fact that mentioned linear relationships allow that for arbitrary chosen contact point position, the total strain can be expressed as the sum of individual strains caused by the individual actions of *Q* and *Y* forces. Mathematically, this can be expressed as follows:

$$\varepsilon_t = \varepsilon_t\left(Q, Y\right) = \varepsilon_t\left(Q, 0\right) + \varepsilon_t\left(0, Y\right) \tag{4}$$

Thus, based on the formed FEM model, stresses and strains of the wheel can be analysed at individual actions of *Q* and *Y* forces in different contact point positions between the wheel and rail (Fig. 5).

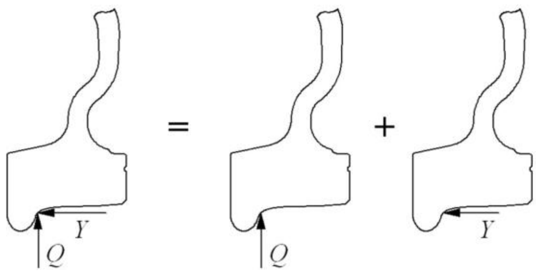

Fig.5. The consequence of linear relationships between wheel strains and forces Q and Y

The primary objective of the stress-strain analysis is to determine the locations with the greatest sensitivity to the individual actions of parameters to be measured (vertical force Q, lateral force Y and contact point position y_{cp}), where there is no mixing of their influence in the values of the wheel strains or output signals from Wheatstone bridges. Placing the strain gauges on such radial distances with high sensitivity and without mixing of influence provide the establishment of a very simple mathematical dependence between the output measuring signal and unknown force that caused it. This dependence is determined by the calibration of the measuring system which can be realized on special test stand or by using the results obtained with the FEM model of the wheel [7]. In this case, the inverse identification algorithm is relatively simple. Based on the value of a measuring signal from radial distance that is the most sensitive to the effect of given force, its value is determined.

However, if for a given wheel geometry there are no such locations, or if the output signal obtained from the measuring bridge placed on the radial distance with the greatest sensitivity to the certain parameter mixed due to the influence of other parameters to be measured, troubleshooting is significantly complicated. It is very important to emphasize that if this problem is not identified, the measurement will be carried out with a large error. In order to achieve high measurement accuracy, one of the solutions is compensation or neutralization of the influence of mixing with the appropriate way of connecting of strain gauges into Wheatstone bridges. Thereby, it should bear in mind the very important fact that mixing can never be completely neutralized. The second approach involves the using of some of the methods that allow the determination of the individual influences of parameters to be measured, based on the values of the mixed output signals from the measuring bridges. In this case, the radial distances with the highest sensitivity should be selected, regardless of the degree of mixing of the influence of parameters to be measured.

So, the way of solution of all these problems depends on the results of stress-strain analysis obtained from the formed model of specific type of wheel of standard wheelset which is chosen as a platform for development of instrumented wheelset. The results of the stress-strain analysis and FEM model should be verified with the experimental tests on real object, or wheel of the selected wheelset.

4. CONCLUSION

The experimental testing is the most reliable way to determine the parameters of the dynamic behavior of railway vehicles, especially those most important – wheel-rail contact forces. There is no universal method or technical solution for experimental determination of these forces. Also, there is no universal technical solution of instrumented wheelset which can be characterized as the best. Every method and technical solution, depending on a purpose and technical characteristics, have certain advantages and disadvantages compared to the others.

In that sense, the aim of this paper was to identify and analyze the basic aspects of the problem of continuous measurement of wheel-rail contact forces using the instrumented wheelsets. The key problems in development of instrumented wheelsets are identified. They are related to the determination of optimal layout, number and way of connection of strain gauges, as well as the development of inverse identification algorithm. The special attention is dedicated to the importance of development of the FEM model of the wheel, which is basis for solving all these problems. The results of this paper give very important guidelines for optimal solving of formulated problems, which is main prerequisite for development of instrumented wheelsets of high accuracy.

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ENERGY CONSUMPTION AND TRAVEL TIME - IMPORTANT FACTORS FOR DECISION ON PROPER TRANSPORT MODE SELECTION

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Abstract – *Consumption of energy (electricity, fuel) in the transport sector in the world is rising, Slovakia is no exception. Transport is a major consumer of petroleum products and this creates tremendous pressure on natural resources and the environment. The paper compares various types of passenger transport using the same type of fuel (diesel) or electric energy. Power consumption and travel time belong to the main factors when choosing a mode of transport. The comparison has been done by simulation (calculation) of travel times and energy consumption used in transport on selected lines and types of trains and vehicles in Slovakia. The advantage of simulations used is due to the satisfactory precision and cost effectiveness. In simulation number of factors acting in real operation have not been considered, the results are more theoretical. Wherever possible the real data for comparison have been used.*

Keywords–Energy consumption, Travel times, Transport mode selection, Railway traffic.

1. INTRODUCTION

Mobility is one of the most important human needs throughout the centuries. Number of trips and the travelled distance is constantly growing. Depending on type and distance of transportation, question of right transport mode selection becomes important.

Energy consumption is one of the key factors that influence this decision. Energy consumption affects the costs (profit) as well as impact on the environment (emissions, noise). Today transportation is largely dependent on oil, as the vast majority of vehicles are driven by engines combusting oil products - hydrocarbon fuels.

Railway transport represents a mode of transport where most of vehicles nowadays are powered by electric traction motors, so the dependence on oil is lower than in case of other transport modes (road, air, water). However, the fact is that in most countries the electricity is produced by burning oil or gas products or coal. All of these are non-renewable natural resources and their volumes have been steadily declining [3, 7].

Considering the above, there is an effort to streamline the transport of energy dependence, as suggested by the legislative measures such as the White Book on a European level or different policies and programs at national governmental level. Energy intensity of transport modes to the greatest extent represents the energy consumption of vehicles. Energy consumption can be also used as an initial indicator (diagnostic signal) of a potential failure [6].

Transport time is also an important factor in transport mode selection especially on long distances.

2. SHORT DISTANCE PASSENGER TRANSPORT

In this case study we consider the passenger transport on the route between Žilina (administrative centre and capital city of north-western region of Slovakia) and small town Rajec with distance 21,3km. On this route, two modes of passenger transport are used in parallel – railway and road. Railway track is not electrified. Speed limit on the railway is 60 km/h but some sections are limited to 50 or 40 km/h.

Transportation times on this track are 37 minutes for train and 42 minutes for bus. As we can see, the time difference on this route with ideal conditions is only 5

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minutes. Therefore, we are focused on the energy consumption in this case.

Simulation of energy consumption has been made for the real vehicles used for this track.

Fig.1. Train set series 813-913 [1]

Fig.2. Bus - type Karosa C 954 [2]

2.1. Calculation of energy consumption

For calculation of the energy consumption, software "Dynamics" has been used. This software works with imported maps and track gradient profiles of railway lines (track sections) and uses selected parameters (locomotive type, train weight, train length, axle load, number and location of stops) to calculate the energy consumption in kWh or litres. The software is able to calculate energy consumption and operating times or ride of any train on any railway line, but it is necessary to import the data of the train and the route.

For relevant comparison of the results for different types of consumed energy, the principle well to wheels should be used (using "wtw" factor).

Calculation procedure for the diesel train using the simulation software is as follows. In calculation the appropriate factors and forms for the procedure for the diesel train are used. The fuel consumption has to be multiplied by a factor of energy for this fuel to calculate the total energy consumption.

$$E_{TF} = FC_V \times e_W = \left[\left(E_{ME} \times BSFC \right) / \rho_F \right] \times e_W \quad (1)$$

where:

E_{TF} – total energy consumed by diesel vehicles [MJ]

FC_V – fuel consumption of vehicle [l, dm^3]

E_{ME} – mechanical energy consumed by the movement of the train (train dynamics software result) [kWh]

ρ_F –fuel (diesel) specific weight (density) [g/dm^3]

e_W –energetic factor "wtw" for defined fuel [MJ/dm^3]

BSFC– break specific fuel consumption of the vehicle engine [g/kWh]

Energy consumption for the bus we obtained from the bus operator who makes regular measurement of fuel consumption. So the real value of average fuel consumption in real load is known.

$$E_{TB} = FC_V \times e_W = \left[\left(F_{CA} \times L \right) / 100 \right] \times e_W \quad (2)$$

where:

E_{TB} – total energy consumed by bus [MJ]

FC_V – fuel consumption of vehicle [l, dm^3]

FC_A – average fuel consumption[l/100km]

L –driven distance) [km]

e_W –energetic factor "wtw" for defined fuel [MJ/dm^3]

2.2. Evaluation

The calculations for this model study were carried out on the track in both directions. The results are shown in figure and graph.

Tab. 1. Comparison results

	All seats occupied		Real passenger number	
Vehicle	Train	Bus	Train	Bus
Fuel consumption (L)	22,98	12,48	17,72	11,76
Total energy consumption (MJ)	981,2	532,9	756,6	502,2
Passenger number	83	49	32	26
Energy per passenger (MJ/person)	11,82	10,88	23,65	19,31

Tab. 1 shows the advantage of the road transport vehicle (bus). It is caused by train tare weight, which is 39t and is about 28t more than about 11t of bus tare weight.

The simulated fuel consumption of the diesel train was compared to the real consumption of this train operated on this track. This simulated result was validated because the simulation error was only -8%. So every consumption results were increased of the value 8% to be closer to the reality. The total energy consumption of the bus represents only 54 - 66 % of the train consumption, according to the actual capacity usage. In the unit expression (MJ/prs) the difference is

lower on account of higher capacity and passenger number values regardless of the effectiveness reached by the road vehicles.

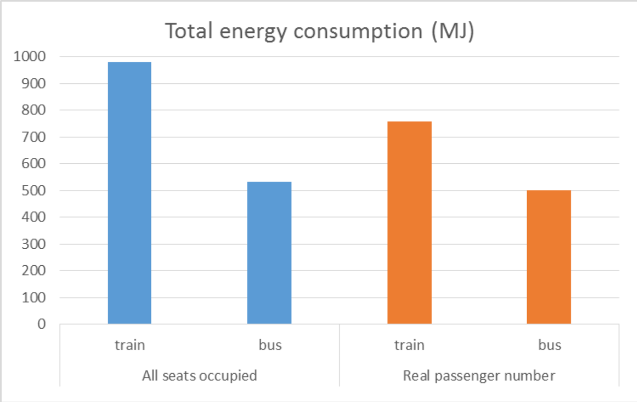

Fig.3. Evaluation of the total energy consumption

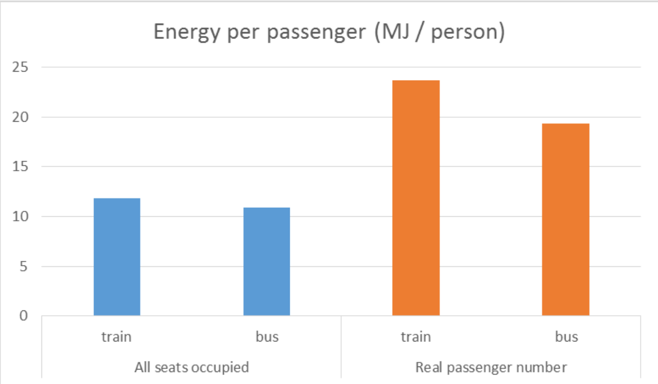

Fig.4. Evaluation of the energy per passenger

3. LONG DISTANCE PASSENGER TRANSPORT

Run of express trains on ŽSR (Slovak railways) infrastructure is limited by maximum track speed, which is rather low comparing to western countries. For domestic traffic, one of the principle lines of ŽSR is the line Košice - Žilina - Bratislava.

We performed simulations in the program "Dynamics" for the route Žilina – Košice with stops in Ružomberok, LiptovskýMikuláš, Štrba, Poprad-Tatry and Kysak in both directions, which are regular stops for Pendolino type train.

In the analysis we used the electrical multiple unit CDT 680 (Fig. 5) with additional weight of 30 tons for passengers, which is a representative of vehicles with tilting body and classical designed train with electric locomotive class 362 (Fig. 6) and 7 passenger coaches; weight of 350 tons and length of 185 meters. These vehicles are actually used on this line.

Fig.5. Electrical multiple unit CDT 680(Czech Pendolino) [4]

Fig.6. Electrical locomotive class 362[5]

We compared their energy consumption and travel times.

In simulation we used three different modes with settings as follows (Tab. 2) where:
normal - the current driving speed limits on the track,
effective - effective rate of speed and consumption,
max. speed - theoretical maximum possible driving speed limits on the track.

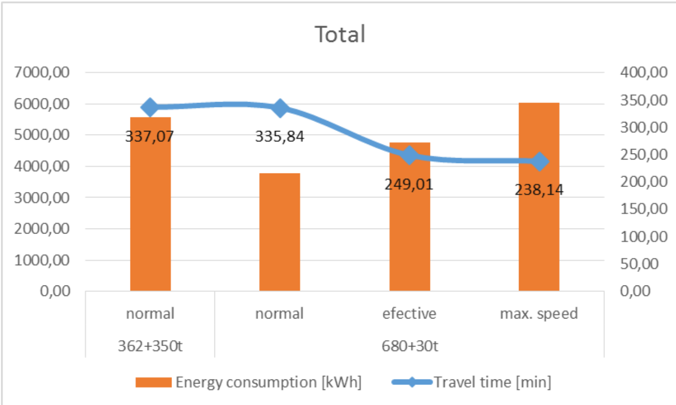

Fig.7. Total evaluation of the energy consumption and travel time

Figure 7 shows energy consumption and travel time in both directions. The figure shows that the best compromise between energy consumption and travel time reaches electrical multiple unit CDT 680 in

Tab. 2. Simulation results

		From Žilina to Košice		From Košice to Žilina		Total	
Train set	Setting limits	Travel time [min]	Energy consumption [kWh]	Travel time [min]	Energy consumption [kWh]	Travel time [min]	Energy consumptic [kWh]
362+350t	normal	167,76	2453,70	169,31	3117,60	337,07	5571,30
680+30t	normal	167,82	1792,60	168,02	1974,40	335,84	3767,00
	efective	124,83	2296,10	124,18	2459,80	249,01	4755,90
	max. speed	121,11	2917,40	117,03	3125,00	238,14	6042,40

effective mode with 14,6% (815kWh) less energy consumption and 26% (88min) less travel time than train with electrical locomotive class 362.

When CDT 680 is using the current driving speed limits on the track, it reaches travel time approximately the same, but energy consumption is significantly lower (32%).

On the other hand when CDT 680 is using maximum speed mode with theoretical maximum possible driving speed limits, on the track it reaches 29% (99min) shorter travel time and 8% (471kWh) more energy consumption than train with electrical locomotive class 362. It is only about 3% better travel time in exchange for an increase in energy consumption by 23% compared to the effective mode.

It should be noted that in the calculations additional energy consumption for auxiliary drives, air conditioning or heating, braking, as well as the consumption during stays at the stations was not considered, although the real operation is not negligible. Similarly, the calculation of the travel times, the stop times at the stations should be added to the travel times. These times are the same for both tilting body vehicles as for the conventional ones, so the relative benefit from reduced run times will be lower.

4. CONCLUSION

This paper considers energy consumption and travel time as one of critical factors in transport mode selection. The comparison was made in passenger transport.

First case study compared diesel train unit and bus on the short distance route between Žilina and Rajec. Transportation times on this route are 37 minutes for train and 42 minutes for bus. As we can see, the time difference on this route is only 5 minutes in ideal conditions. Therefore, we are focused primary on the energy consumption in this case.

The results shows the advantage of the road transport vehicle (bus). The total energy consumption of the bus represents only 54 - 66 % of the train consumption, according to the actual capacity usage. In the unit (specific) expression (MJ/prs) the difference is lower on account of higher capacity and passenger number values regardless of the effectiveness reached by the road vehicles.

Second study compared the electrical multiple unit CDT 680, which is a representative of vehicles with tilting body and classical designed train with electric locomotive class 362 and 7 passenger coaches.

The best compromise between energy consumption and travel time reaches electrical multiple unit CDT 680 in effective mode with 14,6% (815kWh) less energy consumption and 26% (88min) less travel time than train with electrical locomotive class 362.

Besides the technical aspects of energy consumption for selection of transport mode and types of vehicles, certainly the transport logistics and planning play a major role. The best technically working system cannot be effective if operates empty vehicles (no passengers). But this is not subject of this study.

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OPERATIONAL REGIMES OF MOTIVE POWER UNITS AND THEIR UNCONVENTIONAL TRACTION DRIVES

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Martin MIKOLAJČÍK [2]
Juraj GRENČÍK [3]

Abstract *– The utilization of installed power of internal combustion engines (ICE) generally and especially in shunting locomotives and locomotives for industrial transport is very low. The mean output of ICE in the operational mode is about 10 – 20 % of its installed power. The maximum power of ICE is used of about 1–2 % of working time. The changes of ICE output are fast and frequent as well. The result is that most of the time internal combustion engine works in regimes that are far from optimum mode and in transitional regimes. It means that specific fuel consumption and production of harmful emisions are high. Some examples of measured operational regimes of locomotives are given in the paper. Kinetic energy of a classic diesel locomotive is transformed into thermal energy during braking process. Classic diesel locomotives cannot utilize this kinetic energy in a reasonable way. The braking energy should be transformed into a suitable form and stored for following use in traction or for drive of auxiliaries.The improvement can be achieved by using of the unconventional traction drive of rail vehicles. One of the possible ways is using the hybrid traction drive. The hybrid drive includes the ICE and the energy storage device. In this case the installed output of ICE can be substantially lower than in the classic traction. The parameters of such traction drive must be based on analysis of real operational regimes of vehicles. These parameters are particularly: output of ICE, output of traction motors, capacity and output of energy storage devices (accumulators or ultracapacitors).*

Keywords – operational regimes of rail vehicles, hybrid traction drive, utilization of power of ICE, fuel utilization, accumulation of energy.

1. INTRODUCTION

The fuel and energy savings and air pollution in the rail transport should be solved at the present time. A significant number of diesel locomotives with various installed power and age are in operation in the industrial transport and in shunting service on railways. In the domain of main line DE locomotives the situation is similar. Some possibilities how to solve these problems, including usage of unconventional fuels, are mentioned for example in [1, 2, 3].

It is known that the use of installed power capacity of internal combustion engine (ICE) in motive power units (especially in shunting locomotives and locomotives for industrial transport) is very low. Average utilisation of engine power is usually much less than 15 % of the installed power capacity and nominal engine output is utilised only during minimal period of the total time of engine operation (at the level of approx. 1%). The result of this is that most of the operational time the internal combustion engine works in regimes that is far from optimum mode with high specific fuel consumption. At this type of locomotives operation, frequent and fast changes of engine regimes occur, which results in increased fuel consumption and imperfect fuel combustion with increased quantity of harmful emissions. Shunting operation cannot be operated by low powered locomotives. The maximal engine power is needed for acceleration and high load train shunting. If low powered diesel is used there is possibility to supplement the missing power of diesel by power gained from another source of energy, e.g. accumulator, which can cover the peak and short

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requirements of high power. This represents hybrid traction propulsion. Other possibility is using of two low powered engines instead of one high powered engine [4].

The measurements on main line locomotives showed that utilization of engine power is better, but low as well [5]. As example we can state that the main line DE locomotive class 757 with 1 550 kW engine pulling fast train has mean output of traction generator only 317 kW which represent about 20.5 % of installed output of ICE. If this locomotive pulling the light stopping trains the mean output of traction generator is about 170 kW (11 % of ICE output) [6].

Kinetic energy of a classic DE locomotives as well as the DMUs and trains is transformed into thermal energy during braking process. Usually it is not possible to utilize this kinetic energy in a reasonable way. The kinetic energy should be transformed into a suitable form and stored for following use [3, 7]. The hybrid traction propulsion enables at least partially utilization the braking energy. The using of

During this period engine was stopped 5 times with total duration of stopped ICE for 2 hours 14 minutes.

The mean output of the traction alternator was 317 kW. The mean otput of traction alternator was about 20.5 % of installed output of ICE which is much more than at shunting locomotives. Percentage of engine idling (approx. 38 %) was slightly less as in case of shunting and industrial locomotives.

In the case of main line locomotives application of hybrid drive is not appropriate in classic sense. But there are other possibilities of hybrid drive utilization.

The record of the one segment of measurement is given on the Fig. 1. This segment comprises measurement from hauling of the fast train from Banská Bystrica to Margecany (about 180 km) by locomotive Class 757. In the first part (about 96 km) railway line has upward gradient and in the second part has downward gradient. It is evident from the record of application of electrodynamic brake (EDB) at Fig. 1.

It is apparent that EDB was used quite frequently

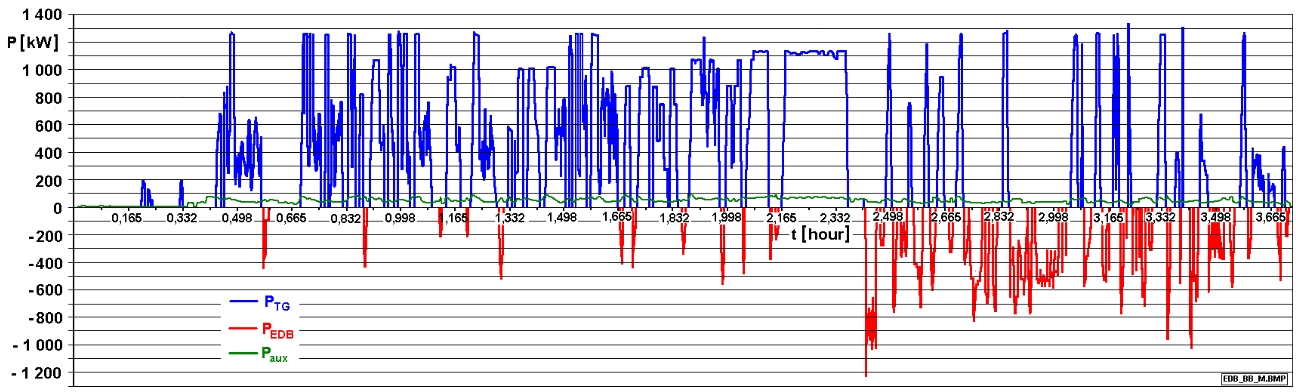

Fig.1. The courses of some operational parameters (output of traction alternator, output of EDB and input of auxiliaries) of main line locomotive Class 757 at the railway line Banská Bystrica - Margecany

accumulators enables also other ways of better utilization of fuel (for example using of energy in exhaust gases).

2. OPERATIONAL REGIMES OF DIESEL LOCOMOTIVES

The knowledge of operational regimes of locomotives is very important and forms basis for searching possible solutions leading to the fuel savings.

The operational regimes of shunting locomotives were published for example in [1, 3, 5, 8, 9]. Now we will deal with operational regimes of main line DE locomotive class 757.

2.1. The operational regimes of fast personal trains

The measurements were carried out at the railway line Zvolen – Banská Bystrica – Margecany. Measurements were realized from 7:40 to 20:36.

and its mean output at this part of measuremnts was 66.4 kW which represents approximately 20.9 % of mean traction output (317 kW). The mean input of all auxiliaries was 48.7 kW. The auxiliaries include fans of primary and secondary cooling circuit of engine, two fans of traction motors cooling, brake compressor and fan of traction and auxiliary generator and ventilator of EDB brake resistors. Maximal input of all auxiliaries is about 151 kW.

Theoretically it would be possible to cover the energy consumption of auxiliaries with the energy produced during electrodynamic braking, but there is a problem with the storage, because EDB produces large amounts of energy for a short period of time. Therefore, they cannot be used for energy storage batteries, because they can´t be charged with high power, which produces EDB, but ultracapacitors must be used, which are capable to accumulate large amount of energy over a relatively short period of time.

The energy produced by EDB and energy consumed by auxiliaries during the trip from Banská Bystrica to Margecany is represented in Fig. 2. Fig. 1 shows that power of auxiliaries is relatively constant and power dissipated by EDB has pulse character. In order to be possible to utilize energy produced by EDB as input of auxiliaries it must be stored in accumulation device. The accumulator equalize produced and consumed energy.

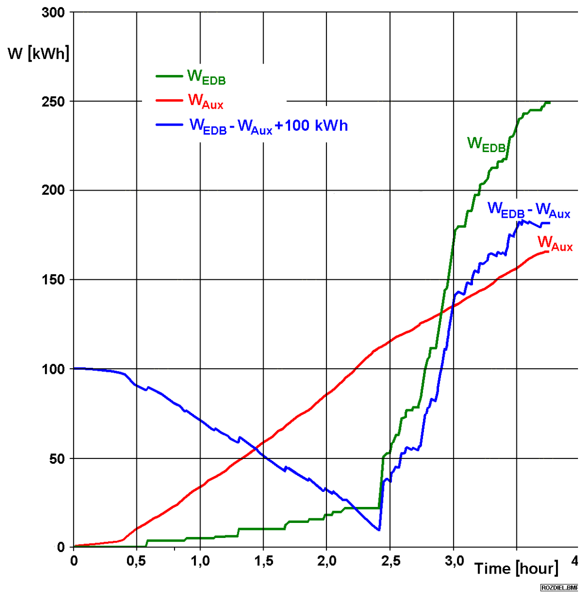

Fig.2. The energy produced by EDB and consumed by auxiliaries at the railway line Banská Bystrica - Margecany

The diagram in Fig. 2 is supplemented with course of difference between energy produced by EDB and consumed by auxiliaries. This line is shifted by 100 kWh upwards.

required by auxiliaries by approximatelly 66 kWh at this case. This amount of surplus energy can cover losses conected with charging and discharging of accumulator and efficiency.

2.2. The operational regimes of light stopping personal trains

The distinct results were gained by measurements on the light stopping trains pulled by the same locomotive. As example we present the distribution of traction alternator and EDB output on light stopping train (three cars) on line Banská Bystrica- Zvolen in the Fig. 3. The mean output of traction alternator in this case is 167,3 kW (10.8 % of ICE output).

For powerful main line locomotives is typical unfavourable utilization of ICE power. The consumption of power for driving of auxiliaries and feeding of pulling cars is very significant. The mean input of auxiliaries in given example was approximately 95.6 kW and mean power for car feeding was 25.7 kW. The mean power for feeding of train is very variable. We have registered the mean power for feeding cars 67.5 kW and 73.8 kW at different measurements. The mesurements were carried out in autumn. The power needed for the feeding of cars heating in winter will be much higher. The mean input of traction motors was 167.3 kW and the mean output of EDB was 69.6 kW in this case.

3. THE POTENTIAL WAYS OF FUEL ECONOMY

The hybrid traction drive is one important way for fuel economy for shunting and industrial locomotives. Another possibility is using of two ICE.

The situation in the case of main line locomotives

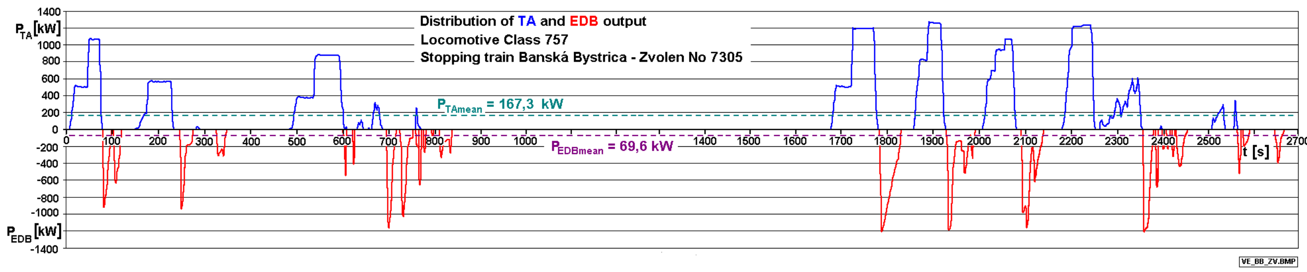

Fig.3. The courses of output of traction alternator and output of EDB of main line locomotive Class 757 at the stopping train on the railway line Banská Bystrica - Zvolen

A character of the actual railway line with long upward gradient and subsequent long downward gradient implicate different character of production of energy by EDB. In Fig. 2 it is very clearly visible at the time of about 2.4 hour (the top of railway line altitude). If input of auxiliaries should be covered by production of energy by EDB, accumulator must have some initial energy (say mentioned 100 kWh) in this case. The energy produced by EDB exceeds energy

for passenger trains is different. The utilization of full hybrid traction drive is not the optimal solution here. But the using of partial hybrid drive may be useful. The energy gained from EDB can be exploited for example for driving auxiliaries or partially for car supply. The accumulation devices needed for hybrid drive can be very useful for utilization of other sources of wasted energy, e.g. from exhaust gases.

Another way for energy savings is better design and control of auxiliaries. The mean of traction current of traction motors was in given case only 122 A. The constant current of used traction motor is 590 A for cooling air flow 80 m^3/min. The very short peaks of current were approx. 500 A or less. The mean input of cooling fans of traction motors was about 32 kW. If reasonable control of cooling fans drive will be used, the major part of fans power consumption could be saved.

About 36 % of released energy from the fuel is lost by exhaust gases. The course of exhaust gases temperature measured at the tests of main line locomotive Class 757 on railway line Banská Bystrica – Margecany (regional expres) is shown in the Fig. 4.

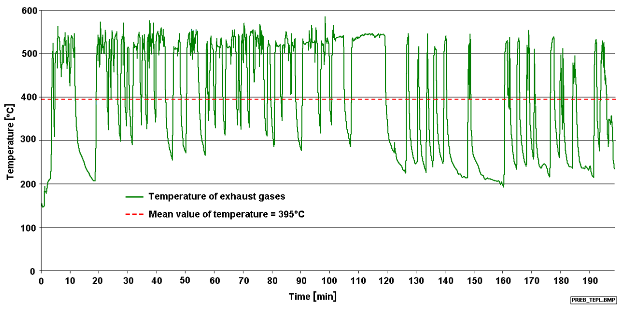

Fig.4. The course of the temperature of exhaust gases at the locomotive Class 757 on the railway line Banská Bystrica - Margecany

The energy of exhaust gases is possible to utilize by several ways. Since the temperature is significantly variable, some device must be used for accumulation of energy. Moreover the accumulator is unavoidable component of hybrid drive.

The necessity of car supply offers the possibility of using two ICEs. The smaller ICE would be designated for car supply. This ICE would be working only in case of need.

4. CONCLUSION

At some types of motive power units the utilization of the output of internal combustion engines is very poor. As was demonstrated, the mean output in many cases is below 15 % of installed output (even at the main line locomotives). This leads to uneconomical operation. One of the possible ways how to solve the problem is using of the hybrid traction drive. Knowledge of operational regimes of locomotives is inevitable for right choice of appropriate parameters of hybrid traction drive.

It is possible to gain about 15 – 20 % savings in fuel consumption of shunting locomotive by introducing a hybrid traction drive. In the case of main line locomotive fuel savings are significantly smaller (usually about 10 %).

It is possible to improve fuel economy also in case of main line locomotives by utilization of energy gained from electrodynamic braking for drives of auxiliaries (so called micro hybrid). This was proved by results of measurements in the real operation of main line locomotive.

There are other possibilities of reduction of fuel consumption, for example using two smaller engines instead of one big, using recovery of exhaust gases energy or using of solar energy. The hybrid drive enables to implement mentioned possibilities of fuel economy and make easier introducing new sources energy as fuel cells or unconventional engines.

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RUNNING RESISTANCE FROM FULL-SCALE MEASUREMENTS OF PASSENGER DIESEL MOTOR UNIT 711

Marija VUKŠIĆ POPOVIĆ [1]
Ivana ATANASOVSKA [2]
Milan PLAVŠIĆ [3]

Abstract – *This article presents determination of running resistance from full-scale measurements of passenger diesel motor unit 711 made by Metrovagonmash for Serbian Railways. The running resistance is determined by calculating the change in kinetic and potential energy and measured by undertaking run-down tests - train coasting. The experimental mesurments of DMU 711 running resistance analyzed in this paper are obtained during the commissioning phase of newly constructed railway vehicles.*

Keywords – running resistance, coasting, testing, disel motor unit

1. INTRODUCTION

Total forces acting on a train against its direction of travel, while braking not applied, make running resistance force. It is experimentally known that the running resistance force F_R and the specific running resistance f_R have the form of the second-degree polynomials (1):

$$F_R = f_R \cdot m \cdot g$$
$$f_R = a + b \cdot V + c \cdot V^2 \qquad (1)$$

where:
m –is a mass of the train (kg);
g – is a acceleration due to gravity (m/s^2);
V – is the train velocity (m/s) and
a, b and c – are the cofficients that vary with type of train, track, weel-rail friction etc. and can be obtained by run-down tests [1].

Coefficients A and a is purely mass dependent, coefficients BV and bV can be viewed as a viscous component partially dependent on the mass-related polling resistances of vehicles under consideration, and CV^2 and cV^2 represent the aerodynamic resistances [1]. At speeds $V \le 27.8$ m/s (≈ 100 km/h), which correspond to the case analyzed in this paper, the resistance force dependents mainly on the train mass.

Total specific resistance forces in addition to specific running (rotating) resistance f_R^{osn} include gradient force resistance f_{Rn}, curve resistance f_{Rkr} and wind resistance f_{RV} (expression 2) .

$$f_R = f_R^{osn} + f_{Rn} + f_{Rkr} + f_{RV} \qquad (2)$$

Rotating components (also known as rotary allowance) of running resistance f_R^{osn} taking into account mechanical resistance due to mechanical energy dissipation in vehicle, track and the contact between wheels and track, and aerodynamic resistance.

Specific gradient resistance force f_{Rn} is slope related and can be added as

$$f_{Rn} = \sin n \approx n \qquad (3)$$

where n is a gradient (‰).

Curving resistance f_{Rkr} is highly dependent on wheel and rail profiles, track cant and the geometry of the vehicle which is concerned. Effects of resistance due to track curvature are small, except for very tight curves with radius less than 250 m [1]. Some of expresions for calculating the specific curve resistance f_{Rkr} are [2]:

$$f_{Rkr} = \frac{650}{R-55} \;\; for \;\; R > 300\,m$$
$$f_{Rkr} = \frac{650}{R-30} \;\; for \;\; R < 300\,m \qquad (4)$$

where R is a curve radius in horizontal plane (m).

Specific wind resistance f_{RV} is usually taking into account through aerodynamic drag with relative wind speed V_{rel} [3]:

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$$V_{rel} = \sqrt{V^2 + V_V^2 + 2 \cdot V \cdot V_V \cdot \cos\alpha} \quad (5)$$

where:
V_V – is wind speed and
α – is wind direction relative to measuring section.

2. RUNING RESISTANCE TESTING

2.1. Test method

Runing resistance testing method is coasting, bringing the disel motor unit DMU 711 to a speed of 100 km/h on a track with almost constant gradient. The drive and braking are redused to zero. Time and position along the mesuring section/or distance started to be determined and recorded from the moment of reduction of drive and braking to zero speed. Runing resistance is determined indirectly by calculated the deceleration or by mesuring deceleration. These methods require the measurement of speed changes and knowledge of the gradients. Precise track data of track altitude and grades, as well as the accurate determination of speed and position of train along the track, are essential.

Costing method used for determining the running resistance is based on the differential equations of train energy, derivated from energy balance equation. Total energy, kinetic and potential, changes due to energy dissipation caused by runing resistance [4]. The theorem of change of kinetic energy defines the differential kinetic energy as equal to the work of the elemental forces, assuming that the weight of the train is concentrated in its center of gravity. So, the following expression is obtained:

$$dE_K = dA$$

$$\left(m + \sum_{i=1}^{n} \frac{J_{Pi} \cdot i^2}{R_t^2} \right) \cdot V \cdot dV = \left(F_V - F_R - F_K \right) \cdot ds \quad (6)$$

where the kinetic energy is equal to the sum of the kinetic energy of the parts that move translational: E_K^t and rotate at same time: E_K^o , (7).

$$E_K = E_K^t + E_K^o = \frac{m \cdot V^2}{2} + \sum_{i=1}^{n} \frac{J_{Pi} \cdot \omega^2}{2} \quad (7)$$

Taking into account that $\omega = \frac{i \cdot V}{R_t}$, as well as there is no traction force ($F_V = 0$) and that the DMU 711 is not braked ($F_K = 0$), following expression is obtained:

$$\frac{(1+\varepsilon) \cdot m \cdot \left(V_1^2 - V_2^2 \right)}{2} = F_R \cdot \Delta s = m \cdot f_R^{osn} \cdot \Delta s \quad (8)$$

On the basis of the expression (8) the specific running (rotating) resistance f_R^{osn} could be determined as:

$$f_R^{osn} = (1+\varepsilon) \cdot \frac{\left(V_1^2 - V_2^2 \right)}{\Delta s} \quad (9)$$

where:
m - is a mass of the train being tested;
ε - is a coefficient taking into account rotational inertia;
V_1, V_2 - are speeds on a particular difference of stopping distances Δs, for some speed V_1 and speed V_2;
$\Delta s = s_1 - s_2$ - is a difference of stoping distances at speeds V_1 and V_2.

2.2. General conditions

Disel motor unit 711 made by Metrovagonmash have two bogies per vehicle close coupled with enclosed gangways.

Testing of runing resistance was carried out on Martinci - Sremska Mitrovica track on relatively straight line in dry weather. The testing was performed from a speed of about 100 km/h, where the testing repeats four times: twice in the direction of Martinci - Sremska Mitrovica and twice in oposit direction.

The slope of the rail on the section of the test average is about 2‰ and has a decline in the direction of Sremska Mitrovica - Martinci, or climb in the opposite direction.

During testing, according to information from the Republic Hydrometeorological Service of Serbia, in the area of Sremska Mitrovica was a strong east wind with maximum impact of 11.4 m/s (41.04 km/h). Wind direction was approximatly same as the direction of the section line on which the test was conducted, whereby during the test in the direction Martinci - Sremska Mitrovica it blews opposite of the train, and in the direction of Sremska Mitrovica - Martinci in the direction of the train.

Because of this slope and strong wind there was a large difference in stopping distance in these two directions. In the direction of Sremska Mitrovica - Martinci (2. and 4. measurment, table 1) stopping distance is about 28% longer than the stopping distance in the opposite direction (1. and 3. measurment, table 1).

Tab. 1. Stopping distance

Number of measurement	Maximal speed [km/h]	Stopping distance [m]
1.	98.5	9901
2.	99.4	13612
3.	98.9	10087
4.	97.4	14180

Influence of head and tail wind according to [3] is considerbly lower for tests then estimated with conventional method by considering relative speed between train and wind. For minimizing wind influence it is recommended to run tests in both directions along the measuring sections [5]. The mean value of running resistance is determined by mean value of polynomial fitted the results for two wind conditions. This is not the same as running resistance for testing without wind because increase in aerodynamic drag due to wind is not the same as decrease when running in opposite directio, even when the wind conditions are the same.

2.3. DMU 711 data

The weight of the DMU 711 during the test is determined in accordance with the expression (10). To the measured empty weight of DMU 711 m_{pr} = 87662,5 kg ready for exploatation was added weight of passengers and staff m_{pu} calculated as product of 21 persons with the average weight of 80 kg per person.

$$m = m_{pr} + m_{pu} = 89342{,}5 \text{ kg} \qquad (10)$$

Coefficient taking into account rotational inertia ε could be calculated according to the equation (9), which is obtained from the expressions (6) and (7). Therefore, following expresion is given:

$$\varepsilon = \frac{\sum_{i=1}^{n} m_{ri} \cdot \frac{D_{ri}^2}{D_t^2} \cdot i_i^2}{m} \qquad (11)$$

where:

i - is part number;

n – is total number of rotating parts;

m_{ri} - is a mass of i^{th} rotating part;

D_{ri} - is a diameter of the ellipsoid inertia of the i^{th} part;

i_i - is a gear ratio of a i^{th} part which is attached to the axle assembly;

D_t - is a wheel diameter.

At DMV 711 there are 8 axle and 4 axle assembly for driven gear. On the basis of the expression (11) and rotating parts data, the coefficient of rotational inertia ε have a value of 0,074.

3. TEST RESULTS

3.1. Running resistance results

Based on the expressions (4), to determine the specific running rotating resistance f_R^{osn}, certain dots couples for speed and specific running resistance (V, f_R^{osn}) were obtained, and then used to obtain a polynomial expressions (12) for each measurement by method of least squares with a confidence interval 95% (Figure 1).

For each of the 4 conducted measurements, the specific running resistance f_{R1}, f_{R2}, f_{R3} and f_{R4} are determined, respectively for the measurement 1, 2, 3 and 4 (Figure 2).

Specific running resistance f_R^{osn} is defined as the mean value of the specific running resistance for all 4 measurements (Figure 2). Additional resistance from the slope and curve are taken into account when the specific running resistance was determining for each measurement separately.

Also, the wind blews approximatly in the direction of the tracks on which the test was conducted, whereby at the cases of 1th and 3th measurements wind was blowing from the opposite direction of the train movement, and for 2th and 4th measurements in the direction of the train.

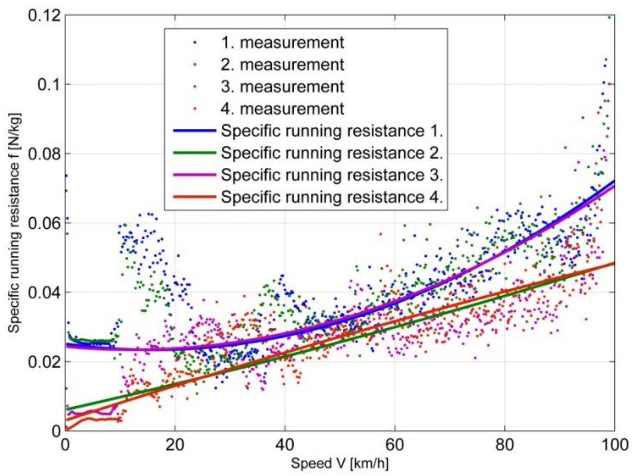

Fig.1. Specific running resistances and measurements

According to [3] it was assumed that the action of the wind was about the same for all four measuring cases and has the opposite directions (which is reflected as a sign in the equation 9). Therefore, it may be considered, that impact of wind is excluded or reduced to a minimum in proces of determining of the mean value of the specific running resistance.

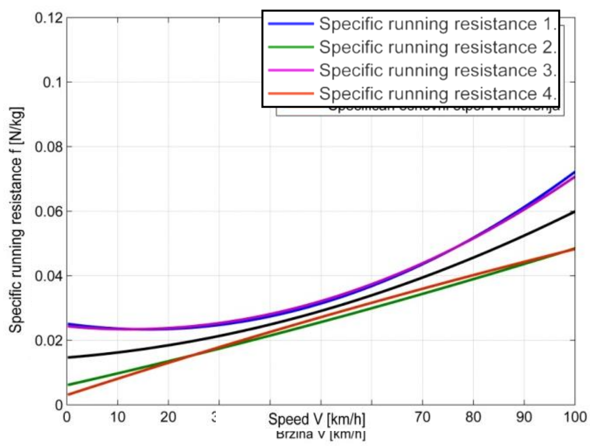

Fig.2. Specific running resistance of DMU 711

Specific running resistance f_R^{osn} of DMU 711 obtained by tests is given with expression (12):

$$f_R = 0{,}014657 + 0{,}00012485 \cdot V + 0{,}000003278 \cdot V^2 \quad (12)$$

The measured specific running resistances of DMV 711 depending on the speed approximate theoretical running resistance (given by manufacturer), but have a higher value from the theoretical to about 340 N at low speeds (Figure 3). This inconsistency may be due to many reasons, for example:

- applied method and data for calculations of teoretical running resistance;
- used values for calculations of coefficient of rotational inertia ε;
- errors in measuring and during testing;
- the impact of the state of the tracks;
- the influence of wheel/rail friction etc.

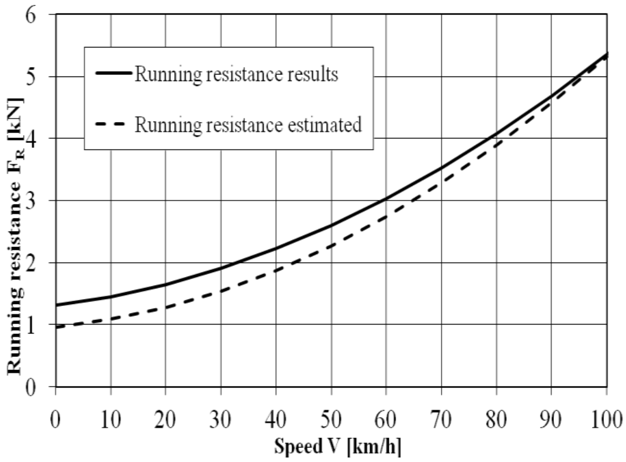

Fig.3. Teoretical and experimental running resistance

3.2. Ersors in estimated running resistance

Running resistance results, like other experimental results, must have estimated errors. The errors can be precision errors that are random, which can be treating using statistical tehniques, and bias errors, which are systematical and occur in the same way each time, resulting in offset from true value.

Precision errors of running resistance results appear due to determination of speed and positioning vehicles [5]:

- Error in measuring precision of wheel radii and the speed;
- Variation in wheel radii due to wheel conicity and variation in track gauge;
- Error in altitude of DMU with respect to the track data.

Longitudinal oscilatory motions is not considered due to a measurement aplication on DMU 711.

The bias erors in the evaluated running resistance are due to determination of speed, train mass and rotating inertia.

4. CONCLUSION

National railways have a various approaches to the calculation of resistance. The availability of the value of actual running resistance is important for determination of the power requirements and running times of travel. Various individual parameters indicate that the use of run-down tests on new vehicels should be preferred method [1]. Therefore, running resistance was determined for DMU 711 which is now running on Serbian railways.

Influence of ambient wind was minimized by averaging polynomials obtained by fitted results of measurements in directions of wind and in oposite direction along the same test track, during similar wind conditions. The difference between the coefficients for wind with particular parameters and one evaluated for zero wind conditions is approximately ±3% for freight trains [5].

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STATIC STRENGTH STUDY OF BODY OF UNIVERSAL FLAT WAGON

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Sanel PURGIĆ [3]

Abstract *– In the first part of the study, a static strength of the initial structural design of body of universal flat wagon was examined. As a result of this part of the study, obtained stress values were exceeding significantly the permissible stress values. After some minor changes in structural design of wagon underframe, a static strength was retested. The obtained stress values from second test were lower than the permissible stress values, thanks to the undertaken minor changes in design.*

Keywords – flat wagon, strength analysis, FEM, design change.

1. INTRODUCTION

The study was conducted at the request of Bulgarian freight wagon manufacturer TRANSVAGON Plc., Bourgas. The object of the study is 4-axle universal flat wagon series Rens, type 192, designed for axle load of 22,5 t. The companies design department developed the design documentation of the wagon in 2007, but the calculation team carried out strength calculations first in 2013. Also in 2013, the Bulgarian National Transport Research Institute (NTRI) tested the wagon and then in same year German railway administration commissioned the wagon.

In the first part of the study, e.g. in preliminary static strength calculations of initial wagon design, calculation team received for some load cases stress values exceeding significantly the permissible stress values. In such cases, most of the teams carriing out the strength calculations (depending on wishes of costumer, as it was in our case) have to make suggestions for improvement of initial design of wagon in order to achieve stress values which not exceed the permissible values.

The calculation team make this suggestions in consultation with costumers design and manufacturing departments in order to find a optimal solutions for improvement of wagon design, which have to be carried out on one hand by minimal structural design changes, on the other hand they should have no influence on the technological and production-related processes.

In the second part of the study, we carried out static strength calculations of improved wagon design, where we received stress values which are not exceeding the permissible stress values.

In accordance with [1] the study was conducted in the following sequence: first a model of wagon Rens 192 was developed; the received theoretical results are compared with experimental test of the wagon a model of the improved wagon design was developed; then new calculations of improved wagon construction are carried out and a proposal for commissioning of new wagon was made.

2. LOAD CASES

European standard EN 12663-2:2010 [2] specifies static load cases and conditions for their application on freight wagon constructions. According to this document and costumers wishes we applied static loads on initial construction of universal flat wagon Rens given in table 1.

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 equals to current mass of vertical load depending on loading width and length, which are given in wagon loading raster. After the preliminary calculations were done, results show that the VLC2 is the "worst case" vertical load of all vertical load cases and length b-b the most unfavorouble length.

3. CALCULATION RESULTS OF INITIAL DESIGN

Theoretical studies have been done by the finite element method. A software used is SolidWorks [3].

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Tab. 1. Applied static load cases

Load case	**Description**
	Longitudinal static loads
HLC1	Compressive force at buffer axis height 2000 kN (Table 2 of [2])
HLC2	Compressive force 50 mm below buffer centre line 1500 kN (Table 3 of [2])
HLC3	Compressive force applied diagonally at buffer level 400 kN (Table 4 of [2])
HLC4	Tensile force at coupler axis level 1500 kN (Table 5 of [2])
	Vertical static loads (Table 6 of [2])
VLC1	Vertical load 33 t placed on two supports at the width of 1,2 m and length a-a = 2 m;
VLC2	Vertical load 44 t placed on two supports at the width of 1,2 m and length b-b = 5 m;
VLC3	Vertical load 52 t placed on two supports at the width of 1,2 m and length c-c = 9 m;
VLC4	Vertical load 66 t placed on two supports at the width of 1,2 m and length d-d = 15 m;
VLC5	Vertical load 28 t placed on two supports at the width of 1,2 m and length e-e = 18 m;
VLC6	Vertical load placed on two supports at the width of 2 m and most unfavorouble length
VLC7	Vertical load placed on two supports at the whole wagon width and most unfavorouble length
VLC8	Vertical load 32 t distributed at the width of 1,2 m and length a-a = 2 m;
VLC9	Vertical load 39 t distributed at the width of 1,2 m and length b-b = 5 m;
VLC10	Vertical load 42 t distributed at the width of 1,2 m and length c-c = 9 m;
VLC11	Vertical load 52 t distributed at the width of 1,2 m and length d-d = 15 m;
VLC12	Vertical load 66 t distributed at the width of 1,2 m and length e-e = 18 m;
	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 [2])
LLC2	Lifting the whole vehicle at 4 lifting positions $1{,}0*g*(m_1+2m_2+m_3)$ (Table 8 of [2])
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 [2])
	Superposition of static loads (Table 9 of [2])
CHLC1	Compressive force at buffer axis height 2000 kN and "worst case" vertical load $1{,}0*g*(m_1+m_3)$
CHLC2	Compressive force 50 mm below buffer centre line 1500 kN and "worst case" vertical load $1{,}0*g*(m_1+m_3)$
CHLC3	Compressive force at buffer axis height 2000 kN and minimum vertical load $1{,}0*g*m_1$
CHLC4	Tensile force at coupler axis level 1500 kN and "worst case" vertical load $1{,}0*g*(m_1+m_3)$
CHLC5	Tensile force at coupler axis level 1500 kN and minimum vertical load $1{,}0*g*m_1$

For the purposes of the study complex spatial calculation model describing precisely the geometry of the wagon was developed as shown in fig. 1. The parameters of the model are: max. size of elements – 49,5 mm, number of elements – 734 869, number of nodes – 367 983.

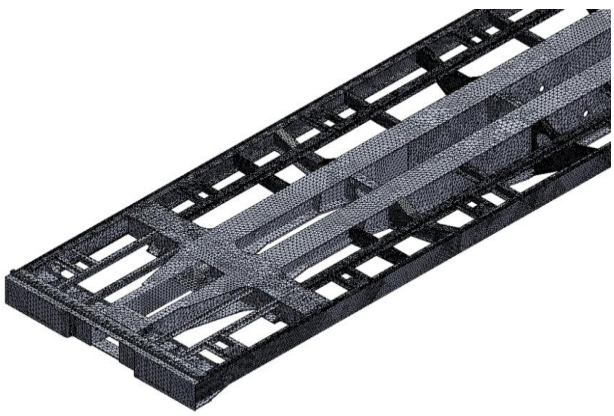

Fig.1.Calculation model of Rens 192

In this model we used finite elements type 3D, because of their advantages to shell elements [4]. In the creating process of the model the convergence of the decision was investigated [5, 6, 7].

This allows us to develop the most appropriate schemes regarding: geometric representation of the object, the application of the current loads and reactions and getting enough accurate results for the distribution of strains, displacements and stresses [8, 9, 10, 11].

As mentioned above, after strength analysis of initial wagon construction, stress values exceeding significantly permissible stress values were detected. This occurs in three load cases: HLC3, LLC1 and CHLC1, as shown in figures 2, 3 and 4.

Permissible stress values for commonly used steel grades are given in table 19 of [2]. For steel S355, from which the wagon underframe is built, permissible (limit) stress has a value 355 MPa for parent material and 323 MPa for parent material in the immediate vicinity of welds.

Tab. 2. Stress values from calculation

Load case	Calculated stress values [MPa]	Permissible stress values [MPa]	Safety factor [-]
HLC3	612,8	323	0,527
LLC1	659,1	323	0,489
CHLC1	357,5	323	0,903

Table 2 contains the obtained stress values, permissible stress values and safety factors for three mentioned load cases.

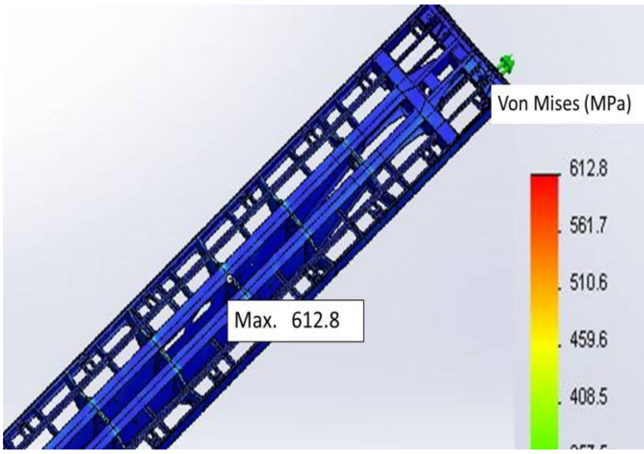

Fig.2.Max. stress for load case HLC3

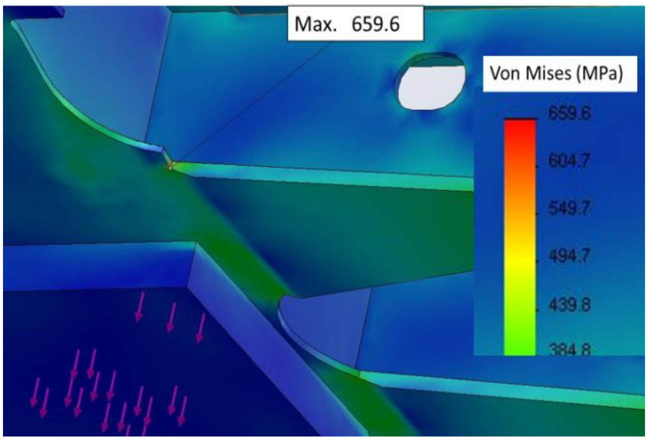

Fig.3.Max. stress for load case LLC1

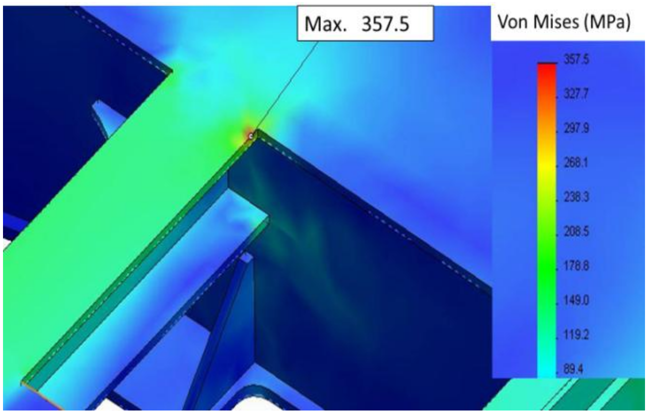

Fig.4.Max. stress for load case CHLC1

From the calculation results given in figures 2, 3 and 4 and table 2 is obvious, that the calculated stress values are inadmissible high and safety factors are smaller than 1.

This was confirmed also in tests carried out at NTRI. For the purposes of test, our calculation team suggested the placement of strain gauges based on the results from calculation. The test results for “clear” longitudinal load cases have similar stress values and are inadmissible high in same areas, which we suggested.

4. CALCULATION RESULTS OF IMPROVED DESIGN

Exceeding the permissible stress values prompted the calculation team after the consultation with the costumer, to modify the initial wagon structural design in order to reduce high stress values. The modifications in structural design should be minimal and should have no influence on the technological and production-related processes, e.g. no need of new welding jigs etc.

After several iterations, we have suggested following minor constructive changes in the initial design, which have led to the reduction of stress values:

1. The thickness of the lower boom at mid-solebar in the area of height transition was increased from 24 to 28 mm (Fig. 5).
2. On both bolsters to the wagon center additional ribs with dimensions 100x100 mm at the right and at left side between the vertical web and double-T-profiles were mounted (Fig. 6).
3. All connections, both upper and lower booms of all transoms with connection to the upper and lower booms of the mid solebar were "released", e.g. cutted by 45 mm.
4. Above the transoms in the center of the wagon in the area between upper booms of the mid solebar (vertical middle web) hourglass-shaped reinforcing plates were mounted. (Fig. 7).
5. From the lower side of the vertical intermediate webs at mid solebars, booms with width 40 mm were mounted (Fig. 7).

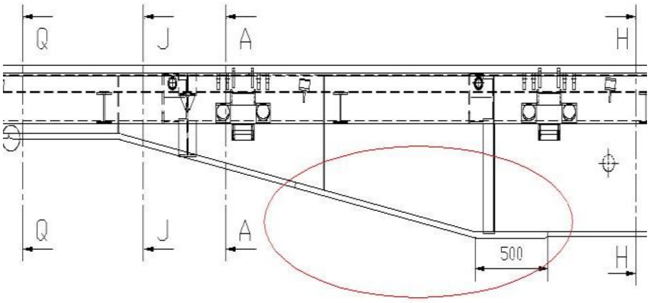

Fig.5. Design change 1

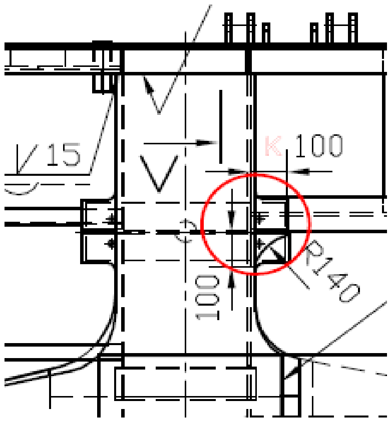

Fig.6. Design change 2

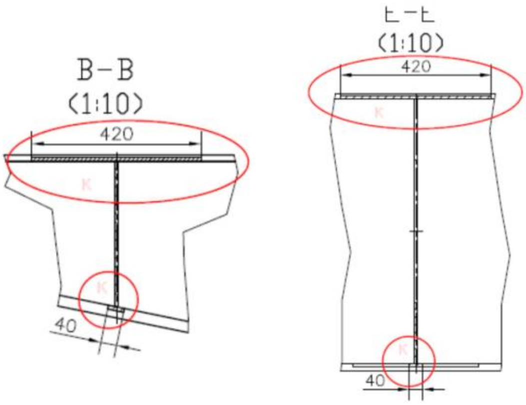

Fig.7. Design changes 4 and 5

Tab. 3. Stress values from recalculation

Load case	**Calculated stress values [MPa]**	**Permissible stress values [MPa]**	**Safety factor [-]**
HLC3	283,3	355	1,253
LLC1	416,7	450,2	1,080
CHLC1	332,1	355	1,068

In this way changed wagon construction was recalculated for all static load cases from table 1.

Table 3 contains the obtained stress values, permissible stress values and safety factors for three "problematic" load cases.

Not only stress values changed, but also the permissible stress values. This means, that maximal stresses have "moved" from areas of weldings in parent material. For load case LLC1 special rules are valid, according to [12] and that's way the permissible stress has value of 450,2 MPa. Since steel used is a ductile material, local stress concentrations can be allowed. Condition for this is that the plastic deformations are so small that no significant permanent deformation occurs, according to [12], Section 5.4.2. Here, the inner supporting effect of the material is taken into account, the outer fibers are prevented to a pronounced flow due to the supporting effect of the internal fibers. Therefore, a further spread of the yield stress is allowed until the edge fibers reach a lasting elastoplastic strain of 0.2%.

5. CONCLUSION

Summarizing the overall work on this study the following conclusions can be drawn:

- Complex calculation model for strength study of wagon Rens 192 was developed. Very good compliance of the results for the stresses and displacements obtained by calculations and those of the wagon test was found. This allows the calculation model to be used for strength study and optimization of improved structural design of wagon Rens 192.
- The stress values obtained from static strength study of initial wagon construction were unsatisfying. This had as a consequence the changes of construction and recalculation of new structural design.
- Obtained stress values from second study part were lower than the permissible stress values, thanks to the undertaken minor changes in design.

This gives rise to a proposal for the commissioning of wagon Rens 192 without conducting of new mandatory tests of the wagon.

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METHODOLOGY FOR DETERMINING THE PARAMETERS OF THE BRAKING SYSTEM OF RECONSTRUCTED FREIGHT WAGONS

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Sanel PURGIĆ [3]

Abstract *– In the reconstruction or modernization of freight wagons a change in their own mass (tare) is often obtained, which leads to a change in the brake weight percentage. This paper is dedicated to the refined methodology for calculating the required parameters of the brake system of such wagons in order to meet the requirements of UIC for braking weight percentage of freight wagons. This methodology can be used in wagon factories, which carried out the reconstruction of freight wagons.*

Keywords – methodology, parameters, braking system, reconstructed, freight wagon.

1. INTRODUCTION

Nowadays many companies dealing with business in the manufacture, sale and operation of freight wagons often cariing out so called "renovation" or also known as a "reconstruction" of freight wagons.

The essence of this process is the purchase of freight wagons, which were significantly long time in service and their entering in the specialized wagon manufacturing or renovation plants. There those wagons are beeing recovered - renovated and often reconstructed, i.e. a given series of freight wagons are processed in another series.

A very important point in this activity, that needs to be clarified, is that in this way the owner of the freight wagon gets reconstructed freight wagon with parameters complying with international requirements, but about 1/3 of the price of brand new freight wagon.

Very often, however, after conducting this reconstruction, the parameters of the braking system change and it is necessary to carry out their recalculation in order to achieve the required national and international conditions for commisioning of wagon and required values of the parameters of braking efficiency [1,2,3].

This paper focuses on the methodology for recalculations of the parameters of the braking system and can be useful in the practice of railway freight wagons reconstruction plants.

2. METHODOLOGY AND ALGORITHM FOR RECALCULATION

Most of freight wagons running under condition “S” have a two level graduated modification of braking force, depending on loading of wagon. In accordance to [3], the braking percentages of these wagons are amended as shown in fig. 1. These values of obligatory braking percentages λ are also given in table 1. Braking percentage of such wagon is expressed by equation (1), [4]:

$$\lambda = \frac{B}{M_W}.100,[\%] \qquad (1)$$

wherein:
λ – braking percentage of wagon;
B – braked weight of wagon, t;
M_W – wagon mass, t.

Before renovation of a wagon, its braking percentage was conforming to these requirements for braking percentages. But very often in this type of activity a mass of empty wagon - M_{w1} increases and the value of its braking percentage does not meet the requirements. In this case, some of the main parameters of the braking system have to be calculated again, i.e. recalculated. This recalculation is performed in the following sequential steps:

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Tab. 1. Values of obligatory braking percentages

Running condition	Speed, km/h	Min. braking percentage λ	Max. braking percentage λ	Position	Changeover
Freight train	90	65	-	G	two level
S	100	65*	125	P	two level
SS/ S	120/ 100	100/ 65	125	P	non-graduated
SS	120	100	125	P	non-graduated

* It is allowed λ to be 55 at changeover mass
** Max. λ can be 130 for cast iron insert

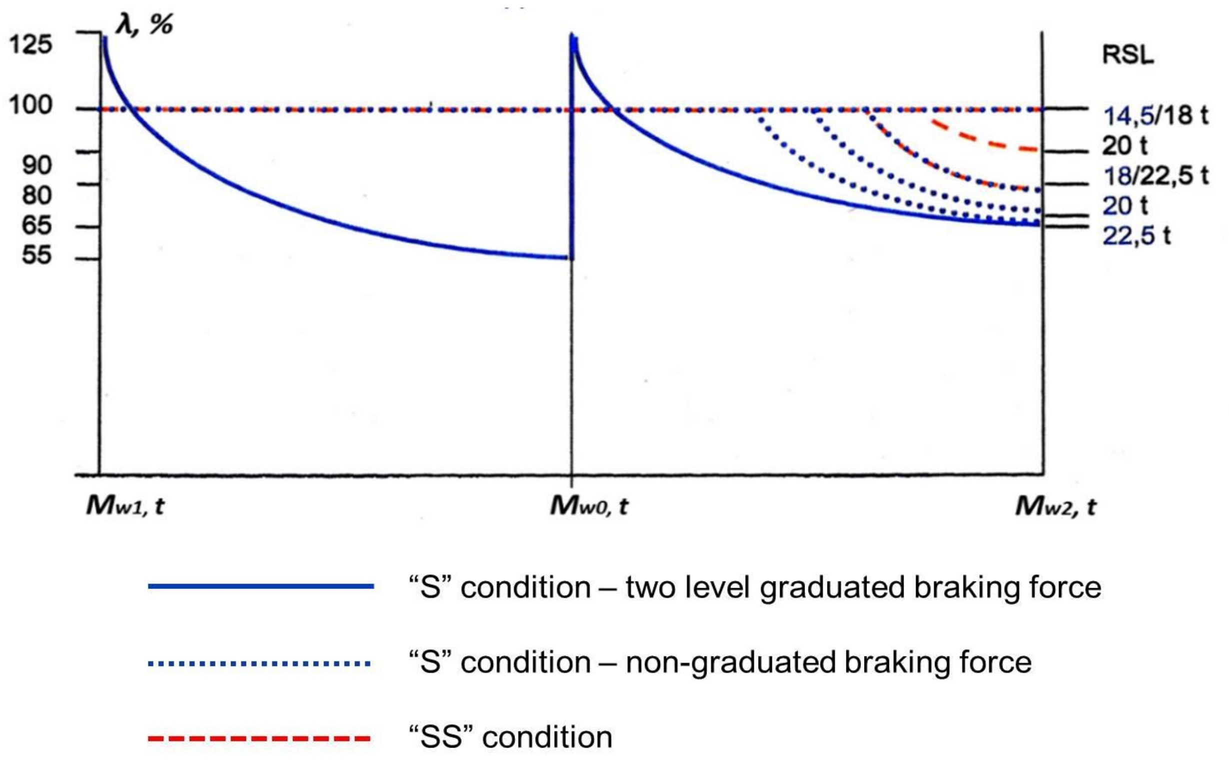

Fig.1. Braking percentages depending on loading of wagon

1. Calculation of the new braked weight of wagon - B_1:

$$B_1 = \frac{\lambda . M'_{W1}}{100}, [t] \quad (2)$$

wherein:
λ – braking percentage of empty wagon – fig. 1 and table 1;
M_{W1}' – new empty wagon mass, t.

2.Calculation of required brake block force $\sum F_{dyn}$

To achieve the calculated braked weight B_1 it is necessary to calculate the value of force $\sum F_{dyn}$. In [4] the equation (3) contains the link between the braked weight and brake block force:

$$B = \frac{k.\sum F_{dyn}}{g}, [t] \quad (3)$$

wherein:
B – braked weight, in this case B_1 [t];
k – assessment factor for determining the braked weight;
$\sum F_{dyn}$ – sum of all brake block forces during the run [kN].

Analysis of equation (3) shows the following:
1. Assessment factor k is calculated by analytical dependence (4), [4]:

$$k = a_0 + a_1.F_{dyn} + a_2.F_{dyn}^2 + a_3.F_{dyn}^3 \quad (4)$$

The values of $a_0 \div a_3$ are constant, given in table in subchapter 2.2.2.1 of [4], depending on the type of used brake blocks.

2. Assessment factor k can also be determined from diagrams given in [4], depending on the type of brake blocks and the value of the brake block force on the friction unit.

From the analysis, it is apparent that the brake block force cannot be calculated from equation (3), due to the pronounced dependency of the coefficient k thereof.

The calculation of the brake block force may be performed in two main ways, a good decision is to do this in several iterations.

First method

It is based on the choice of the brake block force factor as conventionally used in such wagon constructions. This factor is determined according to formula (5) [5, 6]:

$$\delta = \frac{\sum F_{dyn}}{g.M'_{W1}} \quad (5)$$

The recommended values of δ are given in table 2.

Tab. 2. Recommended values of δ

No	Type of rolling stock	δ
1.	Empty freight wagons with one iron cast brake block on both wheel sides	0.63 ÷ 0.68
2.	Empty freight wagons with two iron cast brake blocks on both wheel sides	0.60 ÷ 0.62
3.	Empty freight wagons with one iron cast brake block on one wheel side	0.60

With these values of δ and equation (5), the brake block force can be calculated.

Second method

This method is based on equality of adhesion and braking forces for movement speeds less than 10 *km/h*. In this case:

$$\sum F_{dyn}.\mu_k = M'_{W1}.\mu_S \quad (6)$$

wherein:

μ_k – coefficient of friction in friction unit, determined at certain speed;

μ_S – coefficient of adhesion. For freight wagons with cast iron blocks is permissible μ_S = 0,20. This value is valid for speeds less than 10 *km/h*.

With determined by one of two methods force $\sum F_{dyn}$ is beeing checked whether the calculated braked weight B_1 and regulated braking percentage are received. On the other hand, the power $\sum F_{dyn}$ is determined according to equation (7), [4, 5, 6]:

$$\sum F_{dyn} = \left(F_t.i_G - i^*.F_R\right).\eta_{dyn} \quad (7)$$

wherein:

F_t – effective force at the brake cylinder [*kN*];

i_G – total multiplication ratio for the brake rigging;

i^*- multiplication ratio after the central rigging;

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

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

In this case of the calculation, the possible option to achieve the necessary value of $\sum F_{dyn}$ is by changing the brake rigging ratio i_G. Through this change, the required value of the total brake force in friction units is calculated. This change is carried out with consideration of standardized dimensions of the brake rigging system, valid for an empty wagon.

On the basis of B_1 and the requirements for braking percentages - Fig. 1 and Table 1, the new changeover mass of the empty wagon M_{w1}^0 is beeing calculated.

Analogously is made and the calculation of the parameters of braking system for loaded wagon.

After the calculations, it is also necessary to do reconstruction of functional valve type KE 1c to KE 1d. This applies to valves of this system and if the wagon will travel to different countries of Europe.

3. CONCLUSION

Illustrated calculation is valid for freight wagons running under condition "S" and equipped with cast iron blocks of the two main types Bgu and Bg. In wagons with composite brake blocks calculations are similar, but with different values for the coefficients.

Also these calculations can easily be developed in the form of a computer program and then their performance will be faster and easier.

The methodology of calculation shown in this report is important for designers and technologists in wagon manufacturing and renovation plants and helps to solve this problem in the course of their work.

The effectiveness of this methodology was tested in some wagon manufacturing and renovation plants in Bulgaria and gives very good results.

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DESIGN SPECIFICITY OF EAMS-Z SELF-PROPELLED WAGON

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Abstract – *Self-propelled wagon Eams-Z inteded for bulk material transportation provides enhancement in railway infrastructure construction and maintenance. Its main advantage is possibility of manipulation along tracks and construction material discharging without use of locomotive. Thus this car saves energy, human resources, and shortens the time of transportation and unloading. The car has two crates with the possibility of side and frontal inclining using hydraulic cylinders. These cylinders provide controlled and precise unloading of cargo on 3 sides without need of any extra man or machine power. Power pack, consisting of diesel engine, hydro transmission and two small wheels without flange is positioned in the middle of the car between the bogies. In the self-propelled regime wheels lower down to rails providing traction force needed for wagon manipulation. This car type requires special attention during design and calculations in order to achieve safe manipulation in all regimes.*

Keywords* –*Five key words suggested. At least one of them should be from the field of Railways.

1. INTRODUCTION

Considering tendencies of restructuring of state railways authorities using some of existing and accepted models and methods, e.g. dividing them into a several independent private or state owned companies (infrastructure, passenger traffic, cargo traffic, maintenance providers etc.) each innovation and/or solution that provides some level of independency between these companies for realization of some activities are very welcome, due to possible simplifications in organisation and speeding up their realization.

This paper presents freight car marked as Eams-z manufactured by Factory "RŽV Čakovec", Croatia, intended for transportation of the gravel in the process of track maintenance. The project is the result of three year work of the international consortium, co-funded by EU within Eco-Innovation Programme [1]. Comparing to other standard freight cars inteded for this purposes, this wagon has ability independently to move along tracks during load discharge using power pack installed between load crates. Also, it has special tilting mechanism and openings with doors for controlled and batched unloading of bulk material using hydraulic cylinders and own power.

The wagon operates in the two modes (regimes):

1. Transport mode when it operates in the regular train composition as standard freight wagon,
2. Working mode during load discharging, which enables it independently to move along tracks at lower speeds during gravel discharging and without need to engage shunting locomotive or other external power drive.

In the final phase of the wagon development for obtaining the licenses for operation i.e. TSI certification [2], wagon passed series of the stationary and running tests.

In the next paragraphs are presented wagon design specificities and some of the performed tests and calculations required for this type of wagon.

2. CARBODY AND POWER PACK

The wagon is equiped with two standard Y25L series of bogies [3]. The maximum operational speed is 100 km/h. Its tare weight is 37.34 t and the maximum payload capacity 52.5 t. Payload is distributed in the two separete boxes – cargo crates with total volume of 50 m^3. Cargo crates and power pack are placed on the carbody frame (Fig.1).

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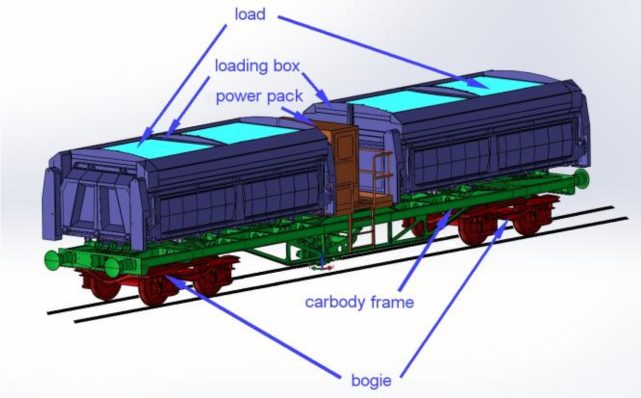

Fig.1. Eams-z wagon design

Each cargo crate has the possibility of side and frontal lifting (tilting) and thus controlled and precise unloading of bulk material on 3 sides using built-in hydraulic cylinders and power pack (Fig. 2).

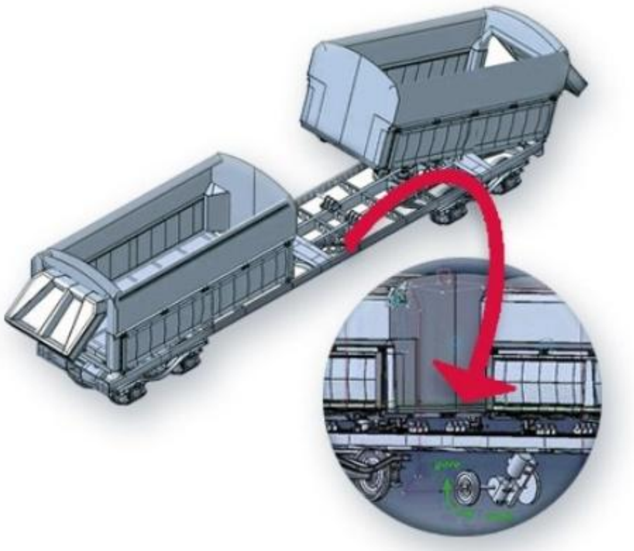

Fig.2. Cargo crates kinematics [1]

Tilted cargo crate in the lifted position during side discharging is presented in Fig. 3.

Fig.3. Lateral tilting of the cargo crate for side discharging

Independent movement in the working mode is achieved using power pack, consisting of 55 kW diesel engine and hydraulic transmission connected with two wheels with small diameter and without flanges. In the working mode these wheels have the ability to lower to rails (Fig. 2).

Control of the wagon movement and operation of the doors for load discharging is possible either from the vehicle, or from the track side, using remote control device.

Thus this car saves energy, human resources and shortens the time of transportation and unloading.

3. CALCULATIONS AND TESTS

Considering wagon Eams-z specifities i.e. that it operates in the two regimes, during wagon design and development one of the main task was to achieve wagon properties that clearly categorize it as a standard freight car when used in the transport mode. Otherwise the wagon would have to pass additional tests of derailment safety, as well as other tests that must be performed in the case of standard traction vehicles (locomotives, motor units, trolleys etc.)

This paragraph presents some of the performed tests required for standard freight cars:

- Stationary brake test,
- Carbody static strength test,
- Determination of the carbody torsional coefficient,
- Brake performance test,
- Buffing impact test, etc.

Fig. 4 presents stationary brake test performed in the ″RŽV Čakovec″ factory. The test was performed by Instute Kirilo Savić [4] in accordance with appropriate TSI and UIC norms.

Fig.4. Stationary brake test [4]

Running brake performance test [5] was performed on the track section Koprivnica- Mučna Reka (Fig. 5) The test was performed in accordance with TSI WAG (321/2013). Stopping distances were measured during slip brake test at 100 km/h for empty and loaded wagon. Corrected measured stopping distances were used for determining mean value. From this value are calculated the braked weight percentage and braked weight B for empty and loaded wagon.

Fig.5. Brake power running test [5]

Static strength test was perforemd in GOŠA Rolling Stock Factory Ltd., Smederevska Palanka [6]. The test was performed in accordance with EN 12663-2: Chapters 5, 6 and 7. Fig. 6 presents combined load case with maximum vertical load and compresive force 2x1000 kN applied over buffers axes.

Fig.6. Carbody static strength test [6]

Fig.7. Buffing impact test – wagon end with installed force and displacement transducers [8]

Buffing impact test [7] was performed on the connecting tracks between the Railway station in Čakovec and Factory ″RŽV Čakovec″. The test was performed in accordance with EN 12663-2, points 8.2.2, 8.2.3 and 8.2.4 trough the series of impacts at speeds upto 12 km/h (Fig.7).

In order to meet the requirements for safety against derailment on the twisted track for standard freight cars, Laboratory of rail vehicles of Faculty of Mechanical Engineering- Belgrade, performed measurement of torsional stiffness coefficient of the carbody [8]. The test was performed according to Annex C of EN 15839.

One out of four supporting points was lifted and lowered, thus to simulate appropriate wagon twist considering wagon geometry (wheelbase, centre pin distance, support points distance etc.). During this process resulting change in force reaction at four supporting points was measured and served for calculation of the torsional stiffness coefficient.

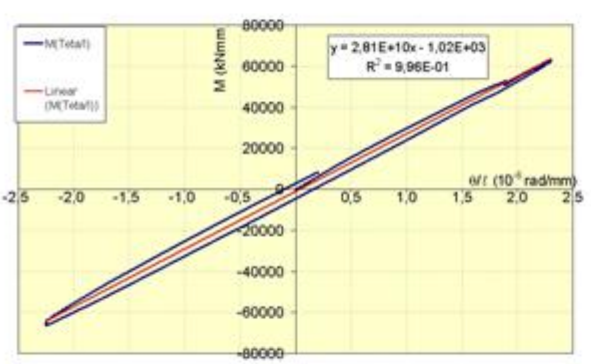

Fig.8. Torsional torque vs. torsional angle per mm of the carbody length

Fig. 8 presents test diagram of measured parameters that serve for determination of the torsional stiffness coefficient.

Based on measured value of the torsional coefficient, along with the fact that the wagon is equipped with running gear of established type Y25L and that calculated parameters of the carbody are within acceptable limits, it was concluded that Eams-z wagon meets the required criteria stipulated in CR TSI WAG and EN 16235 for dispensation from running dynamic behaviour tests according to EN 14363 [8, 9] in the transport mode of use.

In the working mode of use, wagon operates as a working track vehicle at low speeds, under supervision of trained railway staff using auxiliary power pack at isolated track sections. Therefore in this mode of use do not apply standard criteria.

Vehicle gauge calculation in this case was focused on the power pack traction wheels. In order to avoid contact with infrastructure, in the transport mode these wheels are in the lifted position. Gauge calculation [10] was performed in accordance with TSI WAG 2013 considering reference kinematic gauge G1 and according to EN 15273-2:2009 gauge GIC1 for lower parts. Considering wagon vertical movements caused by suspension system deflections under load, vertical dynamics and wear of wheels and other elements, as well as roll coefficient value, roll centre height and possible clearences, permissible vehicle gauge was calculated for the mid cross-section (Fig.9). In order not to jeoperdise vehicle gauge in transport mode power wheels should be securly locked 243 mm above the TOR (top of rail). In the working mode of use, when the wagon operates as a track maintenance vehicle, out of public traffic, the lowered wheels of the traction system are out of gauge GIC1 for lower parts, which is acceptable.

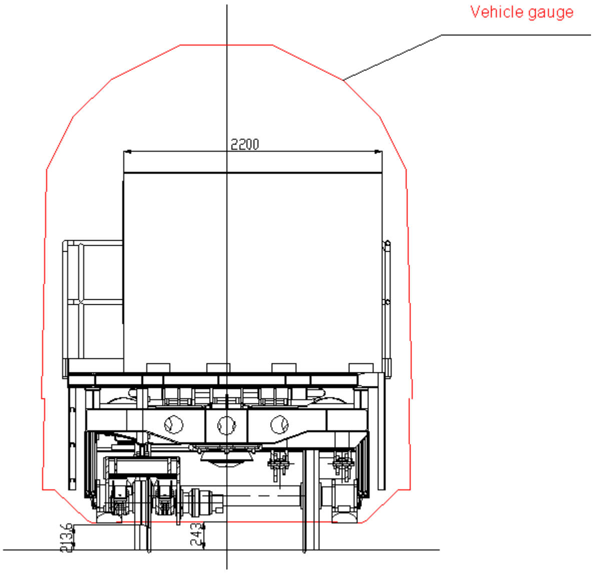

Fig.9. Vehicle gauge in the middle between centre pins at the traction wheels location [9]

4. CONCLUSIONS

In the proces of introduction the new type or non-standard type of vehicle, even in the phase of development and design, engineers should consider valid regulations and norms that define tests and calculations, required for issuing licenses for traffic according to TSI. In the case of standard freight wagon this task is quite clearly defined. Opposite, in the case of non-standard wagons, such as Eams-z self propelled wagon, depending on technical requirements, it is necessary to study wider range of regulations and existing similar vehicles' designs, in order to stay in the planned time schedules and within available funding. In the case of this wagon, apart from the standard tests, which are already expensive and complicated, traction system design required performance of some additional tests and calculations in order to prove wagon's funcionality in both regimes, transport mode of use and when it is used as track maintenace machine.

ACKNOWLEDGEMENT

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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INFLUENCE OF MEASUREMENT METHOD AND DATA PROCESSING ON THE RESULTS OF BRAKE PERFORMANCE TEST

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Abstract – *In order to determine the brake weight of rail vehicles, brake perfomance test has to be perfomed. This test shall be conducted in accordance with the UIC 544-1. This regulation defines the necessary conditions and required quantities that shall be measured (speed, stopping distances, pressure etc.), but does not specify measuring method and all details about data processing. This paper presents possible influences on the results when using different speed measurement techniques or data processing details.*

Keywords – Speed, Stopping distance, Brake weight, Measurements.

1. INTRODUCTION

In accordance with European standards TSI [1], brake performance can be determined by calculation and/or experimentally - by testing. Valid standards allow assessment of the braking performance by calculation only in case of wagons fitted with cast iron brake blocks (P10) which comply also with some other limitations. In all other cases the calculations are only used for pre-determining of braking performance. The brake weight shall be finally verified by tests. The UIC 544-1 [2] prescribes the method of determining braking performance of railway vehicles and train. Braking performance is expressed through the brake mass percentage (for vehicle speeds of up to 200km/h) and deceleration (vehicle for speeds higher than 200km/h).

The regulations define needed conditions and required measuring quantities. However they do not specify way of measurement required quantities, nor details of data processing of recorded signals.

The paper presents variations in some steps during standard test of rail vehicles braking performances and different data processing procedures and potential impacts on the results.

2. DETERMINING BRAKE WEIGHT ACCORDING TO UIC 544-1

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

To determine the brake weight is used the following formula:

$$B = \frac{\lambda \cdot m}{100} = \frac{\left(\frac{C}{s} - D\right) \cdot m}{100} \tag{1}$$

λ [%] – braked weight percentage
m [t] – mass of test vehicle (train)
s [m] – stopping distance
C, D [-] – constants

In accordance with UIC 544-1 braked weight is determined by testing with:

- individual vehicle or
- the train of a certain length

Tests were conducted at different speeds and load cases of vehicles with the technical characteristics of vehicles and the requirements of the regulations.

2.1. Basic testing conditions

The following conditions during tests must be met:

- atmospheric conditions - testing carried out at minimum wind and on dry rail

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- rail gradient – mean gradient on the stopping distance should not exceed 3 ‰, a maximum gradient at the test section must be less than 5 ‰. Testing is not allowed in curve with radius of less than 1000m.
- vehicle speed - the difference between the measured and nominal speed should not exceed 4km/h,
- number of tests -it is necessary to carry out at least 4 valid tests for determining the mean stopping distance
- the condition of the wheels, brake discs and friction components - before tests, the friction components (brake pads / blocks) must be in contact with the brake disc / wheel for at least 85% of the total contact area. The temperature on any measuring point shall not exceed 100 °C and average of all measuring points should be maximum 60 °C.

2.2. Correction of individual stopping distances

After the tests it is necessary to perform correction of the measured stopping distances taking into account:

- the differences between the measured and nominal speed,
- rail gradient.

Corrections are made according to the formulas given in Appendix F.3.1 of UIC 544-1.

Corrected stopping distance must meet the requirements described in UIC 544-1.

2.3. Correction of the mean stopping distance

At the end, it is necessary to perform correction of the mean stopping distances. The correction is done according to the following criteria:

- basic correction - adjusting the existing state of the test vehicle with the general characteristics of the vehicles designed for the series,
- the brake cylinder filling time during the test.

In the basic correction the following factors are considered:

- dynamic efficiency of the brake rigging on test vehicle in relation to the mean value foreseen for operation and, in the case of disc-braked vehicles with average wheel diameter that, in relation to the diameter of the semi-worn wheel.
- in the event of the brake cylinder pressure on the test vehicle deviates from the value assumed for the design series, correction within the tolerance range of ± 0.2 bar shall be done.

3. MEASUREMENT METHODS OF REQUIRED PARAMETERS

During testing the braking performance it is necessary to measure the following parameters:

- speed,
- stopping distance (length),
- acceleration (deceleration),
- pressure in main brake pipe and in brake cylinders.

All parameters shall be measured as a function of time.

3.1. Measurement speed and stopping distance

Speed is measured to determine the initial speed of the braking for each individual measurement and it is used for the correction of individual stopping distance.

Speed can be further used to calculate the stopping distance and deceleration during braking.

The stopping distance is the basic parameter for determining the braked weight percentage. The stopping distance is distance from the moment of brake command to the vehicle stopping.

Measurement of the speed and stopping distance can be carried out using several methods, and using different types of sensors. It is possible to use sensor that directly perform measurements of speed or it can be derived from the stopping distance or from acceleration, by integration or differentiation of these signals.

Two types of sensors are commonly used for speed measurement:

• sensors independent from the wheel revolutions (radar etc.) and
• sensors which depend on the wheel rotation frequency (inductive, optical etc.)

Fig.1. Speed sensors

The bodies for conformity assessment of railway vehicles (Notify Body) usually require speed measurement sensors independent from the wheel rotation frequency (radar). Thus, the stopping distance includes the distance that vehicle eventually travel with blocked wheels. On the other hand, based on the measurement signal obtained by such a sensor it is not possible to detect appearance of wheel blocking which can cause damage of wheels(wheel flats). Blocking of wheels, can be registered on the basis of sensors signals which depend on the wheel frequency and after analysis it is possible to eliminate the causes of this and, if necessary, repeat the test.

The parameters that may affect the accuracy are:

• for the radar: the radar installation angle relative to the ground (nominal it has to be 30%)

• when using an optical sensor result depends on the wheel diameter.

These parameters can be eliminated by sensors calibration using for example laser meter of high accuracy class. Fig. 3 presents calibration of the speed sensors. Wagon was moved several time along track for some distance and measured distance indicated by the laser meter was compared with results of sensors installed on the wagon. Thus, was included correction caused by deviation of the radar installation angle and measured wheel diameter.

Fig.3. Sensors calibration

3.2. Measurement of acceleration

Measurement of acceleration (deceleration) is performed in order to determine the equivalent brake force development time. For high-speed vehicles acceleration represents the only parameter for determining the brake performance.

Also, the acceleration can be obtained by differentiating the speed signal or double differentiation of stopping distance signal.

3.3. Measurement of preassure

The pressure in the brake pipe is measured to determine the moment of brake command (moment when starts the pressure drop in the brake pipe represents the moment of brake command for single vehicle).

The values of pressure in the brake cylinders are used in the correction of stopping distance and could be used for determining the equivalent brake force development time.

4. ANALYSIS OF MEASUREMENT SIGNALS PROCESSING

4.1. Analysis of speed and stopping distance signal

Fig. 4 shows the signals of speed and stopping distance during slip test of Sdggmrss wagon [3]. Measurements were made in parallel by radar and wheel dependent optical sensor. After sensor calibration, if there is no slipping during braking process,, both types of sensors show very similar values (Fig. 4).

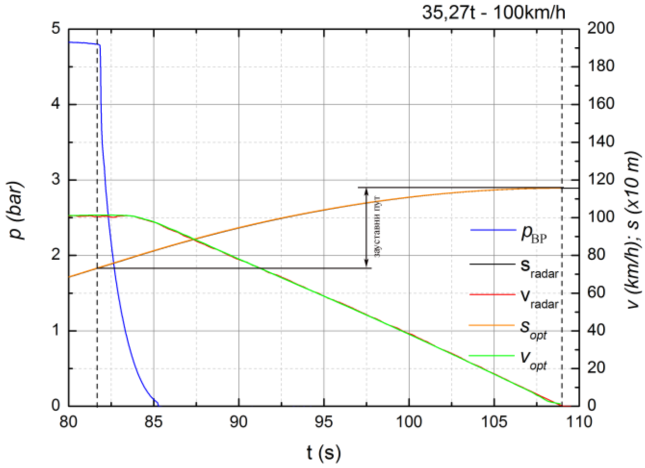

Fig.4. Sdggmrss wagon braking

Brake weight percentage determined on the basis of the results obtained by both sensors is shown in Table 1.

Tab. 1. Brake weight percentage

	Radar	Optical
initial speed (*km/h*)	100	100
corrected stopping distance (*m*	473,83	470,42
brake weight percentage (%)	101,5	100,9

4.2. Analysis of the signal processing measurements in order to obtain the equivalent brake force development time

Equivalent brake force development time t_e is illustrated in Fig. 5[2].

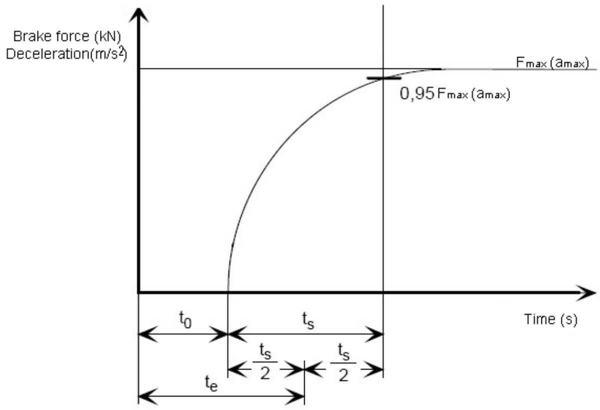

Fig.5. Equivalent brake force development time t_e

$$t_e = t_o + \frac{t_s}{2} \qquad (2)$$

t_e - equivalent brake force development time

t_o – time lag between brake command and start of brake force (deceleration) increase

t_s – brake development time

F_{max} (a_{max}) – fully-developed brake force (deceleration)

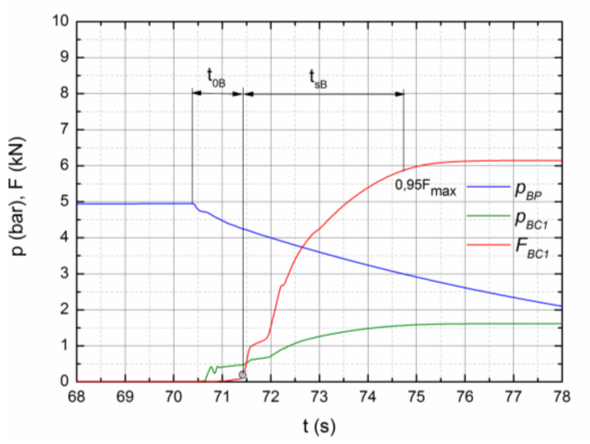

Fig.6. Determination t_e aaccording to the braking force

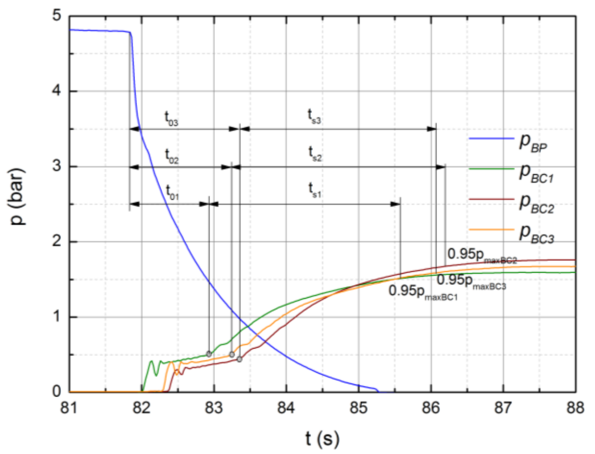

Fig.7. Determination t_e according to the pressure

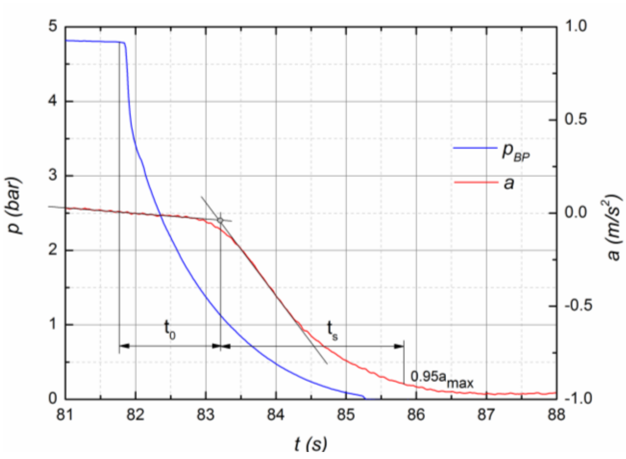

Fig.8. Determination t_e according to the deceleration

Determination of the t_e can be done in several ways:

- According to the braking force measurement signal during stationary brake tests (Fig. 6).
- According to the brake cylinder pressure measurement signal during slip tests (Fig. 7).
- According to the deceleration measurement signal during the slip tests (Fig. 8).

Tab. 2. Brake weight percentage according t_e values

Method of processing signal	t_e (s)	λ (%)
Braking force	2,83	101,6
Brake cylinder pressure	2,73	101,5
Deceleration	2,68	101,5

5. CONCLUSION

Performed analysis of brake performance test shows that the influence of variations of parameters that affect brake performance, individually cause acceptable variations in the test results.

Measured speed and stopping distance obtained by radar and optical sensor during brake testing of freight wagon showed almost identical results, i.e. difference has insignificant influence on the test results.

By analyzing the way of the signal processing in order to determine the equivalent brake force development time it appeared that the existing procedure defined in the UIC 544-1 is almost insensitive to different data processing methods. The value of equivalent brake force development time can be calculated using recorded signals from the brake cylinder pressure or deceleration.

ACKNOWLEDGEMENT

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COMPUTER ANALYSIS OF A WAGON BOGIE RUNNING WITH A FLEXIBLE FRAME

Ján DIŽO [1]
Miroslav BLATNICKÝ [2]

Abstract *– Computer analyses and simulations of rail vehicles are nowadays widely used in the field of designing of new rail vehicles and also in process of renovating the existing rail vehicles. In this way performing the static analyses of individual parts of rail vehicles and dynamic analyses of substructure or complete rail vehicle is possible. Stress analyses of structure are carried out most frequently using Finite Element Method. Dynamic behaviour and properties are analysed, investigated and evaluated by other computer means. In this software a rail vehicle or its subsystem forms Multibody System. Connection of these two approaches considerably extents the possibilities of computer analyses of rail vehicles under various operational conditions. This contribution presents influence of flexible body implementation into the multibody system of a wagon bogie on its running behaviour. The freight wagon bogie was chosen for the modelling and simulation of its running on a track. The flexible multibody system of freight wagon bogie was created and as a flexible body the bogie frame was used. After numerical simulation selected parameters were evaluated in order to assess the flexible body influence on the ride properties of a wagon bogie.*

Keywords – multibody system, railway wagon, computer analysis, flexible body

1. INTRODUCTION

Computer aided modelling and simulations are nowadays widely employed in investigating rail vehicles properties. These include e.g. track interaction and study of track forces, detection and prediction of the mechanism of deterioration and causes of accidents. Therefore it is necessary to develop adequate virtual models of rail vehicles.

2. MOTIVATION FOR RESEARCH

The properties of rail vehicles as mechanical systems can be designed, studied, evaluated, verified and diagnosed by means of experimental methods [1] and measurements [2 and 3], simulation calculations and optimization using computer software [4, 5 and 6] or also by special equipment in laboratories [7].

In investigating dynamic properties and behaviour of rail vehicles we model and describe these vehicles by means of multibody system dynamics.

A standard multibody system of a rail vehicle contains rigid bodies that are connected by ideal joints, coupling elements [8], contact elements, suspension and spring elements [9] and force elements. Rail vehicle dynamics also involves the phenomena of wheel/rail contact [10, 11, 12 and 13], which significantly influences the rail vehicle properties and wheel/rail contact stress conditions.

Rail vehicle analysis includes applications, where deformations of individual bodies have to be considered as well and taken into account in calculations. Therefore, the rail vehicle multibody system is extended with flexible bodies. Generally, the Finite Element Method is most often used for flexible bodies' implementation into the rail vehicle multi-body system [14].

The formulation of the finite element method uses a coordinate system firmly fixed to the body to describe the de-formation field of each body. Flexible bodies and rigid bodies of the rail vehicle multibody system are represented by a set of Cartesian coordinates and have their relative motion restrained by a set of kinematic constraints. There are also other formulations of multibody systems.

Several methods have been developer for kinematic description of the motion of a flexible body performing large displacements [15 and 16].

The floating frame of reference formulation is a

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method that is currently the most frequently used in computer simulation of multibody systems with flexible bodies, and is implemented in commercial multibody computer software [16 and 17].

Principles of mechanics and mathematical description of flexible multibody dynamics is described in various works and more information about it you can find e.g. in [15, 16 and 17].

3. COMPUTER MODELLING AND SIMULATION OF THE WAGON BOGIE WITH FLEXIBLE FRAME

Implementation of the flexible body into the multibody system of rail vehicle requires performing some pre-processing steps to obtain a reduced flexible body. Flexible body reduction can be carried out using FEM software. The general procedure to integrate a flexible body into a multibody system of the rail vehicle bogie can be divided into these main steps:

1. creating a FE model of the rail vehicle bogie component;
2. integrating the FE model of the rail vehicle bogie component into the software for multibody system dynamics;
3. establishing the multibody system of the rail vehicle bogie with a flexible body.

In this part of the paper, we introduce the FE model of the bogie frame of a freight wagon the Y25 bogie. The Y25 bogie is the most widespread freight wagon bogie in Central and Eastern Europe.

Fig. 1. The flexible multibody system of the freight bogie in ADAMS/Rail

Once we have set-up the flexible multibody model of the freight wagon bogie (Fig. 1), we can perform various simulations to verify the correctness of the model, assess the riding properties of the model, we can compare the results of simulation analyses of the freight wagon bogie with a flexible bogie frame with the outputs of dynamic behaviour of a freight wagon bogie with a rigid bogie frame, etc.

In this chapter, we compare the results of simulations analyses of the freight wagon bogie with a rigid bogie frame and a flexible bogie frame.

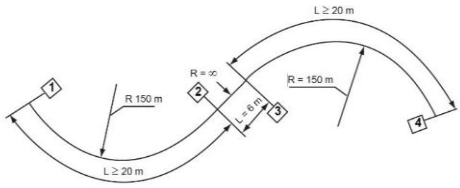

Fig. 2 The test track – S-curve [18]

A simple track model was used to perform simulation analyses. We chose the test track – S-curve with general parameters defined in the UIC code [18]. The test track is shown in Figure 2.

In this case, the S-curve comprises a curve and a reverse curve of R = 150 m separated by a section of straight track measuring 6 m in length. The length of curves is L = 100 m. The track has the normal rail gauge of 1435 mm with UIC60 rail profile. This track has no cant and no irregularities were used in the track model for our purposes.

All wheel of the freight bogie are equipped with the S1002 profile.

Analyses were performed with one freight wagon bogie without load. The freight wagon bogie ran at the constant speed of 40 km/h. We analysed freight bogie running on the S-curve with both rigid and flexible bogie frames.

In this case, the S-curve comprises a curve and a reverse curve of R = 150 m separated by a section of straight track measuring 6 m in length. The length of curves is L = 100 m. The track has the normal rail gauge of 1435 mm with UIC60 rail profile. This track has no cant. Into the track model measured

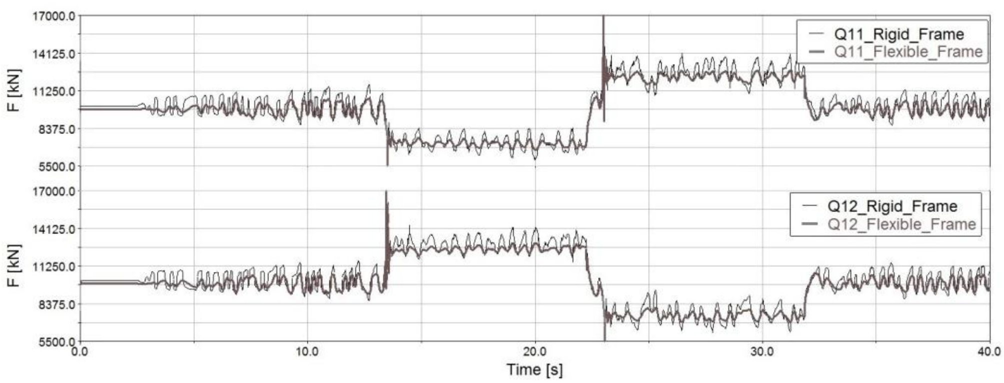

Fig. 3. Vertical wheel forces for the first wheelset, Q11 – right wheel, Q12 – left wheel

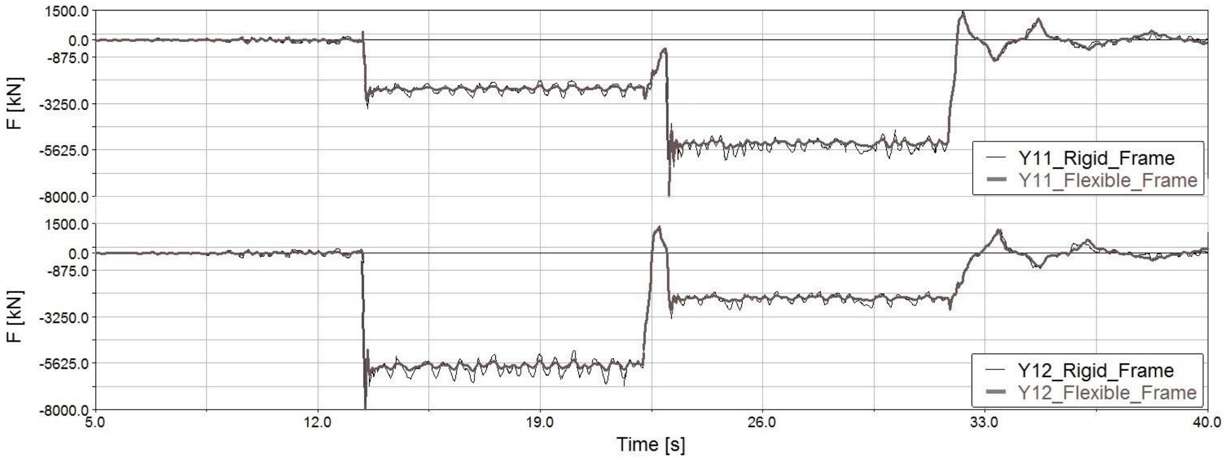

Fig. 4. Lateral wheel forces for the first wheelset, Y11 – right wheel, Y12 – left wheel

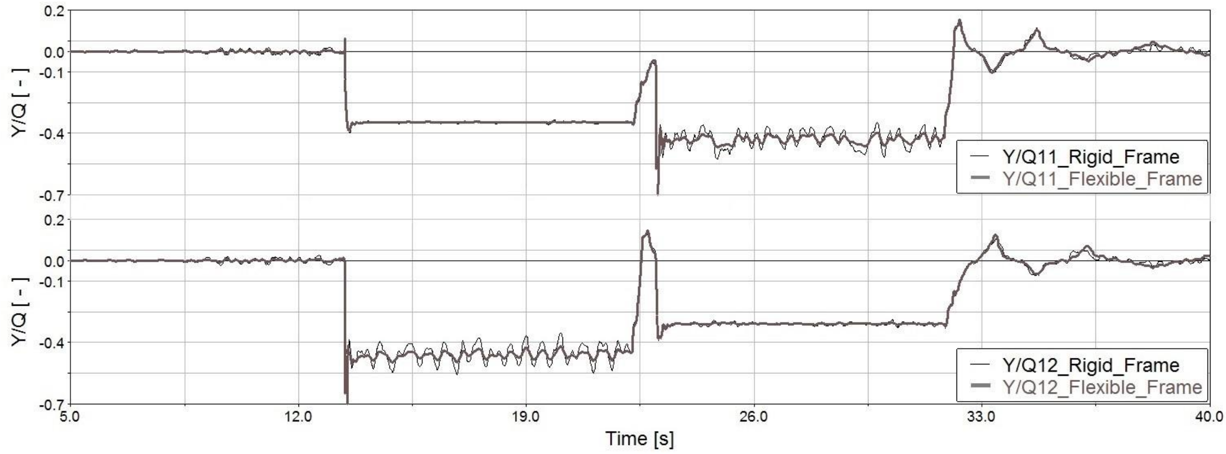

Fig. 5. Derailment quotient for the first wheelset, Y/Q11 – right wheel, Y/Q12 – left wheel

irregularities with the step of 0.5 m were incorporated.

All wheel of the freight bogie are equipped with the S1002 profile. Analyses were performed with one freight wagon bogie without load. The freight wagon bogie ran at the constant speed of 40 km/h. We analysed freight bogie running on the S-curve with both rigid and flexible bogie frames. The analyses results are shown in Figures 3, 4 and 5. In order to assess the riding properties of the freight wagon bogie running with flexible bogie frame, we selected the waveforms of the vertical wheel forces (Q), lateral forces (Y) and derailment quotient (Y/Q). Moreover, each figure contains two waveforms, one for the rigid bogie frame (thinner curved) and one for the flexible bogie frame (thicker curve) and also details.

Let's have a look at Figure 3. When the bogie enters the curve, values of vertical wheel forces increase. In the straight track section, vertical wheel forces correspond to the gravitational load of the bogie. Figure 4 shows that lateral forces increase also when the bogie enters the curve. In the straight track section lateral forces achieve very small values compared to the values in curves. Finally, Figure 5 shows the derailment quotient values. Derailment quotient is the ratio of the lateral and vertical forces, and it expresses safety of the rail vehicle running. As we can see, the maximum values are reached when the bogie is running in curves, similarly to the vertical and lateral wheel forces. We can also see, irregularities caused excitation of the wagon bogie mechanical system. From comparison of the simulation of the freight wagon bogie running with rigid and flexible bodies we can observe the influence of the bogie frame flexibility on the monitored variables. Flexibility of the bogie frame causes a greater damping of vibration.

4. CONCLUSION

The aim of this paper was to describe the options of using multibody system dynamics to analyse a rail vehicle containing flexible components. We presented the most commonly used approach to the reduction of the flexible body. Inclusion of flexible bodies into multibody system dynamics simulations of a rail vehicle running provides advanced opportunities for evaluation of the rail vehicle properties and stress in the structure of the rail vehicle components under real operational conditions. The paper presents including the flexible frame into the freight wagon bogie multibody system, its simulations and evaluation and comparison of results of numerical calculations of the freight wagon bogie running. On one side we found out that the implementation of the flexible body into MBS better correspond to the real bogie behaviour during running but on the other side rising demands on user knowledges, computational time and computer capacity. In our future research we will use this flexible multibody system of a freight wagon bogie to assemble a complete freight wagon model and to perform various analyses for better assessment of the freight wagon riding properties. Multibody dynamics approach with flexible bodies allows better optimization of freight wagon design as well as prevention of potential problems during their long-term operation.

ACKNOWLEDGEMENT

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A METHODOLOGY FOR DETERMINING THE CAUSES OF ROLLING STOCK DERAILMENT

Dobrinka ATMADZHOVA[1]

Abstract *– Breakdowns and accidents in rail transport caused by rolling stock derailment have always represented the biggest share of all train incidents everywhere in the world. With determining the causes of rolling stock derailment, one of the tasks of official investigation is to establish the group of causes, which refers to the particular derailment. The paper presents a methodology developed on the basis of statistical classifications to determine the group of most probable reasons for derailment of freight rolling stock. The experience of the BDZ (Bulgarian State Railways) operation and tests performed by the Research Institute of Transport in Bulgaria have shown that part of rail vehicles are in danger of derailment at operating speeds due to particularly intense horizontal oscillations generally obtained in resonant mode.*

Keywords – rolling stock, breakdowns and accidents, derailment.

1. INTRODUCTION

Railway safety is the first and most important condition of transport process both within the Bulgarian rail system and throughout the European Union. Safety management is a complex process requiring a holistic approach to its solution [1,2]. The breakdowns and accidents in rail transport caused by rolling stock derailment have always presented the highest share of all train accidents everywhere – in most cases over 50% and reaching even to 80-90%.

The problems of train derailment have always been an object of great attention in scientific and technological developments of experts who work in the fields of rolling stock and track in order to create more comprehensive structures and technologies.

According to Directive 2004/49/EC [3], each EU member state has to ensure the provision of rail transport safety and increase of its level in compliance with the Community legislation development and advanced technical and scientific achievements. For this purpose a created special institution, the European Railway Agency (ERA), was established [4]. Its main tasks are to develop technical specifications for interoperability (TSI) and harmonize approaches to safety in railway transport, thus facilitating the growth and development of passenger and goods transportation. To solve those tasks, common safety methods (CSM) were developed aimed to increase the safety level in rail transport and harmonize safety requirements in all EU member states. The national authority rail transport of the Republic of Bulgaria is Railway Administration Executive Agency (RAEA) [5]. In 2006, on safety on the Community's railways, by Decree № 250 of 25 November 2005, the Council of Ministers in Bulgaria established a special unit, Railway Accident Investigation Unit (RAIU) [6] within the structure of the the Ministry of Transport and Communications.

2. EXPERIENCE AND RESEARCH OF BULGARIA TO REDUCE THE NUMBER OF DERAILMENT ACCIDENTS

The experience, research and contributions of Bulgaria, respectively of the Research Institute of Transport with the Bulgarian State Railways (BDZ), to avoid or reduce the number of rolling stock derailment mainly refer to operating speeds up to the maximum admissible speed. From the viewpoint of the "derailment" accident, low speeds are also dangerous. Undoubtedly, it is so if it is considered by comparison that accidents are authoritative in number but not in regard to material damage and human casualties.

The objects of research performed by the Research Institute of Transport were mainly wagon prototypes in initial implementation constituting a relatively small share of newly built types of vehicles in Bulgaria in the period 1964-1990 (more than 30 types), which the tests proved to be of bad dynamical and undercarriage properties with particularly intense horizontal oscillations and tendency to derailment but without occurrence of such accidents.

In connection with that one should take into account that tests. Therefore, in terms of regular and continuous operation of large series, these objects in their original implementation would have necessarily

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shown derailment of mass character.

3. METHODOLOGY FOR DETERMINING THE CAUSES OF ROLLING STOCK DERAILMENT

The data about derailment exist both in the central European databases [7,8,9,10,11] and in separate databases of individual countries[5,6]. The databases belong to different organizations and are presented in various formats differing in structure, information, which considers both criteria and definition of causes for accidents, etc.

The main sources of information include:

- ERA safety database, ERADIS [7]
- European derailment database created by Det Norske Veritas (DNV) [8]
- European UIC safety database [9]
- Great Britain Safety Management Information System (GB SMIS) administered by the Rail Safety and Standards Board (RSSB) [10]
- Rail Accident Investigation Branch (RAIB) investigation reports [11]
- database of railway accidents and incidents of RAEA and RAIU – Republic of Bulgaria [5,6].

Despite the data diversity, multiple data sets with different thresholds increase the size of data set. It is not always easy to make decision which the main cause of derailment is, and many databases of accidents record only the immediate cause.

Overall, the ranking of major derailment causes in Europe is [12,13]:

1. Axle failures (including bearing, axle and journal failures, and hot axle boxes)
2. Excessive track gauge
3. Wheel failures (all types – surface damage and wheel/tyre breaks)
4. Skew loading
5. Excessive track twist
6. Track height / cant failure
7. Rail failures (breaks and profile)
8. Suspension failure.

One of the tasks of official investigation is to establish the groups to causes to refer the specific derailment of rolling stock.

In general terms the task can be assigned to the group of problems called "statistical classifications" and the kinds of constituting technical or technological components can be defined as classes. There are different methods to solve the problem set in this way [14, 15]: an analysis of compliance, discriminant, cluster and factor analysis. The method of artificial neural networks (ANN) [14-18] has been also used widely for the recent years.

The problem is mathematically formulated as follows:

Each derailment *Ci* is characterized by several parameters - p_k ($k = 1 \div N$), for each class of the causes of derailment K_j. For each class of causes K_j a set of parameters ("core class") is created, with a difference with it, derailment occurs due to one of the groups of causes corresponding to the class selected for them, namely k_k ($k = 1 \div N$).

Let introduce proximity measure $d(C_i,K_j)$ for each derailment as a scalar function of derailment parameters C_i and the cores of classes K_j, the numerical values of which are lower as more the parameters characterizing the actual derailment are and correspond to the class core. It is also necessary to calculate the proximity measure to the minimum amount specified in the respective class (the generalized group of causes for derailment).

Proximity measures are often applied [15, 18]:

$$d(C_i,K_j) = \sum_{k=1}^{N} (p_k - k_k)^2 \quad \text{– Euclidean} \qquad (1)$$

$$d(C_i,K_j) = \sum_{k=1}^{N} |p_k - k_k| \quad \text{- Manhattan or “city block”} \qquad (2)$$

where p_k and k_k - values of parameters of the same class derailment C_i and core class K_j (at that the number of parameters of each derailment should correspond to the number of parameters of the cores of classes).

It is necessary to reduce the absolute proximity measures to comparable (dimensionless) values, i.e. to calculate the proximity measures for each parameter referred to the corresponding parameter of class core.

The procedure of calculation is reduced to determination of the absolute and relative proximity measures for each parameter respectively by the formulas:

$$d_{ak} = |p_k - k_k| \quad \text{and} \qquad (3)$$

$$d_{rk} = (p_k - k_k)^2 / k_k^2 \qquad (4)$$

Then the average geometric proximity measure is determined individually for the set of parameters of each derailment and each class of causes for this derailment:

$$d_r(C_i,K_j) = \sqrt{\sum_{k=1}^{N} d_{rk}} \qquad (5)$$

The minimum value of quantities obtained will correspond to the most probable class of causes for the derailment.

To eliminate the effects of the different number of parameters in each class of causes for derailment, the average amounts obtained should be divided into the corresponding number of parameters in each class m_j, i.e.

$$d_m(C_i, K_j) = \left(\sum_{k=1}^{N} d_{rk} \right) / m_j . \quad (6)$$

Then, specifying the number of classes of derailment causes "*j*" and establishing the parameters of each "*j*" class core $\{k_k\}$, the specific derailment of rolling stock with parameters p_k can be referred to class $\{K_j\}$, for which the average sum of relative proximity measure has a minimum value:

$$min\{D_j = d_m(C_i, K_j)\} \quad (7)$$

Then all proximity measures obtained should be ranked according to a certain criterion and probabilities Q_j should be calculated:

$$Q_j = \left\{ 1 - \sum D_j \cdot \left[D_j \left\{ \sum \frac{\sum D_j}{D_j} \right\} \right]^{-1} \right\} .100, \% \quad (8)$$

The process of solving the problem can be schematically displayed in the form of operating units functioning in parallel as shown in Figure 1.

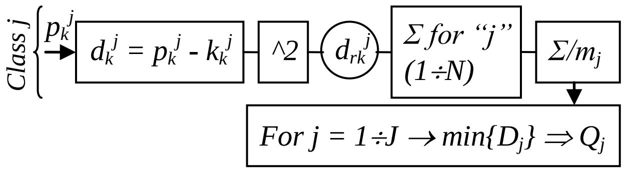

Fig. 1. Block diagram of the solution of problem of determining the classes (groups of causes) of rolling stock derailment and their probabilities

In the figure 1 the blocks marked with "^2" perform an operation of squaring the absolute measure of proximity determined in the previous unit of formula (3). The subsequent blocks in a form of circle perform an operation of calculating the relative measure of proximity for each parameter in formula (4).

The algorithm of problem solution using a neural layer in the part of weight factors looks schematically similar to the one presented in Figure 1 (after the blocks are squared). Coefficients $1/(k_k^j)^2$ of formula (3) are nothing but fixed specified weight factors for each input parameter.

If some weight factors w_n are used instead of them or with a supplement to them, in practice a single-layer neural network will be obtained. The weight factors have to be selected based on the analysis of parameters of the investigated rolling stock derailment including a summator at the output (in terms of neural networks – weighted summator), blocks with non-linear characteristics that are configured for a certain kind of "activation function" and the level of threshold of activation as well as implementation of additional channels in the scheme to process the input parameters, including with one-way and non-numerical limitation.

These weight factors are initially specified based on the analysis of the presented number of rolling stock derailments or expert method. However, after each subsequent derailment, an internal software for their recalculation (or determination of the "weight" parameter in iteration method) is started in compliance with the criteria of minimizing the error of classification of derailment causes to a particular derailment class.

To determine the required class, it is necessary to select one of all summators of neural layer; it has to be with minimum output – that is done by interpreter, the software makes arrangement of displayed summators in an order by their growth, which can be supplemented by the procedures shown above to calculate the probability of categorizing the derailment causes to one or another class.

The activation function in this case is not used (it is rather meant as linear).

However, the method of application of neural networks can be implemented only after collecting sufficient derailment data.

Let examine the solution of the problem with a specific example of comparing some track parameters p_k^r and freight wagon parameters p_k^w (obtained with conditional official investigation on rolling stock derailment) to parameters of the core of classes of rolling stock derailment due to track geometry defects k_k^r and wagon failures k_k^w respectively.

The output parameters and results of calculations by the scheme presented on Figure 1 are shown in Table 1. The results in columns 5, 6, 7, 8 and 9 are obtained by using formulas (3), (1), (4), (6) and (8) respectively.

From the calculations, it is obtained that the minimum average proximity measure (0.153) corresponds to the derailment class of track geometry defects with a probability of 63%. By comparing the minimum values of relative proximity measures in column 7, it is found that the greatest impact of these results on categorization of derailment causes is due to excessive track width (0.0000567), track gauge slope and step in splicing (0.040) in the area of the derailment.

For wagons, the minimum values of relative proximity measures (0.005) refer to flange parameters. As a whole, the average value of the relative proximity measure (0.256) for vehicles is bigger than the same value for track (0.153). Therefore, the state is more satisfactory with vehicles than the one with infrastructure. (The probability of categorizing an event to "rolling stock derailment" class due to vehicle failure is 37% while for the track it is 63%).

Table 1. *Output parameters and results of calculations of a control sample*

Object (or class of derailment causes)	Parameters	Values of parameters		Absolute Manhattan proximity measure	Euclidean proximity measure (dimension as in column 2)			Proba-bility %
		Obtai-ned	Class core		Abso-lute	Relative	Avera-ge	
1	2	3	4	5	6	7	8	9
Track	Excessive track gauge, mm	1450	1461	11	121	0,0000567	0,153	63
	Rail gauge slope, ‰	3	4,5	1,5	2,25	0,111		
	Track level, mm	18	30	12	144	0,160		
	Crossing, mm	15	25	10	100	0,160		
	Collapse, mm	10	30	20	400	0,444		
	Step in splicing, mm	6	5	1	1	0,040		
Waggon	Uneven wheel flats profile, mm	0,8	2	1,2	1,44	0,360	0,256	37
	Flange thickness, mm	30	28	2	4	0,005		
	Vertical flange cutting, mm	6,5	18	11,5	132,25	0,408		
	Difference in distance between the internal front surfaces of wheels on one axle, mm	1	3	2	4	0,444		
	Position the cup of bogie friction dampener, mm	6	10	4	16	0,160		
	Summary clearance in supports), mm	12	20	8	64	0,160		

Checking calculations with Manhattan proximity measure, it is seen that they differ only in the values of probability for categorization of events to the derailment classes of track geometry defects (58%) and vehicles (42%).

In the future, with development of derailment databases, the proximity measure of next derailment parameters can be determined. This expands the opportunity of derailment categorization to the individual classes according to the causes for accidents.

4. CONCLUSION

This paper analyses the experience, research and contributions of Bulgaria to reduce rolling stock derailment. The objects of examination are mainly wagon prototypes in initial implementation. From the tests performed, it was established that they have bad dynamical and undercarriage performance with particularly intense horizontal vibrations and tendency to derailment.

The methods of determining the most likely group of causes for rolling stock derailment are developed using statistical classification. The methodology is designed for automated solution of the problem of detecting the groups of derailment causes. The trends, suggested for further development of this methodology, need to use approaches applied in artificial neural networks.

The paper examines also the solution of the problem of comparing some parameters of the track and a freight wagon obtained with conditionally official investigations on the rolling stock derailment performed according to the methodology proposed in the paper.

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BAGGAGE TRANSPORT SYSTEM – PASSENGER'S REQUIREMENTS

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***Abstract** – Luggage is one of the main reasons why people choose their car instead of public transport. In order to support more sustainable and active forms of mobility, it is necessary to develop ground-breaking logistic systems not only for travellers themselves but also for their luggage. Due to the complexity of efficient and customer-oriented independent "public luggage transport" and as a first step, an exploratory project "GepäckLoS" (founded by the Austrian Ministry for Transport, Innovation and Technology and the the Austrian Research Promotion Agency) considering all reasonable, possible and thinkable options was launched. In order to minimise the development risks it was first necessary to survey and define all requirements. Therefore, extensive customer surveys were conducted. With the data assembled there is now a secondary project with the purpose of developing a goal-oriented and efficient system.*

Keywords – Baggage transportation, Baggage service, Customer needs and expectations.

1. INTRODUCTION

For future-oriented, attractive and also economically realisable service features concerning the transport of luggage and goods independent from passenger traffic, it is essential to know the needs and demands of potential users. Moreover, it is necessary to define scenarios in the context of which there is a need for the transport of luggage.

The purpose of this paper is the inquiry into, and the analysis and interpretation of the needs and demands of different potential users. First of all, the relevant scenarios, groups and with them the connected chains of transportation were defined. Basically, there are two groups of users in the project "GepäckLoS", travellers and people on their daily travel routes.

The group of "travelers" is made up of people who are on a journey with luggage to a certain target destination. All opportunities for transportation are included. But you have to be careful because journeys with public transport are multimodal by definition. As a result, luggage handling is also more time-consuming. Multimodal transport will substantially profit from a system such as "GepäckLoS".

The "daily travel routes" include for example, different shopping tasks (shopping for food, electronic equipment, etc.) or travel in the context of which a person must carry a certain piece of luggage over a longer period of time. This could be a sports bag for example, which the person has to take to the office because he or she needs it to go to the fitness centre in the evening. Daily travel routes describe a very heterogeneous group of routes, on which one or more pieces of luggage have to be taken from or to a residence. The system developed in the project "GepäckLoS" is going to make the transport of these pieces of luggage substantially easier. Moreover, in many cases it will make it possible to use environmentally sustainable means of transportation such as public transportation or a bicycle.

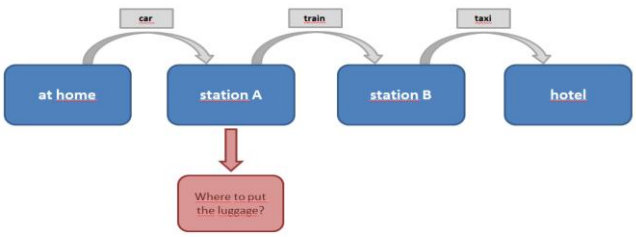

Fig. 1: example of a (multimodal) chain of transportation with luggage

The "daily travel routes" include for example,

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different shopping tasks (shopping for food, electronic equipment, etc.) or travel in the context of which a person must carry a certain piece of luggage over a longer period of time. This could be a sports bag for example, which the person has to take to the office because he or she needs it to go to the fitness centre in the evening. Daily travel routes describe a very heterogeneous group of routes, on which one or more pieces of luggage have to be taken from or to a residence. The system developed in the project "GepäckLoS" is going to make the transport of these pieces of luggage substantially easier. Moreover, in many cases it will make it possible to use environmentally sustainable means of transportation such as public transportation or a bicycle.

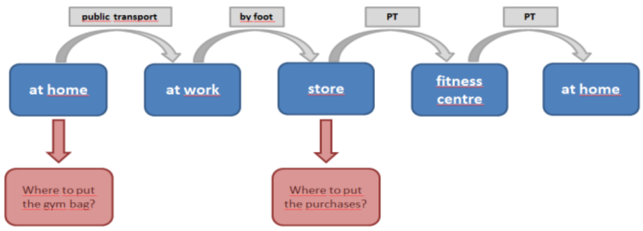

Fig. 2: example of a (multimodal) chain of transportation with luggage of daily life

The demands and specifications of these two groups are estimated very differently. For that reason the survey tried to go into the demands and specifications to find a good solution.

Five different questionnaires were developed for data collection to get a good view of all the different groups of potential users. The questionnaires include demographic information, questions about actual or general habits and situations concerning shopping or travelling.

The five different questionnaires were used to question potential users:

- on their journey in trains,
- in shopping malls or shopping streets,
- during their stay in rehabilitation centres,
- online about shopping and
- online about travelling.

With the help of the results of the surveys, it was possible to get detailed information about the special interests the survey groups have in a luggage logistic system as well as their needs and demands. Additionally, qualitative surveys were done with business proprietors to determine their interest in and demands for a luggage logistic system. They also showed an interest in the service, especially to oppose the online trade. The results of the surveys provide a basis for the design of the whole system and for the evaluation of the new system and still working systems.

This paper only includes the results of the survey concerning luggage transport.

2. INTEREST IN THE LUGGAGE SERVICE

Altogether, 8,800 passengers were questioned in long-distance trains in Austria, Germany and Switzerland. Most of them (78%) were between 18 and 59 years of age. The age group between 18 and 26 made up with 26% of all passengers the largest group. The gender relationship was balanced; 51% were female and 49% male.

One fourth of all passengers stated as the purpose of their journey, travel to or from work, school or other training programmes. Other travel purposes were longer holidays (18%), short getaways (17%), private issues (16%), business trips for one or more days (12%) and day trips (10%). The passengers are rarely weekly commuters or on a shopping trip. Ninety-eight percent of all passengers had some baggage with them. Handbags and shopping bags also counted as baggage. Large pieces of luggage such as medium and large suitcases as well as travel bags and backpacks were carried by 37% of all passengers. One third of them felt hindered by their luggage. Most difficulties occurred upon boarding the train, finding a seat and stowing their luggage.

In addition to direct questioning in the trains, there was also an online questionnaire. Patients of the rehabilitation centres in Weyer, Saalfelden, Bad Schallerbach and Bad Hofgastein also participated in the survey. The reason for the survey in the rehabilitation centres was that there is a similar service in Germany, which is often used by patients of such centres.

By direct questioning in trains in Austria, Germany and Switzerland 12% of the participants said that they would use the service "GepäckLoS" during their current journey. Ten percent of them said that they would likely use the service. In addition, persons who answered "likely no" or "no" were asked if they would use the service in general, for example during another journey. Twenty percent answered this question with yes and 27% with likely yes. Twenty-five percent of the respondents of rehabilitation centres, who usually have a lot of luggage because of their long stay, said that they would have used the service for their current stay. Twelve percent said that they would have likely used it. All patients were also asked if they would use the service for general journeys or other rehabilitation stays. Thirty-one percent answered that they would generally use it and 21% would generally likely use it. In the online questionnaire people were only asked if they were interested in using the service in general. "Yes" was the answer of 37% and "likely yes" of 40%.

Through specific analysis of the direct surveys in the train, the parameters influencing the use were determined. Following is a ranking of the top influencing factors concerning the use during the current journey:

- Hindrance because of the luggage
- The service would be used by:
    - 56% of the passengers who feel hindered at the train station because of their luggage,
    - 53% of the passengers having problems boarding the train,
    - 49% of the passengers having hindrances during their journey to the train station,
    - 42% of the passengers having problems directly in the train.
- Travellers with babies and infants (between 1 and 6 years)
  The service would be used by:
    - 50% of the travellers with a pram
    - 47% of the travellers with babies
    - 44% of the travellers with infants between one and six years of age.
- The larger the pieces of luggage, the more likely the service would be used. Forty-nine percent of all passengers with three large pieces of luggage would use the service.
- Forty-eight percent of passengers with physical disabilities, which may cause them to have problems with luggage transport, would use the service during the current journey.
- Forty-three percent of passengers who arrived by taxi at the train station would use the service.

3. WILLINGNESS TO PAY

The willingness to pay for the service asked of passengers in the train can be seen in the next chart.

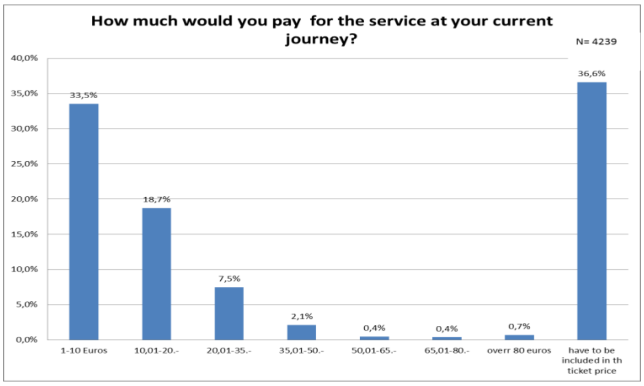

Fig. 3: Representation of the willingness to pay by train passengers

The following is a ranking of the top influencing factors concerning the willingness of the train passengers to pay.

- Travellers with babies and infants (between 1 and 6 years)
  More than 10 Euros would be paid for the service by:
    - 57% of the travellers with babies,
    - 46% of the travellers with a pram,
    - 45% of the travellers with infants.
- Forty-eight percent of the passengers having a bicycle with them would pay more than 10 Euros for the service.
- The willingness to pay increases with the number of large pieces of luggage. Forty-seven percent of the passengers with at least three large pieces of luggage would pay over 10 Euros for the Service.
- Passengers who arrived by taxi or motorcycle had a higher willingness to pay. Forty-thee percent of the passengers arriving by taxi and 43% of the passengers arriving by motorcycle would pay more than 10 Euros. But 40% of the passengers arriving by motorcycle thought that the service should be included in the ticket price.
- Passengers who were travelling first class had a higher willingness to pay. Forty-two percent would pay more than 10 Euros.

4. REASONS FOR NOT USING THE SYSTEM

It didn't matter whether they would use the system or not, but older passengers had more apprehensions concerning the luggage logistic system. They had for example, fear of a high price, luggage arriving late or not at all and theft or damage. Passengers with physical disabilities, which may cause them problems with luggage transport, had fewer fears than the average

5. DISCUSSION AND CONCLUSION

In principle, these surveys showed that the points "shopping" and "travelling" couldn't be considered as one system. There must be a separation between "shopping" and "travelling" to find and develop the best system for each.

On the whole, independent of pieces of luggage, age and other points 22% would have used the described system for their luggage during their current journey. If people felt uncomfortable because of their luggage, they would definitely use the service more often. Fifty-six percent of the passengers who felt hindered at the train station would use the service. Accordingly, the question was, which passengers felt hindered at the train station because of their baggage. The hindrance at the train station was independent of age, gender, nation, travel class, physical disability and baggage. It mattered if the passengers were travelling with a baby, an infant or also a 7 to 14 year old child.

However, what is dependent on gender and to some extent on age were the problems in boarding the train. Fifty-three percent of passengers with problems in boarding would use the service. Women (15%) had more problems boarding the train with their luggage than men. Also, older passengers showed a few more difficulties concerning boarding the train. Thirteen percent of the passengers between the ages of 60 and 74 had problems boarding the train.

Forty-two percent of the passengers who had hindrances directly in the train would use the service. There were many differences between certain groups. For example, there were country- and travel-class-specific differences. Austrians had fewer problems stowing their luggage in comparison with the Swiss (14%) and Germans (25%). Passengers who were travelling first class had fewer problems stowing their luggage than passengers travelling second class.

Passengers who arrived by taxi were often travelling with large pieces of luggage. Here is the place for some environmentally-minded thoughts. If travelers could check in their luggage at the residence door or a check-in terminal, they would not have to take a taxi but could instead use public transport.

According to the direct survey, other groups, which would like to use the service, were travelers with a baby (47%), an infant (44%) or a pram (50%).

Although the difference wasn't that clear (29%), people travelling with another adult or teenager would likely use the service. Very interesting was that there was a country-specific difference. Passengers who were asked in Switzerland would least use the service (16%). Twenty-three percent of people asked in Austria and 28% of those asked in Germany would use the service.

In addition to the questions about their interest in using the service, passengers were also asked about their willingness to pay. An economically realistic price wouldn't be under ten euros. For this reason, which groups had a higher willingness to pay and which factors had an influence on this was more precisely considered.

The group which had the highest willingness to pay were travellers with a baby (57%) or an infant between the ages of one and six (45%). Also the elderly would pay a higher price. Thirty-eight percent of passengers between the ages of 75 and 84 would pay more than ten euros. With 38% they placed only sixth in willingness to pay. More influencing factors on willingness to pay can be found in 2.3.

There are three main user groups deriving from interest and the willingness to pay:

- Travelers with a baby or an infant between the ages of one and six,
- Elderly travelers (at least 60 years old),
- Travelers with large pieces of luggage.

People with physical disabilities would surely be an interesting target group. However, their willingness to pay was relatively low. More consideration would be necessary concerning funding a developed system for this group.

In summary, the survey showed that fringe groups were especially interested in using the service. Concerning needs and demands, the results showed that people who would likely use the service were willing to assume compromises and made smaller demands on the service. For example, all interest groups expressed less demand that the luggage had to be at their destination at the same time they themselves arrived.

With regard to the location for the pickup and delivery, the main groups would particularly like a pickup or delivery directly at the residence door. That would certainly be a sensible configuration since the online survey of people not travelling by train as well as the survey of those in the rehabilitation centres showed pickup or delivery directly at the residence door as being the favourite choice.

In conclusion, one more positive remark about the system should be made. The wish of the public for a pickup/delivery time slot of two hours would certainly be realizable.

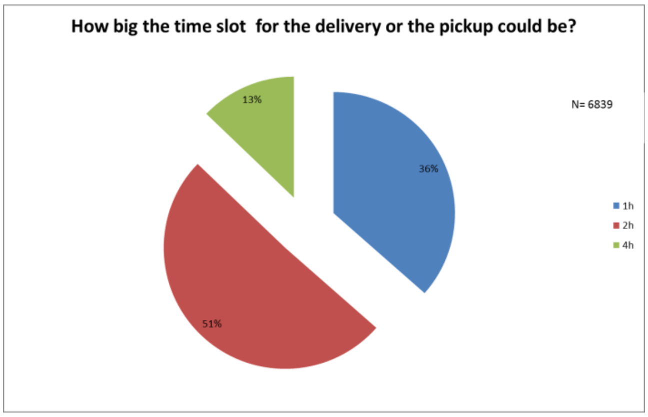

Fig. 4: Size of the time slot for the delivery or the pickup

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There are no external references. The whole paper is based on the internal project results including surveys (project GepäckLoS --> http://GepaeckLoS.netwiss.at

RAIL VEHICLE INTERIORS - DESIGN MISTAKES TO BE AVOIDED

Bernhard RÜGER[1]

Abstract *– In order to be "competitive" as a railway, operating efficiency counts as an important imperative. In the context of railway carriage interior planning this is often made subordinate to other substantial aspects such as for example, expediency. This leads in practice to the opposite wished for result. Misunderstood operating efficiency concepts such as a maximal utilization of space for seating can in reality lead to a decline in operating efficiency, operational problems and in incidents to serious safety risks.*

Keywords – Vehicle interiors, Efficiency, Customer experience, Baggage handling

1. INTRODUCTION

The railway finds itself, especially in long-distance travel, in an area of tension between both of its competitors, road travel and air travel. People who travel by air have or at least see no alternative to air travel. This leads to an acceptance by air travellers of comfort constraints which arise due to economic pressures on the airlines. Airlines can afford to arrange the seats in the passenger cabin to achieve a maximum of seating. Since in airline travel reservations as well as the check-in of luggage are compulsory, all seats can actually be used and sold.

For the railway such restrictions or drastic loss of comfort are not common and are therefore seldom implemented. Depending on travel duration and distance at least half of railway passengers could use the alternative of auto or air travel. Over 50% of travellers on ÖBB long-distance trains say that they have a driving license and have an auto available at any time. Also, because airline tickets are to some extent inexpensive, the cost argument regarding this mode of transportation is often eliminated. This in turn makes air travel more attractive.

The railway cannot afford to ignore the demands and needs of travellers. In order to achieve the high proportion of railway travellers wished for in transport policy, which as a rule also actually contains economic benefits, the railway must bring into play the advantages which it has over other modes of transportation.

However, the tendency in recent years to equip vehicle interiors with the highest possible number of seats contradicts these considerations. This leads not only to a loss of comfort, which approximates the comfort level of air travel, but also in a number of ways constitutes serious operational problems. These problems are often not considered especially in the purchase of vehicles. The often applied evaluation criterion of the highest possible number of seats and thereby expected lower purchase- and operating costs per passenger is one-dimensional and therefore inadequate since it clearly contradicts reality in more ways than one.

Especially in long-distance train travel but also on many local routes particularly in the service of cruise ship ports and airports the volume of luggage is often underestimated and not taken seriously in sufficient measure as an influence factor on the criteria of station dwell time, achievable seat occupancy rate, comfort, customer satisfaction and ultimately safety.

2. LUGGAGE ACCOMMODATION

2.1 Passenger behaviour

Regarding luggage accommodation there are two fundamental principles. Travellers do not want to have to lift their luggage; and for security reasons they want to have visual contact with their luggage at all times. If these two criteria are not sufficiently taken into account from the very beginning of planning, inefficient and in an "incident" quite dangerous conditions in the vehicles can be expected.

For 88% of passengers visual contact to their luggage is important or very important. This means that luggage must be able to be stowed in close proximity to the traveller. If there is no adequate possibility for this, and the luggage must be stowed at a greater distance, such as in luggage racks near the entrance, for most travellers this results in a corresponding uneasiness and loss of comfort. However, from an operational viewpoint the risk is

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even greater from luggage which due to a lack of visual contact has been stowed disruptively. Seventy-five percent of travellers indicate explicitly that they are prepared to stow their luggage disruptively in order to meet the need for visual contact.

As a result, luggage is placed on or in front of seats or in aisle areas. This leads to an increase in unusable seats and obstructions to passenger flow.

The second important criterion with regard to planning appropriate luggage racks is the willingness to lift luggage. For example, only 20% of travellers are prepared to lift heavy luggage into the overhead rack; over 50% are under no circumstances ready to do such lifting. With medium sized luggage at least 50% are prepared to lift it into the overhead rack. With regard to luggage racks, at least 50% of travellers are prepared to lift heavy luggage up to waist level (see Fig. 1). These specific values make it clear that it is pointless to provide overhead racks with no exception or alternative. Also, the existing number of luggage racks must be adequately dimensioned!

The sampled readiness regarding luggage accommodation has been confirmed by extensive objective observations. Although in some cases up to 50% of the overhead racks are not used, a variety of pieces of luggage are placed on the floor, in front of seats, in the aisle or on seats.

At lower occupancy rates of up to 35%, thirty percent of medium and large trolleys are placed on or in front of seats or in the aisle. Even at high occupancy rates of over 70%, by which making seats free can be expected, up to 20% of large and medium sized trolleys are placed in these positions. With rucksacks and travel bags nearly the same behaviour has been observed.

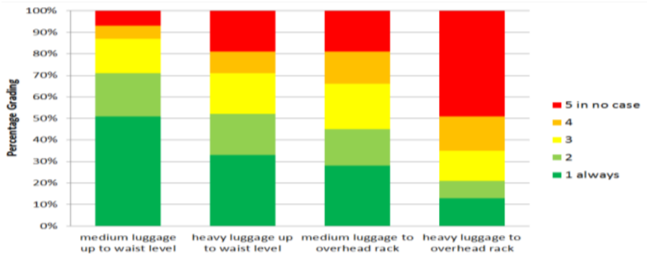

Fig. 1. Readiness to Lift Luggage (Source: Plank)

2.2. Possibilities for Accommodation

The basic possibilities for luggage accommodation are: overhead racks, luggage racks and spaces between the seat backrests. In part, areas under the seats can also be used. However, as a rule these areas can be used only for those pieces of luggage which fall under the category of hand luggage.

In order to design luggage storage space so that even with a very high occupancy rate all luggage can be properly accommodated, the following principles must be observed:

- Above mentioned principles "not lifting" and "visual contact"
- Determination of the actual luggage volume
- Reliable knowledge of the shape of the luggage

In order to efficiently design the most popular storage spaces between the seats and in the luggage racks, knowledge of the shape, size and volume of the luggage is by all means essential. Experience shows that luggage racks which are only a few centimetres, often only 5 cm to 10 cm too narrowly dimensioned, or whose shelf heights are too high or too low, can hold up to 50% less luggage than suitably dimensioned shelves!

The same applies to the space behind or between the seat backrests. Here 10 cm to 15 cm of too little usable space can lead to 70% less storage space.

In addition to the appropriate sizing of luggage racks and seat spacing, it is also important to ensure a well considered distribution of luggage storage possibilities in the vehicle. These must be distributed as evenly as possible over the vehicle to allow good visual contact to luggage from each seat and not impair the flow of passengers.

3. CONSEQUENCES OF UNSUITABLE LUGGAGE ACCOMMODATION POSSIBILITIES

3.1 Passenger boarding and deboarding time

There are many factors which affect passenger boarding and deboarding time. These include passenger related factors which manufacturers and operators have no control over. These factors include age, gender, accompanying luggage and any kind of mobility limitation.

However, the vehicle-side factors are important. On one hand, by correct planning the passenger-side factors can be correspondingly reduced; on the other hand, by improper planning these can be exacerbated. These factors include for example, the entry height and door width, potentially any existing level entrances, location and number of entrances, the suitability of entrance spaces as collection areas, any restrictions to passenger flow and the overall design of the vehicle interior.

From the perspective of passenger boarding and deboarding time the difference between the best and the worst vehicles currently in use is at a ratio of 1:4. This means in concrete terms that with an assumed passenger boarding and deboarding time of one minute in the best case, the time for the same number of passengers in the worst case can be up to four minutes! It should be noted here that with some exceptions younger generation vehicles which are currently in operation tend to produce higher values.

The influence of interior design between the best and worst case already produces an affect with a ratio of 1:2. This means for example, in the best case at a high rate of passenger exchange in conventional vehicle constructions, a passenger boarding and deboarding time of two minutes can be achieved. Whereas, in the worst case it requires four minutes.

In Fig. 4 fundamental concepts are presented; in such a way whereby in this example in row seating practically only overhead racks are available and in vis-a-vis seating luggage can be well stowed between the seat backrests. There is similar data from approximately ten basic vehicle interior categories. All findings show the clear correlation between time demand and luggage storage. The more suitable the design of luggage storage areas, the less time is needed for boarding and deboarding.

3.2 Occupancy rate

From an operational point of view, the second relevant effect of well planned or vice versa insufficiently thought out luggage storage areas, is the actual occupancy rate.

In long-distance traffic the only significant occupancy rate is the seat occupancy rate. With unsuitable and insufficiently designed luggage storage possibilities, even this can decline noticeably. In conventional passenger carriages with a length over buffers of 26.4 meters, a maximum of 80 seats for standard days and 78 seats for travel days are provided (see Fig. 2). This number is achieved if the remaining areas are used in suitable form for luggage storage. If this is the case, up to 100% of the seats can be occupied. If there are more seats over these limits, it is at the expense of customer-oriented luggage accommodation; and the actual number of available seats as well as the occupancy rate sink drastically. Previous studies by the Research Centre for Railway Engineering at the Technical University of Vienna show that the average achievable occupancy rate in comparable vehicles with 88 seats is only about 80%. This means that on average only 70 of the 88 installed seats can be used (see Fig. 2)!

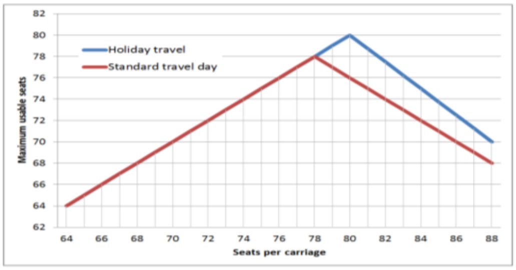

Fig. 2. Maximum possible number of seats in passenger carriages with a length of 26.4 meters (Source: Rüger)

The reason for the sharp decline in occupancy is that there is not enough luggage accommodation capacity available and the existing areas are frequently unsuitably designed. This leads to the fact that part of the luggage is stored not only in the aisle but also on and in front of the seats.

3.3 Operating efficiency

The consequences of falsely planned luggage storage possibilities presented so far ultimately have significant operating efficiency impacts. The hope or goal to also be more efficient through a greater number of seats is transformed as a general rule into the opposite. Under the premise that the goal is to want to take advantage of the highest number of available seats, the following circumstances always prevail:

Delays: Vehicle interiors following the idea of seat maximization inevitably lead to long station stop times. With a high passenger exchange, four to six minutes per station are the result. Whereas, ideally designed vehicles require only one to one and a half minutes. This fact in the case of a close sequence of stations leads to corresponding delays.

Declining operating quality: When they cannot be made up for, the aforementioned delays lead to a decline in operating quality. This is especially important if delays are carried over to connecting or opposite trains, or if the results are missed connections.

Higher energy consumption: If it is at all possible to make up for the delays, it is only possible by constant use of maximum line speed, which means a significant additional energy consumption especially at a high rate of speed.

Lower occupancy rate: There are seats installed which in practice are not available. At the same time the achievable seat occupancy rate declines up to 20%!

Declining passenger satisfaction: The declining seat occupancy rate causes a correspondingly high number of standing passengers, which accordingly reduces passenger satisfaction. Comfort is significantly reduced by the in part "chaotic" conditions in "overcrowded" vehicles. For nearly 18% of travellers high occupancy together with the already mentioned associated effects means a high stress factor!

4. FUNDAMENTAL PLANNING ERRORS

From past experience, both on the part of the purchaser as well as on the part of the manufacturer, fundamental errors which lead to the inefficient conditions described above can be identified in the planning and ordering process.

Error 1: Volume calculation: Every cuboid-like object has a volume and also three definite dimensions. As a rule In tender documents there is only information on the total volume required for luggage accommodation. For cuboids the volume is known as the product of width, length and height. This means that an often called for volume of approx. 0.125m³ per passenger can either correspond to the dimensions of a midsized trolley with dimensions of 50x70x35 cm, or at the same time, a trolley with dimensions of 1x4160x30 cm! Accordingly, it is also common practice to multiply every small cross-sectional area by the available depth and to sum the resulting volumes to a total volume! As a rule, in practice a maximum of 50% of the calculated volumes are available. It is therefore necessary to have precise knowledge of the statistical distribution, shape and dimensions of the luggage!

Error 2: Disregard of passenger behaviour: If the principles of "not lifting" and "visual contact" with regard to luggage storage construction are disregarded, the planned storage areas will be only in part accepted by the passengers. In practice this leads to the condition that up to 50% of all storage areas remain unused and yet a larger amount of luggage is stored disruptively.

Error 3: False awareness of luggage volume: The actual luggage volume has to be calculated for each route and expected passenger or travel purpose mix. Frequently blanket assumptions are made, or days are taken as a basis for calculation on which only a below average luggage volume can be expected.

Error 4: False dimensioning: Meanwhile, luggage accommodation is increasingly being taken into account in vehicles with regard to the installation of luggage racks and the space between the seat backrests. However, here it must be noted that the dimensions of luggage racks are often oriented to seat spacing resulting in very inefficient dimensions. The same can be observed in the spaces between the seat backrests. When dimensioning the respective storage areas it is advantageous to take into account the forms and dimensions of the luggage as well as the storage behaviour of passengers. Seat spacing and luggage racks are often dimensioned a few centimetres to small, which can lead to an actual storage loss of 50% or more.

Error 5: False evaluation criteria for orders: In vehicle orders it can often be observed that evaluation criteria are applied which are not logically understandable. A popular evaluation criterion in tenders is to define the minimum number of seats. Usually this involves specifications which can be classified as a psychological perception; and thus, they often jump to increments of 100. If for example in the tender as a fictitious number it is predetermined that a train must have 500 seats, then the hands of the manufacturer are already bound in the tender phase; and from the outset actually efficient solutions are not possible. These figures are usually based on a previously calculated maximum number per vehicle and thereby disregard reality. With the fictitious example mentioned it can be expected that a maximum number of 450 seats will actually be available in the train. Thus, it would be much more efficient to make no such requirement, but rather to allow the manufacturers to search for efficient overall solutions. With appropriate solutions it can be expected that vehicle design concepts can be found which in the example mentioned offer approx. 470 seats. Seats, which in the end can actually be used!

5. CONCLUSION

Fifteen years of research and development as well as participation in numerous vehicle plans make it clear that at all times with vehicle development and orders an overall optimum for vehicle interiors should be sought. Many negative examples make clear that the exclusive pursuit of a maximum number of seats can in practice lead to inefficient and dangerous situations. In particular, luggage storage possibilities must be precisely and thoughtfully planned in order to contribute to efficient overall systems. Experience further shows that it is very critical to lay aside blanket assumptions about design. Each vehicle must be assessed individually in terms of attainable overall efficiency which ultimately leads to an actual maximum seating occupancy.

Requirements for luggage storage must be thoughtfully formulated in the tender. Furthermore, in order achieve the greatest possible degree of efficiency, where and which luggage storage areas can be installed must be precisely considered in the beginning phase of vehicle planning. Later changes are usually achieved only with great difficulty or with little effect.

Fortunately, in recent times one can discern an awareness regarding these problems. Numerous recent projects confirm that both on the part of the operators as well as the manufacturers, interest in and willingness to develop efficient overall systems have emerged; and that some efficient overall solutions can be developed with negligible additional cost.

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COMPARATIVE STRENGTH ANALYSIS OF UNDERFRAMES OF FLAT WAGON VARIANTS WITH WOODEN AND STEEL FLOOR

Svetoslav SLAVCHEV [1]
Valeri STOILOV [2]

***Abstract** – We examined static strength of two variants of the frame design of the flat wagon - with wooden and with a steel floor. The results for different parameters, such as stiffness of the wagon body, stresses under static load, deflection of the underframe under vertical loads and other were obtained and then compared for both wagon modifications. A comparative analysis of the obtained results shows the advantages and disadvantages for each version of the wagon body design with different types of floors.*

Keywords – flat wagon, strength analysis, FEM, wagon floor.

1. INTRODUCTION

The study was conducted at the request of Bulgarian freight wagon manufacturer TRANSVAGON Plc., Bourgas. As a prototype of a newly designed wagon Rens 192B served flat wagon Rens 192 (Figure 1) whose design documentation was developed in the company in 2007, tested in National Transport Research Institute (NTRI) and was commissioned in 2013 by the German railway administration.

Fig.1. Flat wagon series Rens

In accordance with [1] the study was conducted in the following sequence: first a model of wagon Rens 192 was developed; the received theoretical results are compared with experimental test of the wagon; the results of both theoretical and experimental test were comparad and analysed; a model of the new wagon Rens 192B was developed, which is close enough to the model of the prototype; then the calculations of new wagon construction are carried out; the theoretical results from a study of both modifications of the wagon structure were compared and a proposal for commissioning of new wagon was made.

2. LOAD CASES

In accordance with international standards, each newly designed wagon is submitted to theoretical (by calculation) and experimental studies to determine stresses and deformations. Load cases and conditions are specified in European standard EN 12663-2:2010 [2], TSI subsystem "Rolling stock" [3] and leaflet 577 [4] of the International Union of Railways (UIC). According to documents cited loads are divided into the following groups:

2.1. Longitudinal static loads:

HLC1- Compressive force at buffer axis height 2000 kN (Table 2 of [2]).

HLC2- Compressive force 50 mm below buffer centre line 1500 kN (Table 3 of [2]).

HLC3- Compressive force applied diagonally at buffer level 400 kN (Table 4 of [2]).

HLC4- Tensile force at coupler axis level 1500 kN (Table 5 of [2]).

2.2. Vertical static loads:

VLC- Vertical maximum operating load $1,3*g*(m_1+m_3)$ (Table 6 of [2])

After the preliminary calculations were done, results show that the VLC2 is the “worst case” vertical load of all vertical load cases. This is the reason that only this vertical load case is reviewed below. This load case represents: Vertical load placed on two separate supports at the width of 1,2 m and length b-b = 5 m; $1,3 * g * (m_1 + m_{3(b-b)}) = 1,3 * g * (16t + 44t)$. Loading lengths and load weights are given in fig. 2.

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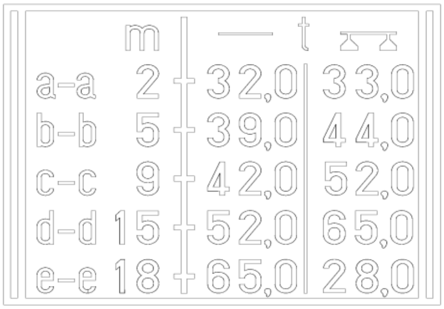

Fig.2.Loading lengths and weights for wagon Rens

2.3. 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 [2])

LLC2- Lifting the whole vehicle at 4 lifting positions $1{,}0*g*(m_1+2m_2+m_3)$ (Table 8 of [2])

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 [2])

2.4. Superposition of static loads:

CHLC1- Compressive force at buffer axis height 2000 kN and "worst case" vertical load $1{,}0*g*(m_1+m_3)$ (Table 9 of [2])

CHLC2- Compressive force 50 mm below buffer centre line 1500 kN and "worst case" vertical load $1{,}0*g*(m_1+m_3)$ (Table 9 of [2])

CHLC3- Compressive force at buffer axis height 2000 kN and minimum vertical load $1{,}0*g*m_1$(Table 9 of [2])

CHLC4- Tensile force at coupler axis level 1500 kN and "worst case" vertical load $1{,}0*g*(m_1+m_3)$ (Table 9 of [2])

CHLC5- Tensile force at coupler axis level 1500 kN and minimum vertical load $1{,}0*g*m_1$ (Table 9 of [2])

2.5. Fatigue load cases.

2.6. Eigenfrequency analysis [5].

3. COMPARATIVE ANALYSIS OF THEORETICAL CALCULATION RESULTS FOR WAGONS *RENS 192* AND *RENS 192B*

Structural difference between the two flat wagons is that the modified wagon (Rens 192B) instead of the wooden floor is equipped with steel sheet floor plates with a thickness of 8 mm. At the insistence of the manufacturer - Transvagon Plc., the underframe of wagon Rens 192B is designed and tested in the original, not reinforced version of Rens 192 [6], as it was expected that stiffening and hardening in the areas with insufficient strength occurs because of replacement of wooden non-bearing floor with bearing steel floor. There are also some minor changes in structural elements such as ribs, radius of curvature, transitions, links and others that are made mostly by technological considerations and based on the results of calculations and tests of the prototype Rens 192.

Theoretical studies have been done by the finite element method. A software product used is SolidWorks [7].

For the purposes of the study complex spatial calculation models describing very precisely the geometry of the wagons were developed as shown in fig. 3 and fig. 4. In the creating process of both models the convergence of the decision was investigated [8, 9, 10]. This allows us to develop the most appropriate schemes regarding: geometric representation of the object, the application of the current loads and reactions and getting enough accurate results for the distribution of strains, displacements and stresses [11, 12, 13, 14].

The most important parameters for the models are shown in Table 1.

Tab. 1. Parameters of calculation models

Parameter	Rens 192	Rens 192B
Software used	SolidWorks	SolidWorks
Type of finite elements used	3D	3D
Max. size, mm	49,5	49,5
Number of elements	734 869	958 576
Number of nodes	367 983	501 699
Load cases according to	EN 12663-2:2010	EN 12663-2:2010

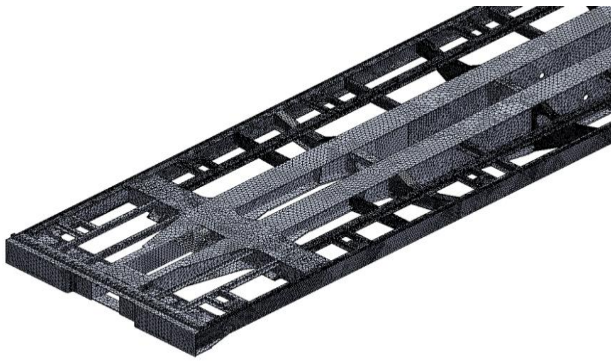

Fig.3.Calculation model of Rens 192

Fig.4. Calculation model of Rens 192B

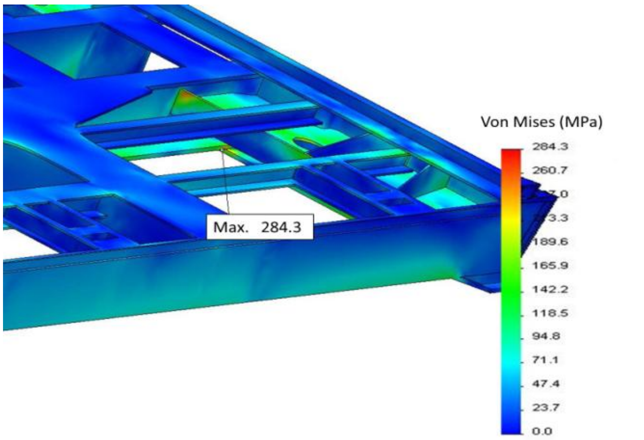

Fig.5. HLC1 stress distribution for Rens 192

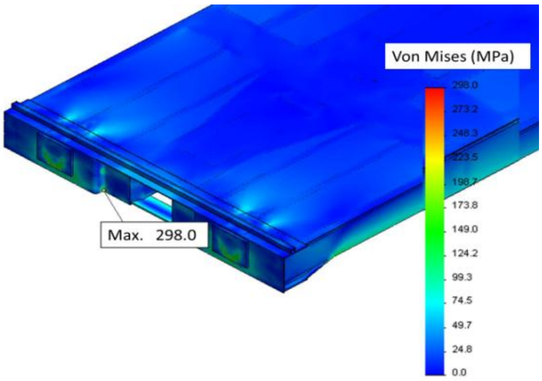

Fig.6. HLC1 stress distribution for Rens 192B

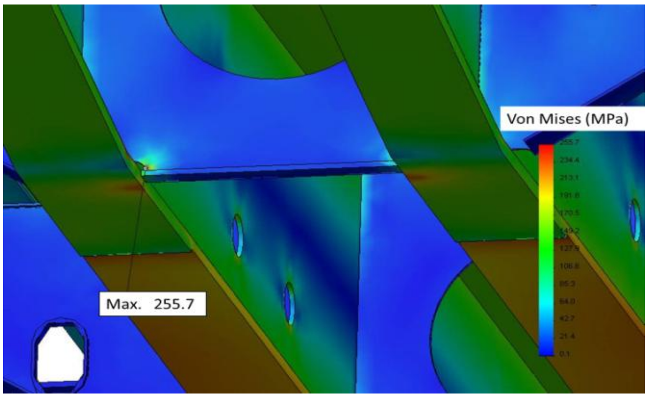

Fig.7. VLC2 stress distribution for Rens 192

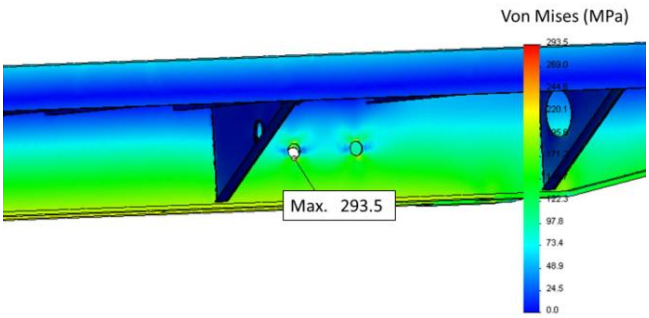

Fig.8. VLC2 stress distribution for Rens 192B

After the calculations, a comparative analysis of the results obtained theoretically for both wagon modifications was done for:
- Mass moments of inertia - Table 2;
- Torsional stiffness - Table 3;
- Maximum deflection at the lowest underframe point in the middle of the wagon - Table 4;
- Values of maximum stresses - Table 5 and figures 5 to 8;
- The values of fatigue safety factors for the areas with welds and stress notches - Table 6.

Tab. 2. Mass moments of inertia

Mass moments of inertia	**Rens 192**	**Rens 192B**
Jxx (kg.m^2)	5489,43	7176,50
Jyy (kg.m^2)	318372,22	395881,09
Jzz (kg.m^2)	323069,49	402078,62

Tab. 3. Torsional stiffness

Torsional stiffness	**Rens 192**	**Rens 192B**
c_t * (kNmm^2/rad)	0,6021.10^{10}	1,4508.10^{10}

Tab. 4. Maximum deflection at the lowest underframe point

Maximum deflection	**Rens 192**	**Rens 192B**	**Permissible deflection**
Δh (mm)	41,5	29,5	44,58

Tab. 5. Obtained stress values

Load case in accordance with EN 12663-2:2010	**Max. stresses (MPa)**	
	Rens 192	***Rens 192B***
HLC 1	285,9	286,0
HLC 2	284,3	298,0
HLC 3	283,3	116,6
HLC 4	291,4	273,8
VLC 2	255,7	293,5
LLC 1	416,7	363,5
LLC 2	340,6	229,2
LLC 3	337,4	229,1
CHLC 1	332,1	290,2
CHLC 2	304,6	302,3
CHLC 3	292,9	288,1
CHLC 4	313,8	319,5
CHLC 5	292,0	266,0

Tab. 6. Fatigue safety factors

Underframe element	***Fatigue safety factors S***	
	Rens 192	***Rens 192B***
bolster	1,41	4,62
centre solebar	1,003	1,01
crossbars	3,15	2,25
centre bars links	4,19	1,47

Analysis of the data from tables 2 to 6 allows to formulate the following conclusions:

- Calculation models used in the study for both wagons Rens 192 and Rens 192B have similar parameters, development principles and ways of application of restrictive conditions;
- Mass moments of inertia are similar and as logicaly expected - higher at Rens 192B;
- Torsional stiffness of the wagon Rens 192B with steel floor is about 2,4 times higher than that of the wagon with a wooden floor;
- Deflection in the middle of the wagon Rens 192B with steel floor is 1,4 times smaller than that of Rens 192 with wooden floor;
- The maximum stresses in the new structure with steel floor are close to or smaller than the corresponding values of the stresses in the structure with wooden floor. Exceptions are found only in load cases HLC1, HLC2 and VLC 2 due to constructive changes made (additional strengthening of the wagon at the upper part of the underframe trough welded steel sheet floor);
- Fatigue safety factors in the areas with welds on the new wagon are higher than those of the prototype for the main underframe beams. The smaller safety factors in crossbeams occur due to their stiffening at the upper end of the steel floor.

4. CONCLUSION

Summarizing the overall work on this study the following conclusions can be drawn:

1. Complex calculation model for strength study of wagon Rens 192 with wooden floor was developed. Very good compliance of the results for the stresses and displacements obtained by calculations and those of the wagon test was found. This allows the calculation model to be used for strength study and optimization of other similar objects with a similar structure, such as the wagon Rens 192B with metal floor.

2. A comparative analysis of the theoretical results for wagons Rens 192 and Rens 192B was conducted. It has been found that, in newly designed wagon mass moments of inertia, torsional stiffness and deflection of the underframe are logically changed due to the replacement of the wooden floor with a metal one.

3. Static load cases stresses and safety factors in the study of fatigue in the areas of welds for both wagons are close to each other, and in most cases are in favor of the newly designed wagon Rens 192B.

This gives rise to a proposal for the commissioning of wagon Rens 192B without conducting of mandatory tests of the wagon.

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DETECTION OF TORSIONAL OSCILLATIONS IN DRIVING AXLES OF ELECTRICAL VEHICLES BY APPLICATION OF SPECTRAL ANALYSIS

Petar MARKOVIC[1]
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Abstract – *This paper presents a method for real-time detection of the torsional oscillations in the driving axles of the electrical locomotive with DC or AC traction motors. The method is based on the spectral analysis of the traction motor's measured or estimated quantities. Torsional oscillations are caused by slippage of the traction wheels, and they reflect in oscillations of the torque and angular velocity at the resonant frequency of the driving axle. Torsional oscillations are, further, reflected on the rotor's angular velocity, and on the electromotive force induced in the rotor. Measurement data obtained by testing the ZS series 444 locomotive in real conditions are used for analysis. Spectral analysis of the measured rotor voltage signal confirms that occurrence of the spectral component at the resonant frequency coincides with slippage of the traction wheels. Possibilities for implementation of the proposed method in the vehicles with AC traction motors are discussed. Simulation model of the vehicle with asynchronous traction motor is realized in Simulink. Results of simulation shows that, when slippage of driving wheels occurs, estimated rotor's velocity contains spectral component at natural frequency of the driving axle-wheels system.*

Keywords - Torsional oscillations, Spectral analysis, Adhesion, Electrical motor, Locomotive.

1. INTRODUCTION

Torsional oscillations are a phenomenon which is caused by slipping of driving wheels in the traction regime, or by blocking/sliding in the braking regime, when the operating point of the adhesion curve is in the unstable region [1] [2]. The resonant frequency of the mechanical system consisting of the driving axle and wheels is a function of the stiffness of the axle and moments of inertia of the system's parts. Torsional oscillations lead to the occurrence of the torque oscillations of the high amplitude at the resonant frequency. As well, angular velocities in the system oscillate at the resonance frequency. Therefore, some anti-slip control techniques are based on the presence of the spectral component at natural frequency in measured or estimated values of torque or angular velocity [2].

Hence, besides measurements of torque of the driving axle [3], torsion oscillations can be detected by the measurement/estimation and spectral analysis of the wheel's angular velocity. In order to detect a spectral component, expected around 50Hz, it is required that sampling frequency of the position signal taken from optical encoder, presently used for measurement of angular velocity on locomotives ZS series 444, is well above 100Hz in order to avoid aliasing effect. However, such high sampling frequency leads to the problems related to the limited resolution of the optical encoders and amplification of the noise created by differentiation.

A simple solution is measuring of electrical values by the sensors, already present in the vehicles for the purposes of the control and monitoring, which can be sampled at a considerably higher frequency. Since electromotive force of DC traction motor is proportional to rotor velocity, by measuring voltage across the rotor, applying sampling frequency of 2 kHz and performing spectral analysis, torsion oscillations are easily detected [4].

Modern electrical vehicles are driven by AC traction motors. Rotor electrical quantities cannot be measured, but only estimated. Rotor velocity can also be estimated [5] [6], providing the possibility for detection of the torsionall oscillations, as explained in the next sections.

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2. TRANSMISSION OF DRIVING TORQUE FROM THE MOTOR TO WHEELS

The developed torque of the driving motor is transmitted from the driving axle of the rotor, via gearbox, to the driving axle which is stiffly bound to the wheels. Typical appearance of the mechanical subsystem for transmission of the driving torque from traction motor to driving wheels, where at the contact with the rail it is converted to the traction force, is shown in Fig. 1

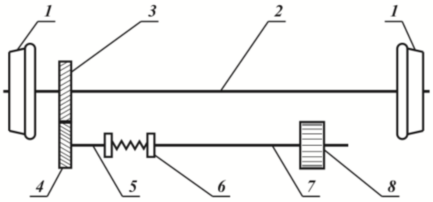

Fig. 1. Diagram of the transmission system of an electric locomotive: 1-wheels; 2-driving axle; 3-axle cogwheel; 4-driving cogwheel of the motor; 5-auxiliary axle; 6-elastic coupling; 7-torsional axle; 8-rotor of the motor

From the point of view of the simulation model, it is considered that all elements of the mechanical system, from rotor to gearbox, are moving with the same angular velocity $\omega_m = \dot{\theta}_m$, where θ_m is angular position of the rotor.

The reduction gear is considered to be ideal, with transmission ratio i_R. Therefore, the driving axle is driven with the torque equal to $i_R T_m$, where T_m denotes torque of the traction motor. Angular position of the gear's larger cogwheel is $\theta_{gb} = \theta_m / i_R$, while all inertia elements can be reduced from motor's side to driving axle's side of the gearbox. J_{gb} denotes moment of inertia of motor and gearbox reduced to the driving axle.

The phenomenon of slip of the driving axles, caused by loss of adhesion, is accompanied by torsional oscillations of the driving axle. The torsional oscillations are caused by elasticity of the driving axle, i.e. by the fact that the applied torque is proportional to the angle of torsion. Therefore the following equations apply:

$$i_R T_m - T_{sr} - T_{sl} = J_{gb}\ddot{\theta}_{gb}, \quad (1)$$

$$T_{sr} = k_{sr}\left(\theta_{gb} - \theta_{wr}\right),\ T_{sl} = k_{sl}\left(\theta_{gb} - \theta_{wl}\right), \quad (2)$$

$$T_{sr} - T_{ar} = J_{wr}\ddot{\theta}_{wr},\ T_{sl} - T_{al} = J_{wl}\ddot{\theta}_{wl}. \quad (3)$$

In these expressions: T_{sr} and T_{sl} - torsional torques in the right and left part of the axle, k_{sr} and k_{sl} - stiffness constants of the of the right and left parts of the axle, J_{wr} and J_{wl} - moments of inertia of the right and left wheel, $T_{ar} = F_{adh,r}R_w$ and $T_{al} = F_{adh,l}R_w$ - adhesion torques at the right and left wheel, R_w - wheel radius, F_{adh} - adhesion force developed at the wheel-rail contact; θ_{gb}, θ_{wr} and θ_{wl} - angular positions of the larger cogwheel of the gearbox, right and left wheel.

Expressions (1) to (3) describe dynamics of the transmission mechanism from rotor of the traction motor to the contact between the wheels and rail.

2.1. State space model

The system of state space equations of the mechanical subsystem is derived from expressions (1)-(3), with the state vector consisting of the angular velocity of axle side of gearbox, angular velocities of the left and right wheel, and torsion angles between gearbox and right and left wheel, $\theta_{sr} = \theta_{gb} - \theta_{wr}$ and $\theta_{sl} = \theta_{gb} - \theta_{wl}$.

$$\begin{bmatrix} \dot{\omega}_{gb} \\ \dot{\omega}_{wr} \\ \dot{\omega}_{wl} \\ \dot{\theta}_{sr} \\ \dot{\theta}_{sl} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & \frac{-k_{sr}}{J_{gb}} & \frac{-k_{sl}}{J_{gb}} \\ 0 & 0 & 0 & \frac{k_{sr}}{J_{wr}} & 0 \\ 0 & 0 & 0 & 0 & \frac{k_{sr}}{J_{wl}} \\ 1 & -1 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 \end{bmatrix} \begin{bmatrix} \omega_{gb} \\ \omega_{wr} \\ \omega_{wl} \\ \theta_{sr} \\ \theta_{sl} \end{bmatrix} + \quad (4)$$

$$+ \begin{bmatrix} \frac{1}{J_{gb}} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} i_R T_m + \begin{bmatrix} 0 & 0 \\ -\frac{1}{J_{wr}} & 0 \\ 0 & -\frac{1}{J_{wl}} \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} T_{ar} \\ T_{al} \end{bmatrix}$$

When the linearized dependence of the increment of adhesion torque ΔT_{adh} upon increment of angular velocity of the wheel $\Delta\omega_w$ is included, an extra damping is added to the model. The system becomes unstable, as explained in [1] [2], and prone to self oscillation when the increment of adhesion torque with respect to the angular velocity of wheel is negative, i.e. $k_{adh} = \Delta T_{adh} / \Delta\omega_w < 0$. This phenomenon is characteristic for situation when the operating point is in the unstable zone of the adhesion curve, slip zone. When the operating point is in the stable zone, i.e. $k_{adh} = \Delta T_{adh} / \Delta\omega_w > 0$, the system is stable and there are no torsional oscillations.

The frequency of torsional oscillations is equal to the natural frequency of the corresponding two-inertial system $f_{nl} = \frac{1}{2\pi}\sqrt{k_{sl}\left(\frac{1}{J_{wl}} + \frac{1}{J_{gb}}\right)}$ for the left part of the axle (from gearbox to left wheel) and $f_{nr} = \frac{1}{2\pi}\sqrt{k_{sr}\left(\frac{1}{J_{wr}} + \frac{1}{J_{gb}}\right)}$ for the right part of the driving axle.

3. EXPERIMENTAL MEASUREMENTS AND THE SELECTED RESULTS

The proposed method for detection of the torsional oscillations is verified by performing spectral analysis of the measurement data obtained by testing the ZS series 444 locomotive in real conditions [3]. The analysis is performed in Matlab.

Measured values of interest are angular velocities of the wheels, obtained by counting edges from optical encoder with sampling period of 100ms, and rotor voltage, sampled with frequency of 2kS/s.

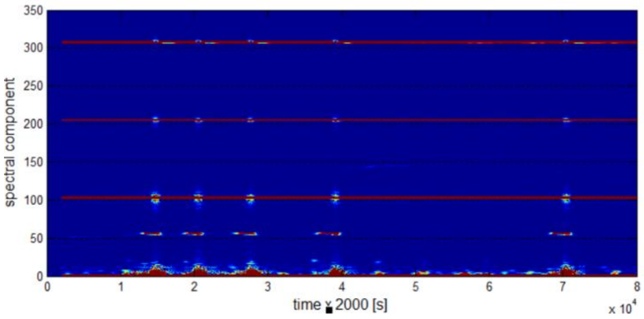

Fig. 2. Time diagram of the rotor's voltage signal's spectrum

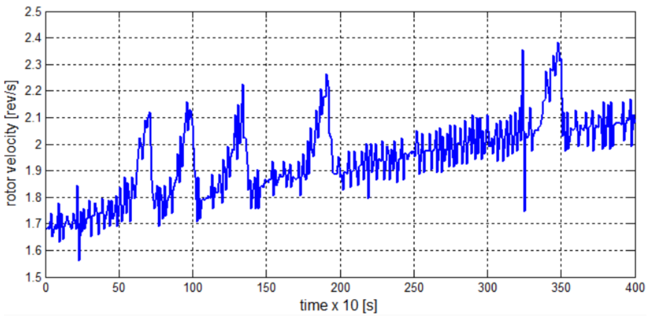

Fig. 3. Measured angular velocity of a wheel

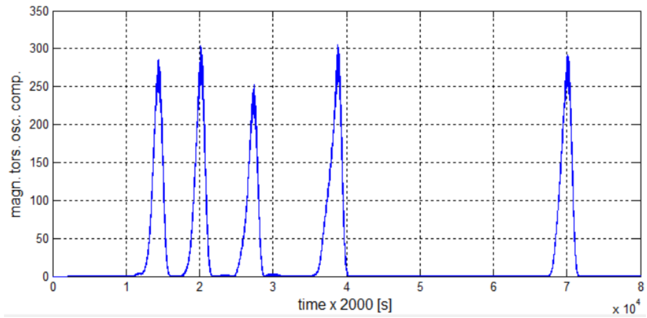

Fig. 4. Magnitude of the spectral component nearest to the frequency of torsional oscillations

Time diagram (40 seconds) of the rotor's voltage spectrum is presented in the Fig. 2. FFT algorithm is conducted on the sliding windowed time records with length equal to 2048 samples, on the sample by sample basis. It is concluded that besides expected spectral components (0, 100Hz, 200Hz...) the only significant spectral component is the one at around 55Hz, that coincides in time with slippage of the traction wheels.

Fig. 3. shows the time diagram of the angular velocity of a wheel that slips five times in the interval of 40 seconds. Fig. 4. shows the time diagram of the magnitude of the most significant spectral component (around 55Hz), nearest to natural frequency of the torsional oscillations. It is clear that rise of the magnitude coincides with slippage and sudden rise of the angular velocity.

4. DETECTION OF THE TORSIONAL VIBRATIONS IN VEHICLES WITH AC TRACTION MOTORS

In the past decades 3-phase AC traction motors have been used in transportation systems due to rapid development of high power semiconductor technology and various vector control algorithms (field-oriented control). Asynchronous machines usually have short-circuit squirrel cage rotor, while synchronous PM machines have permanent magnet rotor. In both cases, rotor electrical quantities cannot be measured. Therefore, torsional oscillations are hard to be detected by spectral analysis of the measurable electrical signals.

Rotor speed value is of great importance for proper motor control and it can be measured and/or estimated. Numerous speed/position sensorless algorithms for torque and speed control have been developed. They implement techniques for estimation of immeasurable quantities, such is rotor flux orientation, required for vector control (direct field-oriented control, DFOC). MRAS (Model Reference Adaptive System) based algorithms are successfully used for estimation of the rotor's velocity, both for asynchronous machines [5] and PM synchronous machines [6]. Such MRAS algorithm is implemented in a Matlab2013/Simscape Power Systems Library's model, AC3 - Sensorless Field-Oriented Control Induction Motor Drive [7]. Detection of the torsional oscillations' spectral component in the estimated rotor velocity is presented the next subsection.

4.1. Simulink model with AC motor drive for detection of torsional vibrations

The simulation model, realized in Simulink, is given in Fig. 5. The model has one wheelset and one AC traction motor. Mechanical transmission system, consisting of the gearbox, driving axle and wheels, is realized on the basis of the equations (1)-(3). Motor drive is imported from the Simscape library model *AC3-Sensorless* [7].

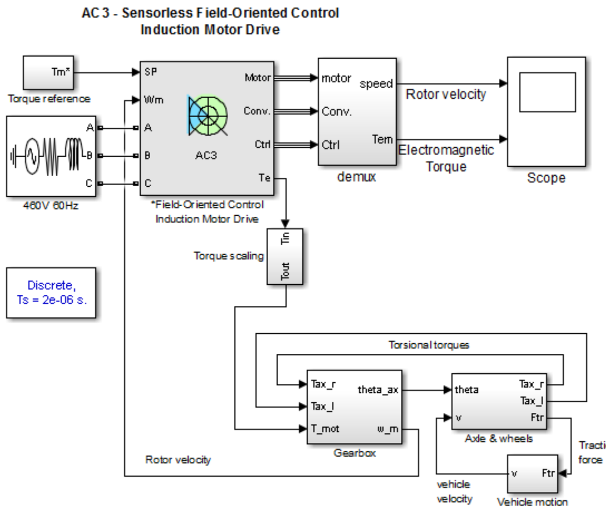

Fig. 5. Simulink model of the single-motor vehicle

Results are given in the Fig. 6, showing oscillations of torque in the longer, left, part of the driving axle during a slippage caused by running into a section with poor adhesion properties at $t = 6\text{s}$.

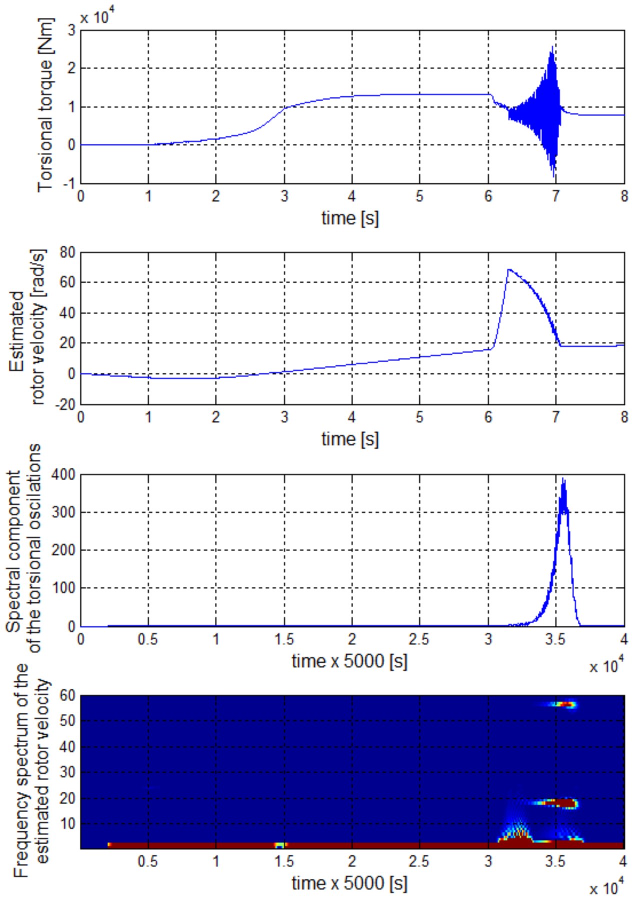

Fig. 6. Results of the simulation that confirm presence of the torsional oscillation component in the spectrum of the estimated rotor velocity

At instant $t = 6.3\text{s}$ reference torque of the motor is reduced and the slip is stopped together with oscillations of torque. Fig. 6. shows the associated effects, oscillations of angular velocity of the slipping wheel and presence of the corresponding spectral component in the estimated rotor velocity.

5. CONCLUSION

Experimental results, given in this paper, confirm that torsional oscillations in driving axles affect rotor velocity. Hence, spectral analysis of the rotor voltage presents reliable method for detection of the torsional oscillations in the driving axles of the electrical vehicles with DC traction motors. In order to implement this method in vehicles with AC traction motors, rotor velocity has to be estimated. Simulation, described in this paper, achieved satisfactory results.

ACKNOWLEDGEMENT

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ANALYSIS OF VEHICLE DIAGNOSTIC OUTPUTS GENERATED BY THE SYSTEM RV07

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Abstract – *For all new or modern railway vehicles occur after a relatively-large variety of electronic systems. Proper function and also maintenance of these systems is very important based on appropriate technical diagnostics. At the moment it is practically impossible to function and maintain electronic systems properly and reliably secure when it is not properly built and adapted the corresponding diagnosis. At the same time the relevant electronic system itself gives real basis for the application of modern diagnostics. It is important to note that the resulting electronic systems malfunction, location of the place of the fault and determine its relevance to the technical condition of vehicles is always a hierarchy of many levels of the entire electronic systems. The advantage of the built-in diagnostics is to connect a large number of components, giving the foundation for a fairly solid grasp on the operation of most structural components and also funk-financial units. A disadvantage of electronic diagnostics is a fairly large number of error codes and no follow-up hierarchy disorders in several levels as part complicates precise identification of the problem. Diagnostics, which is installed in the locomotive series 757 is a comprehensive and modern tool for fast, accurate and high-quality maintenance. If required for vocational training that are intended for maintenance respectively repairs of locomotives series 757, appears to be that type of diagnosis is very promising and useful for further Org - mentation and increasing the effectiveness of technology and technological processes in their maintenance. The paper will provide examples from the normal operations such as error codes on the display unit the precise identification of the actual display, the phase and corrective action for failures, including graphic display of failures formation and development [5,6,7].*

***Keywords* – diagnostics, failures, locomotives, maintenance.**

1. INTRODUCTION

All modern or even modernised locomotives feature a relatively large number of different electronic systems. Proper functioning and also maintenance of such systems are highly significantly based on appropriate technical diagnostics. At the moment it is practically impossible to properly and reliably provide the functioning and maintenance of electronic systems, since corresponding diagnostics is not built-in and suitably adapted. At the same time the relevant electronic system itself gives a real basis for the application of modern diagnostics. It is important to note that a failure that occurs in electronic systems, localisation of the fault occurrence site and determination of its significance for the vehicle technical condition always constitutes a hierarchy of many levels of the entire electronic system used [1,2,3].

Locomotives series 757 represent the latest project of locomotive modernisation. All modern or modernised locomotives feature a relatively large number of different electronic systems. This is the case of locomotive series 757 as well. Proper functioning and also maintenance of such systems are highly significantly based on appropriate technical diagnostics. At the moment it is practically impossible to properly and reliably provide the functioning and maintenance of electronic systems, since corresponding diagnostics is not built-in and suitably adapted. At the same time the relevant electronic system itself gives a real basis for the application of modern diagnostics. It is important to note that a failure that occurs in electronic systems, localization of the failure occurrence site and determination of its significance for the vehicle technical condition always constitutes a hierarchy of many levels of the entire electronic system used.

Locomotive series 757 generate a large number of fault codes and messages. This leads to the fact that the vehicle is quite often under repair or maintenance

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for a longer time, during which it cannot fulfil the tasks for which the vehicle was designed and manufactured. Therefore, it is necessary to well understand the processes of diagnostics and be able to utilize it as a tool for quick and precise identification of an impending or already occurred malfunction [1, 2, 3].

2. DIAGNOSTIC PROCEDURES WHEN FAILURE OCCURS

Diagnostic procedure to zoom the example of asymmetry fault currents of anchorages.

This failure belongs to category „electrical" failures. A significant asymmetry in the currents can result in excessive loss in the motor stators and rotors, and can lead to their total destruction or shutdown of the thermally overloaded motor. More real details we can see in next figures (Fig. 1 and Fig. 2).

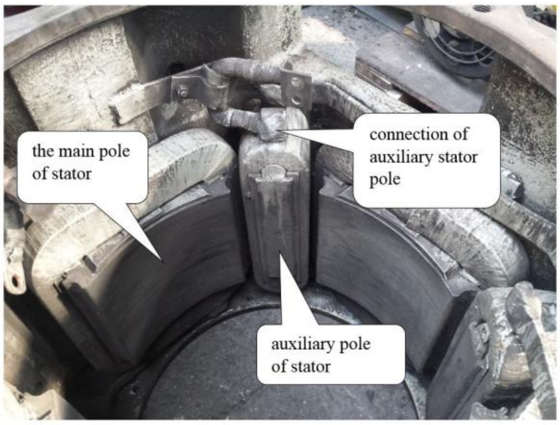


Fig.1. Stator poles traction motors and their connection

Although motors are designed to manage a certain asymmetry, when the predefined threshold is exceeded it is necessary to reduce the load on the motor, or disconnect it from the power supply network. Service life of motors is radically shortened at high voltage asymmetry [1].

Fig.2. Worn brushes traction motor

When a failure occurs it is detected by the AR07 control system and displayed on the A7 display unit using a failure message in the form of a code. The failure code displayed after the occurrence of the described failure is as follows:

„068,NMS ,NR1-JG03 ,---, Armature Currents Asymmetry", what means:

- > 068 – failures sequence number,
- > NMS – failure code,
- > NR1 – source of report (NR1 – Locomotive control system and electronic regulation),
- > JG06 - source of report (JG06 – Specific card of the control system).

The failure removal process, if possible directly on the track, initially solves the locomotive operator. When the failure occurs and the failure message is displayed, the operator has the option to view the details of that failure. These details include further description of the fault occurred and possibly also the instructions how to remove the failure or measures to be taken to continue safe driving. These instructions are intended solely for the locomotive operator.

Example instructions displayed on the A7 panel at the "Armature Currents Asymmetry" fault look like this:

"The relative difference in armature currents between the motor groups exceeded the value of 2/3. This state may occur for example in slippage or even at a fault of the armature circuit of one traction motor. As long as the fault persists and slippage is not suspected (not signalled), it is possible to use the extended display menu ZJ A7 (A7*) on the "Regulation/Traction" panel to trace and identify which armature current reaches a large difference compared to the others. Then, it is necessary to shut down that motor group."

If the operator/driver fails to completely remove the fault that occurred, he selects "Fault accepted" on the A7 display unit and continues driving, if it is possible. After the fault occurs the operator/driver records it in the fault log that is present at each locomotive driver's cab. After the end of the daily driving the engineer browses through the fault log and writes a fault report on the fault occurred or a complaint to the manufacturer, if the locomotive is still within the warranty period. The fault report is further handed to the responsible maintenance (repair) staff who takes steps (carries out operations), based on the information contained in the report, to determine the exact cause of the fault [1, 4].

In step 1, it is necessary to carry out the locomotive diagnostics, which contains "downloading" all operational parameters, variables and values from sensors, and commands issued by the operator/driver for the period in question, which is two weeks in this case. This database is gradually renewed with new days´ data and the oldest days are automatically deleted. Locomotive series 757 diagnostics is carried out directly at the first position of the locomotive driver. This operation requires a USB flash memory with sufficient capacity (at least 2GB), mouse and keyboard. This hardware is placed into prepared USB slots on the left-hand side of the control panel.

Tab. 1. File names of diagnosis

File name – abbreviation	Meaning
DO	Digital inputs
DI	Digital outputs
TPT	Analogue inputs
MEN	Converter data
BUD	Excitation data
KUR	Heating data
TRK	Traction data
CAT	Combustion engine data
ERR	Failutr data
DAT	Train driver and train data
VYK	Performance data
ODP	Water resistance test data
GRA	Voltage and current data
GRB	Voltage and current data

Example file name: GRA_240215_07, what means:

> GRA – voltage and current data,
> 240215 – date of the file: 24/02/2015,
> 07 – hour of entering the record in the document (07:00 – 07:59).

In step 2 it is necessary to open the file named "ERR – Failure Data". This file records all indicated failures that occurred while driving the locomotive on that day. Figure 3 shows a part of the table of the daily "ERR" faults records dated 24/02/2015. On that day, a fault occurred that will serve us to show the fault diagnostic and solving procedures. This table clearly shows the time the fault occurred, the fault sequence number and other information needed for further action. At 7:01:52 (as seen in Figure 3) the "Armature Currents Asymmetry" fault occurred. This fault is repeatedly featured in the fault log with short time intervals. At 7:02:22 the control system recorded "Traction Excitation Blocking". The "ERR" table features "Traction Excitation Blocking" repeatedly as well [1,3].

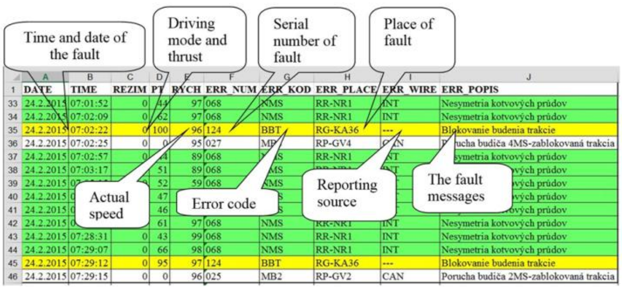


Fig.3. Daily record disorders

The next step is to determine the proper .xlsx file from which we will be able to read the data necessary to determine the specific cause of the locomotive fault. In this case, it is a document entitled "GRA" that is a recording of the currents and voltages in the locomotive electric system. Figure 3 shows a part of the "GRA" table. We already know from the "ERR" file that the fault recorded by the locomotive control system occurred at 7:01:52. It my seem that the permissible difference in armature currents TM (2/3) was exceeded even earlier, for example at 7:01:43, but the control system has not yet evaluated it as armature currents asymmetry. This is due to a certain time delay being set. And also slippage is not evaluated as a fault.

At 7:01:55 there is another change in the "IK1 – IK4" values in the "GRA" table, as seen in Figure 5. The "IK1 – IK4" values at the above-mentioned time dropped to zero, which was caused by blocking the traction motors excitation. Excitation blocking can be seen in the "GRA" file also in the "IBZ" column – "Desired excitation current of the main alternator" that has a value of "0" at the de-excitation time (7:01:55 – 7:01:59). De-excitation can occur due to slippage and traction motors protection (overvoltage, asymmetry). In this case, de-excitation was caused by traction motors´ armature currents asymmetry. Subsequently, at 7:02:02 the control system unblocks the traction excitation again. As can be clearly seen in Figure 4, armature currents asymmetry persists and exceeds the permissible extent of 2/3.

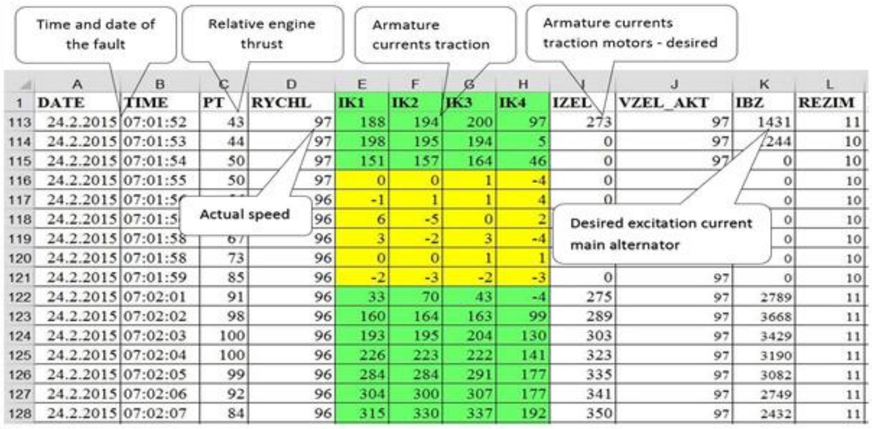
In the above case, asymmetry and the subsequent traction excitation occurred repeatedly several dozen times throughout the locomotive ride. Each occurrence of this phenomenon was recorded by the control system as a repeated fault.

After carrying out diagnosing and the follow-up inspection of the traction motors we discovered the cause of the recurring asymmetry. Specifically, the cause was short carbon brushes on the fourth traction motor. These short carbon brushes failed to transmit large enough currents onto the traction motor armature [1, 3, 4].

The values of currents on traction motors armatures in the "GRA" file may seem confusing. Therefore, these data can be displayed in a chart. Figure 5 clearly shows that in its first part the armature currents are approximately the same and the control system does not indicate a fault. After 7:01:45 there is a clear difference between the IK1 – IK3 currents compared to the IK4 current, resulting in indication of the "Armature Currents Asymmetry" fault.

3. CONCLUSION

The 757 locomotives diagnostics defines a relatively large number of fault codes and the associated hierarchy of faults and causes. In order to better utilise diagnostics and understand the processes we have elaborated and drawn up several procedures aimed at rationalising the maintenance operations in a locomotive depot [1, 8].



	A	B	C	D	E	F	G	H	I	J	K	L
1	DATE	TIME	PT	RYCHL	IK1	IK2	IK3	IK4	IZEL	VZEL_AKT	IBZ	REZIM
113	24.2.2015	07:01:52	43	97	188	194	200	97	273	97	1431	11
114	24.2.2015	07:01:53	44	97	198	195	194	5	0	97	244	10
115	24.2.2015	07:01:54	50	97	151	157	164	46	0	97	0	10
116	24.2.2015	07:01:55	50	97	0	0	1	-4	0		0	10
117	24.2.2015	07:01:5[illegible]	[illegible]	96	-1	1	1	4	0	[illegible]	0	10
118	24.2.2015	07:01:5[illegible]	[illegible]	96	6	-5	0	2	[illegible]	[illegible]	0	10
119	24.2.2015	07:01:58	67	96	3	-2	3	-4	[illegible]	[illegible]	0	10
120	24.2.2015	07:01:58	73	96	0	0	1	1	[illegible]	[illegible]	0	10
121	24.2.2015	07:01:59	85	96	-2	-3	-2	-3	0	97	0	10
122	24.2.2015	07:02:01	91	96	33	70	43	-4	275	97	2789	11
123	24.2.2015	07:02:02	98	96	160	164	163	99	289	97	3668	11
124	24.2.2015	07:02:03	100	96	193	195	204	130	303	97	3429	11
125	24.2.2015	07:02:04	100	96	226	223	222	141	323	97	3190	11
126	24.2.2015	07:02:05	99	96	284	284	291	177	335	97	3082	11
127	24.2.2015	07:02:06	92	96	304	300	307	177	341	97	2749	11
128	24.2.2015	07:02:07	84	96	315	330	337	192	350	97	2432	11

Fig.4. Values of the document "GRA" – blocking the traction motors excitation

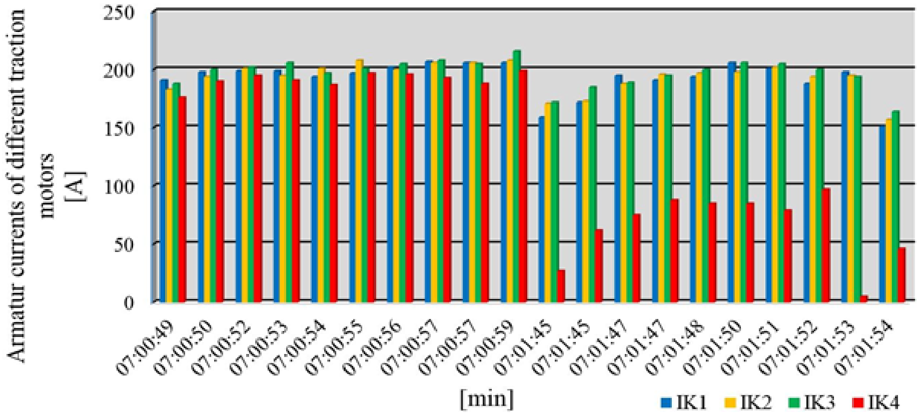


Fig.5. Streams anchors traction motors – the emergence of disturbances

Overall, a proper diagnostic appro.ach – starting from the fault occurrence through to its elimination – requires an extensive, demanding and intensive process. When a fault message is generated and a diagnostic code is displayed, data downloading (collection) is done from the diagnostics memory. Such data are subsequently subject to analysis, which has several fixed steps. After analysing a number of files downloaded from the diagnostics memory the operator is able to determine the range of devices where the fault/disorder occurred, localise the fault itself, determine the severity of the disorder and recommend a preliminary repair plan and interventions. This leads primarily to a reduction in the locomotive downtime while under maintenance/repair, which also obviously increases the time of the locomotive on-track use and hence the effectiveness of its operation.

ACKNOWLEDGEMENT

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '16

DETERMINATION OF RESIDUAL STRESS IN RAIL WHEEL DURING QUENCHING PROCESS WITH FEM SIMULATION

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Milan BANIĆ [3]
Miša TOMIĆ [4]

Abstract *– The residual stresses of railway wheels are caused by the heat treatment during the manufacturing process, usually by the quenching process. Residual stresses within the rail wheel can be dangerous for the rail wheel. Determination of the residual stress in the rail wheel is important for understanding the damage mechanisms and their influence on proper operation of the rail wheels. This paper presents a method of determination of the residual stresses in the rail wheel during the quenching process using directly coupled stress analysis in ANSYS software.*

Keywords – rail wheel, residual stress, FEM, thermal load

1. INTRODUCTION

Today, computer simulation has allowed engineers and researchers to optimize product design process, increase its efficiency and explore new designs, while reducing costly experimental trials.

Residual stress as unavoidable during manufacturing and can be important for damage of wheel and rail. Residual stress are defined as a tensile or compressive force within a material, such as steel, without application of thermal gradient or an external force. Phase transformation, plastic deformation, or thermal effects such as contraction upon cooling cause residual stresses. Newton's laws require that compressive residual stresses at surface of a material are balanced by tensile stresses within material [1].

Residual stresses in rail wheels can be caused mechanically due wheel/rail operation, or due to press fitting process of bandage wheel as well as during quenching process.

The residual stresses of rail wheel usually caused by the heat treatment process. Masoudi Nejad [2] estimated the residual stresses by elastic-plastic finite element model in the railway mono-block wheels caused by heat treatment process. He showed that residual stress achieve very values and they are important factor for crack initiation and fatigue life [3].

The object of several investigations on manufacturing processes is to show a layer of compressive residual stress on the surface of parts to inhibit propagation of cracks. The effects of the residual stress and metal removal on the contact fatigue life have been estimated by Seo et al. [6, 7]. Okagata [8] evaluated the fatigue strength of Japanese railway wheel and presented the fatigue design method of the high-speed railway wheel by considering the effect of manufacturing conditions on the fatigue strength of the material.

Wang [4] showed in his study the heat treatment process of a 36” (914 mm) freight car wheel manufactured by Griffin Wheel Company. He simulated ideal and non-ideal heat treatment processing and the effect on the residual stress after on-tread braking.

Masoudi Nejad [5] showed the approach how to predict accurately the residual stresses due to quenching process of an UIC60 rail using FEM. He simulate the quenching process by applying the elastic–plastic finite element analysis for the rail. His analysis includes two parts, a nonlinear transient thermal analysis and a nonlinear static structural analysis with creep effects.

All of the noted researches preformed numerical analysis by sequential coupling of thermal and structural field. This paper consider the occurrence of residual stresses due to quenching, but with a new approach – direct coupling of thermal and structural field.

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2. RAIL WHEEL

UIC CODE 510-2 [6] contains the conditions relating to the design and maintenance of wheels and wheelsets for coaches and wagons used on international services. It covers wheel diameters from 330 to 1000 mm, and indicates the permissible axle loads from the standpoint of stresses of the metal used for the wheel and the rail.

UIC CODE 510-2 contains detail coordinates of wheel rim line. It is valid for a nominal track gauge of 1435 mm and cannot be readily transposed to apply to other track gauges. Figure 1. shows the wheel profile which is used in further analysis.

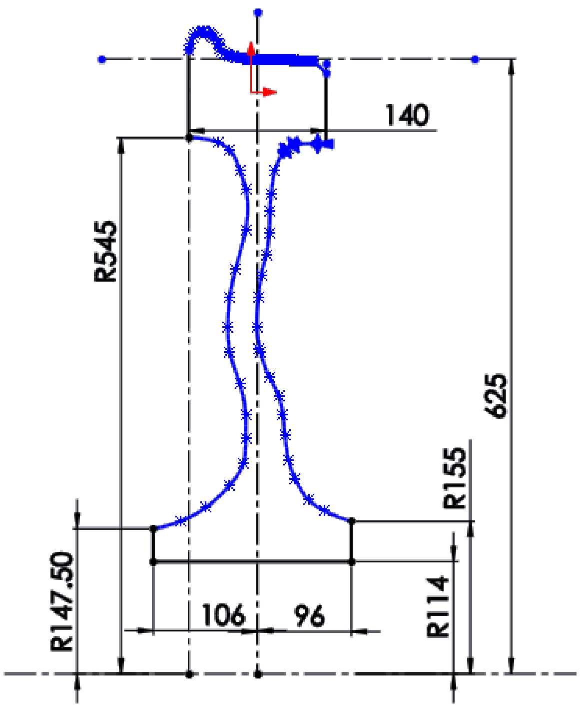


Figure 1. Rail wheel profile (Solid Works sketch)

3. MANUFACTORING PROCESS

The train wheels are manufactured by casting (in some case by forging). Afterwards they are heat-treated to achieve a specific hardness and reheated to remove undesired residual stress that occur in the wheels after noted procedures. Reheated temperature goes from 800 to 920 °C. After homogenisation, rims are quenched with water spay (to the temperature of 300°C) on the tread surface using water spray equipment shown in Figure 2. The quenching process consists of several steps, each of which imposes different boundary conditions on the model.

The heat treatment of rail wheels is the most important step in manufacturing process, which gives adequate mechanical properties to the rail wheel. Material properties depend on the cooling rates in the different parts of the wheel. A goal of the heat treatment is to homogenise the microstructure of the rim in a radial and circumferential direction.

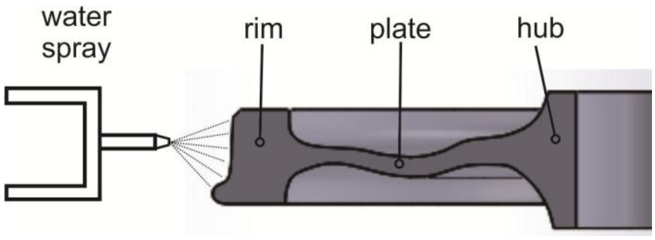


Figure 2. Wheel quenching equipment

Quenching process of rail wheel increases the strength of the steel, improves wear resistance and induces desirable residual stress in the rim. Water spray quenches the hot rail wheel rim which cools and shrinks. Under the wheel rim, steel is still hot and has reduced yield strength due to high temperature. The rim and the plate are in compression caused by colder rim which leads to yielding. Further cooling is performed in air, which gives rim high strength and compressive residual stress. After finishing the rim quenching, plate and hub are still at temperatures near transition temperature.

After quenching the wheels are placed in a tempering furnace at 500 °C temperature for five hours [1] which reduce the residual stress. During this phase there is a tension between cooler outer rim and hotter part of rim and plate. On the end, the rail wheel is exposed to ambient temperature.

This heat-treatment result in the beneficial residual compressive stresses in the rail wheel rim. These stresses are helping the prevention of the formation of rim fatigue cracks in railroad service.

4. SIMULATION

There are two main approaches by using ANSYS to simulate residual stress occurrence. One is to perform sequential analysis, a nonlinear transient thermal analysis and a nonlinear static structural analysis with creep effect. Second approach, proposed in this paper, is to perform direct coupled transient analysis. Advantage of second approach is that stress results are available in all steps of the transient analysis. Disadvantage of direct coupled analysis is that initial thermal condition can not be introduced which leads to higher simulation times.

For the heat treatment simulation, a coupled thermo-mechanical analysis was performed to estimate the residual stress as result of manufacturing within the rail wheel with diameter of 1250 mm. Due to computational demands, the material of the wheel was considered as linearly elastic.

In order to perform coupling of the thermal and structural field, higher order SOLID226 [9] was used for meshing of the model. To increase the accuracy of FE computations the contact of wheel and rail was meshed with fine density mesh as shown on Figure 3. The model consist of 34668 nodes which form 6254 finite elements.

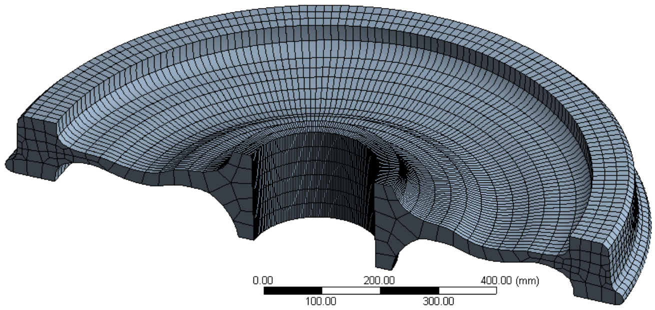


Figure 3. Finite element model of wheel

The setup of analysis reflects the quenching process as described in the previous chapter. The model thermal load and thermal boundary conditions were defined in a multistep analysis via the software command interface as there is no user graphical interface for direct coupling of thermal and structural field.

The wheel rail was initially heated to a uniform temperature of 920 °C and then cooled down to ambient temperature of 22 °C The heat transfer coefficient for wheel to air was 27 W/m^{2}C. The convection occurs from all the rail surfaces during the quenching process. The heat transfer coefficient for the portion of the wheel, which was exposed to the water spray during the quenching process, was 3000 W/m^{2}C. Radiation from all surfaces of the wheel was omitted during the heat transfer analysis.

5. RESULT AND DISCUSSION

Figure 4. shows the temperature-time histories for 60 s of three nodes in the model (on the rim of the wheel, the plate of the wheel and another at the hub of the wheel), beginning at the initial temperature (920 °C), through the quenching process. One can see that temperature in the rim and hub are decreasing much slower than temperature in the plate, which is characteristic for a wheel quenching.

Figure 5 shows the temperature distribution due to the quenching process in the FEM model after 5, 10, 30 and 60 seconds where can be seen the effects of cooling. From the noted figures, one can conclude that the highest temperature stays in the middle of rim and hub. Noted temperature distribution is realistic and correspond to findings by other authors [2].

Figure 6 shows the contour plots of the stress field after 5, 10, 30 and 60 seconds. It shows that, without counting the peripheral zone of the hub, the highest rates are on the rim surface. The maximum equivalent stresses during time are shown in Table 1.

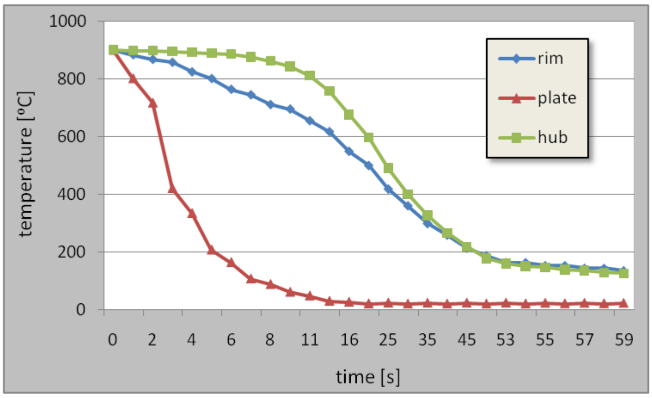
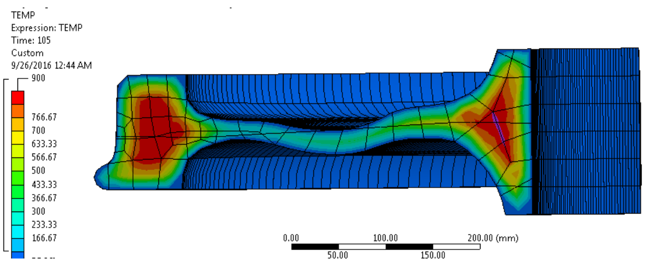
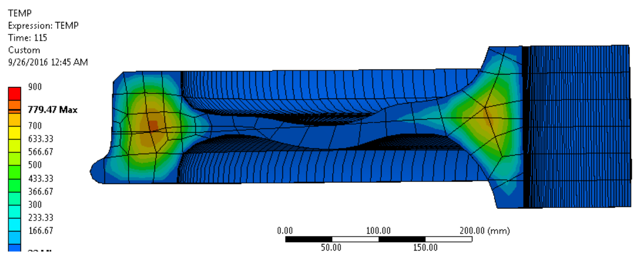


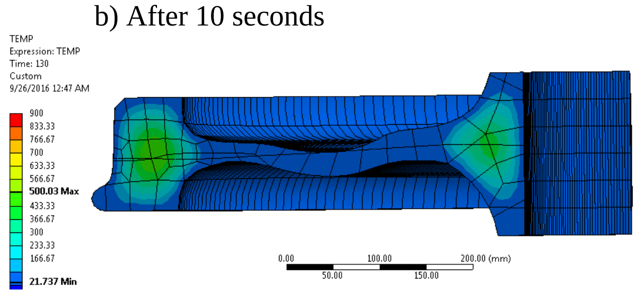
Figure 4. Node temperature on rim, plate and hub during time



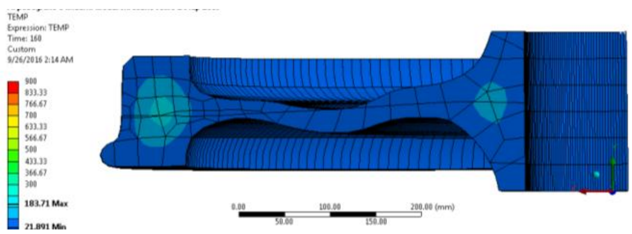
a) After 5 seconds



b) After 10 seconds



c) After 30 seconds



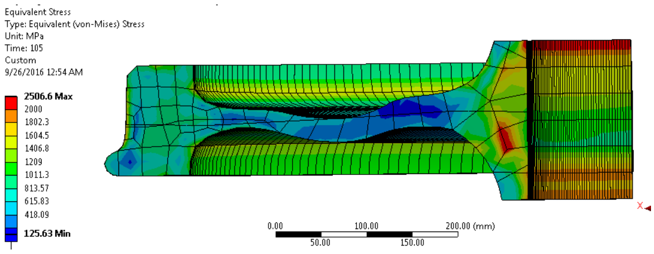
d) After 60 seconds

Figure 5. Temperature field due to the quenching process of rail wheel after 5, 10 and 30 seconds

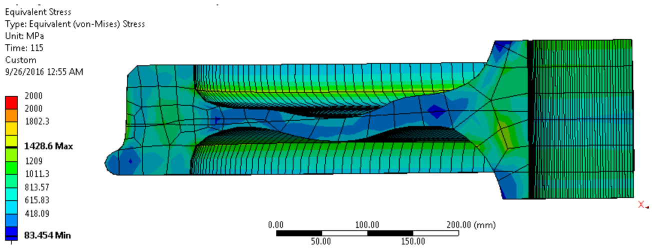
It is clear from the maximum stress values and contour plots that the stresses obtained in quenching simulation are unrealistically high. This is a consequence of linear material model used during the analysis. Such approach was adopted due to very high computuational demands necessary for implemanting an elasto-plastic material model. It was decided to first validate the temperature distribution with a simple material model and than to continue research with more complex material models.

Table 1. Maximum equivalent stresses on the rim surface

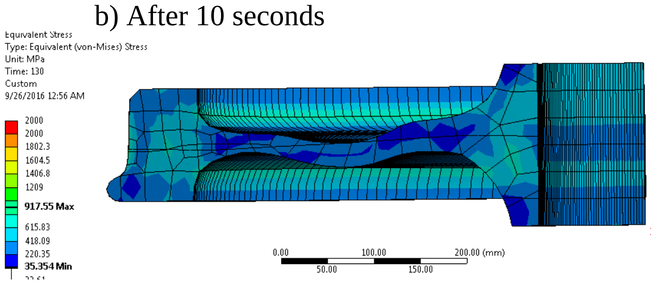
Time, s	Maximum equivalent stresses, MPa
5	1750
10	1599
30	916
60	335



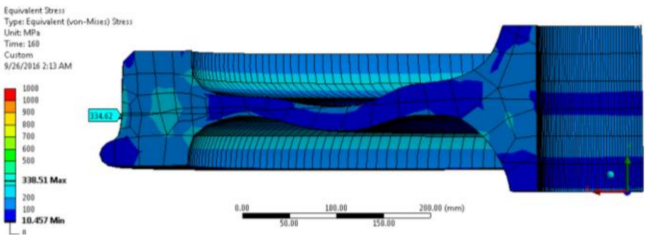
a) After 5 seconds



b) After 10 seconds



c) After 30 seconds



d) After 60 seconds

Figure 6. Equivalent stress field due to the quenching process of rail wheel after 5, 10, 30 and 60 seconds

6. CONCLUSIONS

It is possible to simulate residual stress occurrence with modern simulation tools. The direct coupled finite element analysis enables extraction of temperature and stress results in all time points of the process.

The results revealed that the stress field is highly sensitive to the variable thermal loads. Therefore, this factor significantly affects the stress field of rails during the quenching process.

The results of temperature distribution shows that temperature in the hub and rim centers are much higher than in the plate which correspond to realistic scenario of wheel quenching.

The results of the equivalent stress shows that their values are unrealistic if linear characteristic material is used.

Future research should be done with non-linear material characteristics that would lead to realistic values of residual stresses.

ACKNOWLEDGEMENT

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '16

COMPARASION OF CLASSICAL BRAKE FOR FREIGHT WAGONS WITH THE NEW INTEGRATED BOGIE BRAKE IBB 10 FOR FREIGHT WAGONS

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Erdinč RAKIPOVSKI[2]
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Abstract *– The introduction of integrated (compact) bogie brake systems has opened a new chapter of improvements in freight wagon performance, efficiency, reduction of weight and noise, simpler installation, reduction of installation space, lower operating costs and reduced maintenance. Because of all these benefits from using integrated bogie brake systems, many producers of railway brake equipment have developed their own compact brake systems. In this paper will be described a comparison of classical (conventional) brake system and the integrated bogie brake system type IBB 10 from the railway brake equipment producer Wabtec MZT.*

Keywords – railway, bogie, brake, freight, wagon.

1. INTRODUCTION

As freight operators focus on the need for greater improvements in efficiency and safety, there is a significant need for advances in wagon brake systems. The use of integrated bogie brake systems is allowing freight operators and maintainers to benefit from higher network capacity and reduced maintenance costs. These advanced bogie brake systems that include integrated brake cylinder, slack adjusters and parking hand brake are adding to these benefits through additional capacity improvements, significant safety improvements for operators and maintainers and optimized life cycle costs [1].

The aim of this paper is to make direct comparison of classical (conventional) bogie brake system for freight wagons and the integrated bogie brake type IBB 10 in terms of efficiency, weight difference and brake shoe (block) wearing.

2. CLASSICAL BRAKE FOR FREIGHT WAGONS

The most common classical (conventional) brake system for freight wagons (excluding all of the pneumatic units), consists of one brake cylinder, one slack adjuster, pull rods, brake riggings, brake triangles, hangers, brake shoe holders and brake shoes. The description of the classical brake system is shown in fig. 1 and the schematic view of this system is shown in fig. 2.

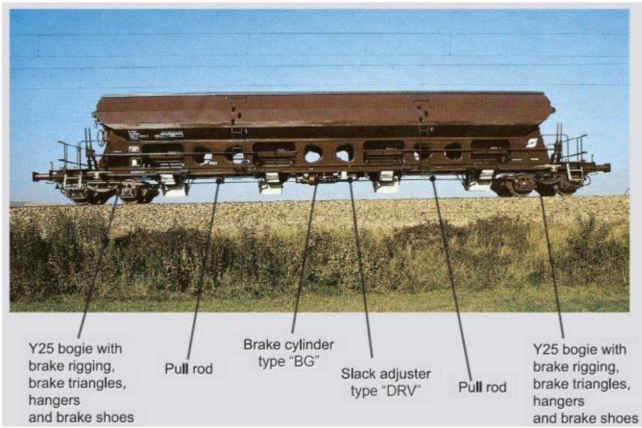

Fig.1. Description of classical brake system

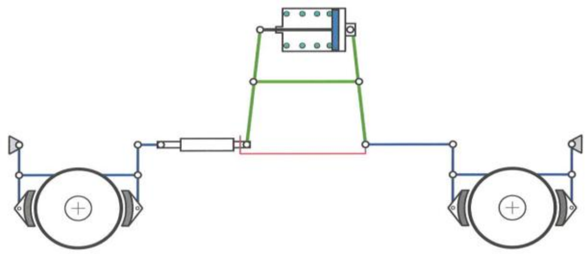

Fig.2. Schematic view of classical brake system

The simplicity of the classical brake system has made this brake equipment dominant in the freight market worldwide until the arrival of compact integrated bogie brake systems.

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3. INTEGRATED BOGIE BRAKE SYSTEM TYPE IBB 10

The patented integrated bogie brake type IBB 10 was developed for freight wagon application. It is the lightest brake on the railway market so far [2].

The invention in general relates to the area of braking devices for railway vehicles, and regards especially to bogie brake devices and slack adjusters for the use with bogie brake devices. Braking devices are used for the realization of braking of railway vehicles by introducing of air under pressure into the relevant cylinder chamber. Through a system of levers and slack adjusters the created force in the brake cylinder is intensified and transferred directly onto the wheels of the bogie [3].

This design enables easy assembly and disassembly of each component separately, which is a big advantage taking into consideration overhauling and maintenance of the system. The assembly of IBB 10 is located between the bogie wheels and it fits the standard interfaces of Y25 bogie family. Its function is to provide equal braking force application simultaneously on four wheels. The design is based on the use of a brake cylinder as an executive unit with (or without) hand brake application and two double-acting slack adjusters for automatic gap regulation between all four wheels and brake shoes [2]. The air pressure in the brake cylinder creates a force which is intensified and transferred to the slack adjusters by levers, and equal force is transmitted to the primary and secondary beam from which the brake shoe holders apply the braking force on the wheels through brake shoes (blocks).

On one bogie can be assembled one IBB 10, and because the most common variant is one wagon to have two bogies, usually total of two IBB 10 are needed per wagon as a set. Because each wagon needs to have the function to be parked in stationary position when it is removed from the train composition, at least one IBB 10 needs to have a parking hand brake. Because of different types of wagons, two types of hand brake systems were developed by Wabtec MZT - platform hand brake (when the activation is done from the platform of the wagon) and side hand brake (which is assembled on the bogie and activated from lateral side of the wagon).

On fig. 3 is shown the integrated bogie brake type IBB 10 without hand brake.

On fig. 4 is shown the integrated bogie brake type IBB 10 with platform hand brake. It has the same function as IBB 10 without hand brake with addition of manual hand brake application from the platform of the wagon. The platform hand brake mechanism should be connected with telescope cardan shaft and hand wheel, which is operated from the platform of the wagon from longitudinal direction. The hand brake activation is realized by rotation of the hand wheel and this torque is transferred onto the spindle of the hand brake mechanism by the telescope cardan shaft. The hand brake mechanism consists of system of levers which activate the brake cylinder by rotation of the hand brake spindle. With the activation of the brake cylinder the braking function occurs just like in service braking.

On fig. 5 is shown the integrated bogie brake type IBB 10 with side hand brake. It is very similar with IBB 10 with platform hand brake, with only difference that the hand brake application is realized from the ground and from the lateral sides of the bogie. Because the hand brake activation needs to be operated from each side of the wagon, a gearbox needs to be installed on the body of the bogie, which will cause the hand brake application to be realized by rotation of the hand wheel in the same direction from both sides (usually rotation in clockwise direction). The hand wheels from each side need to be connected to the gearbox and in the same time connected to the spindle of the side hand brake mechanism with telescope cardan shaft.

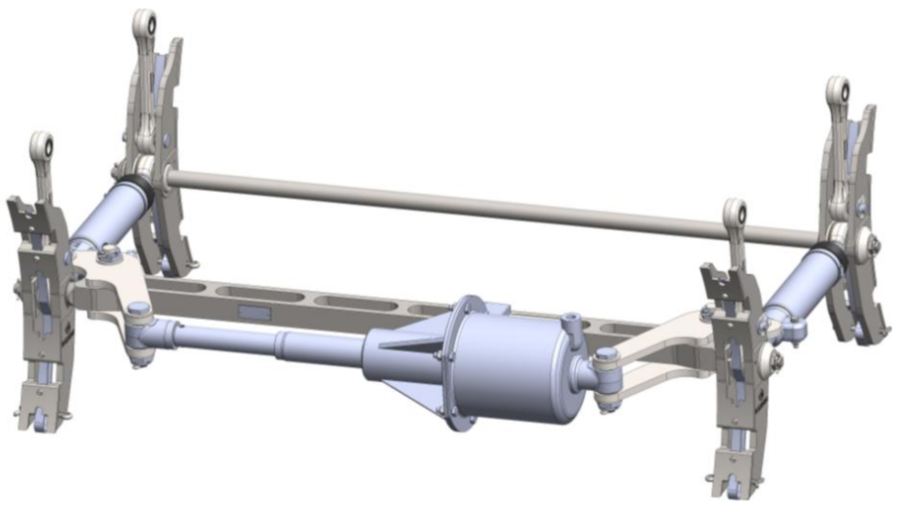

Fig.3. IBB 10 without hand brake

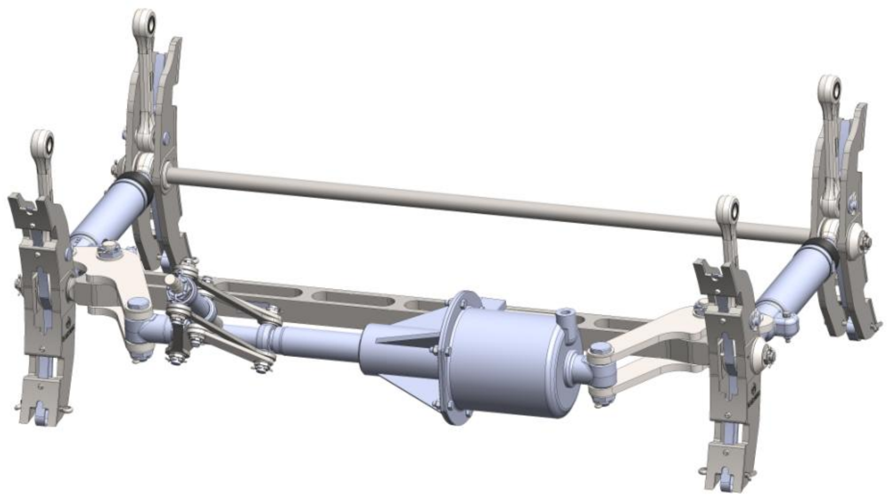

Fig.4. IBB 10 with platform hand brake

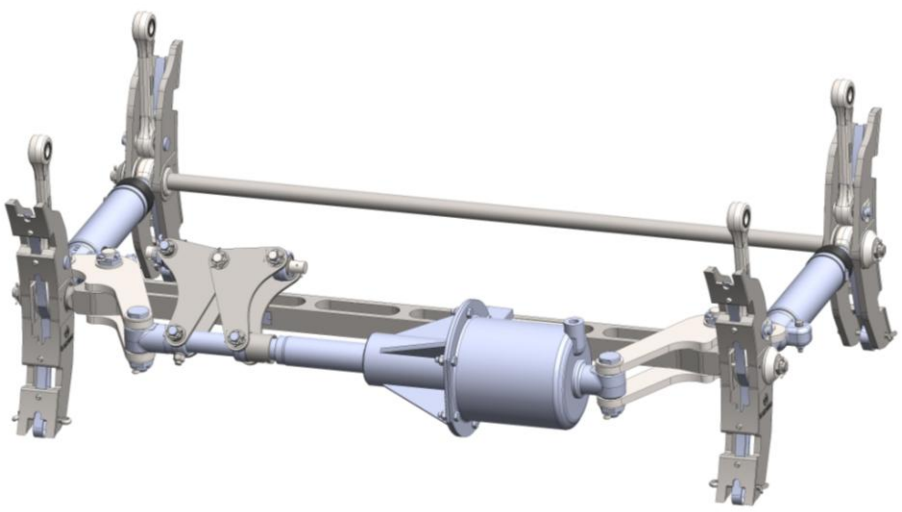

Fig.5. IBB 10 with side hand brake

4. COMPARISON OF CLASSICAL BRAKE AND IBB 10

In order to evaluate the benefits from using integrated bogie brake in freight wagons, a direct comparison has to be done in terms of weight, efficiency and wear of brake shoes difference.

In tab. 1 is shown the weight difference between the classical brake and set of IBB 10 per one wagon for different type of wagons.

Table 1. Weight difference between classical brake and IBB 10

Type of wagon	Weight of classical brake (kg)	Weight of IBB 10 set (kg)	Weight difference (kg)
Tanoos wagon	1070	400	670
Feldbinder wagon	1260	400	860

From tab. 1 can be noticed that that the savings in weight for Tanoos wagon is 670 kg per one wagon and for Felbinder wagon is 860 kg per one wagon. This means that wagons with IBB 10 can allow higher network capacity by this weight difference.

On fig. 6 is shown static efficiency comparison between classical brake system and the IBB 10. It can be easily noticed that the efficiency in classical brake systems is in relation with the brake cylinder pressure. The efficiency increases with the increase of brake cylinder pressure. However, even for the highest allowed pressure of 3,8 bar, the efficiency is much less than the efficiency of the integrated bogie brake type IBB 10. Also, the decreasing efficiency for classical brake over time is highly evident.

On fig. 7 is shown brake shoe (block) wear comparison between classical brake and IBB 10. The wearing pattern for IBB 10 is linear over time, whereas for the classical brake the wearing decreases over time due to reduction of the brake efficiency.

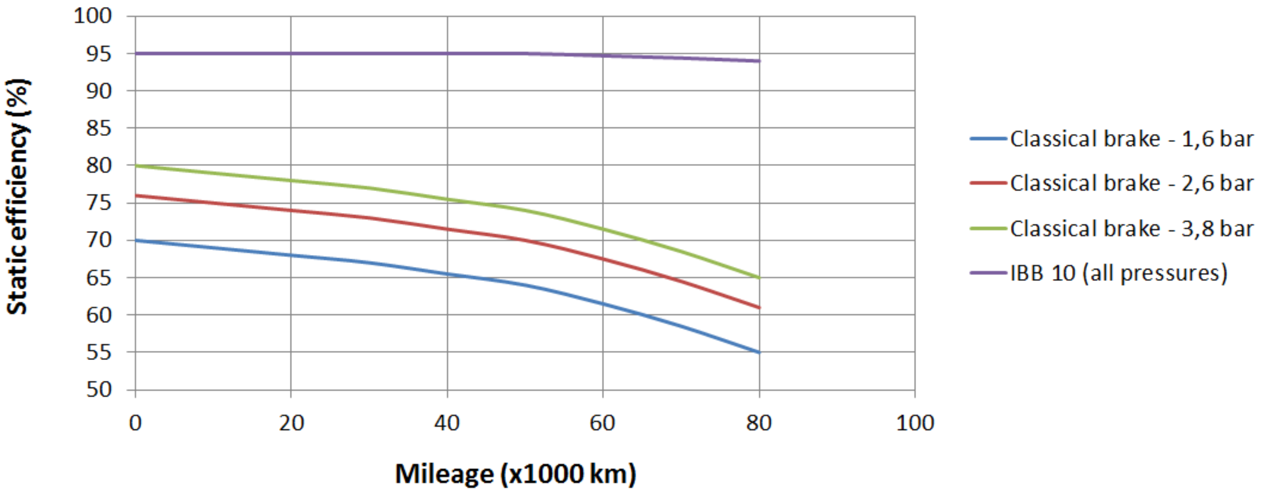

Fig.6. Static efficiency comparison

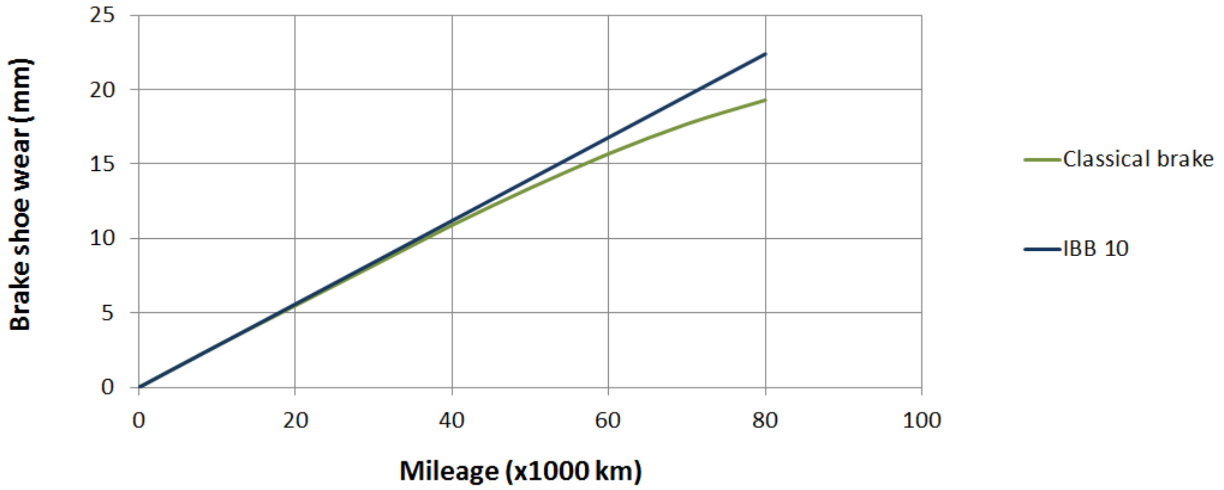

Fig.7. Brake shoe wear comparison

5. CONCLUSION

From all of the data analysis made in the comparison of classical and the integrated bogie brake type IBB 10, we can conclude that there many benefits for freight operators and maintainers in terms of additional capacity improvements and optimized life cycle costs. Because of all of these improvements implemented in integrated bogie brakes, there is very large increase in the popularity of these type of bogie brakes and in near future is expected most of the brakes for new freight wagons to be realized with integrated bogie brakes.

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Traffic and Transport

MAINTENANCE OPTIMISTATION OF CAPILLARY RAILWAY NETWORK WITH CLUSTERING METHOD

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Abstract – *Maintenance optimisation of railway infrastructure includes several kinds of aspects, such as safety, economic, operational, organisation and regulatory issues. Among them the regulatory issues are not possible to change and they increase a lot the maintenance costs. This is especially true on the local regions railway network – capillary network – where only freight transport exists. Hence, the question is how to respect regulatory issue and make optimisation of maintenance? To solve this problem we propose clustering approach. The idea is to cluster tracks, considering elements of railway infrastructure as attributes. Once railway tracks are clustered in groups with similar attributes, then the maintenance can be organized more efficiently. Minimum sum of squares clustering and variable neighbourhood search heuristic are used as model and solution method respectively. Based on the results of clustering and available real and simulated data we report 22% savings in maintenance schedule for clusters.*

Keywords – Maintenance, railway infrastructure, optimization, minimum sum of squares, variable neighbourhood search.

1. INTRODUCTION

In this paper we take into account regulatory issues as one of really important aspect of railway maintenance optimization. The regulatory issues are fixed, and national safety railway law defines them as national safety rules, standards and internal rulebooks of the railways companies. This chain increases the maintenance costs significantly. This is especially true in so-called capillary networks (local regional railway networks), where only the freight transport exists.

The question is how to respect regulatory issue and make optimisation of maintenance? To solve this problem, we propose a clustering approach. The idea is to cluster tracks, considering elements of railway infrastructure as attributes. Once railway tracks are clustered in groups with similar attributes, then the maintenance can be organized more efficiently. In this paper, Variable Neighborhood Search (VNS) metaheuristic is developed to solve minimum sum of squares clustering problem. We used eight methods such as: k-means, k-means+, h-means, j-means, VNS: j-means, VNS: j-h-k-means, Variable Neighborhood Descent (VND): k-h-means and VND: Nested j-h-k-means. Based on the results of clustering and available real and simulated data we report 22% savings in maintenance schedule for clusters.

2. ATTRIBUTES FOR CLASSIFICATION

Clusters analysis groups data objects based only on information found in the data that describes the object and their relationships. The goal is that the objects within a group be similar (or related) to one another and different from (or unrelated to) the objects in another groups. The greater similarity (or homogeneity) within a group and the greater difference between the groups, the better or more distinct the clustering. According to this, we have been chosen some attributes which also present the important elements of railway infrastructure.

Namely, after comparing several rulebooks for the maintenance of railway infrastructure for the speed under 40km/h and taking into account leaflet of

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International union of railways (UIC) for Classification of lines for the purpose of track maintenance, we found out that exists only three attributes as parameters for definition the volume of the maintenance: traffic loads, speed and axle-loads.

European commission adopted on 2015 regulation EU 2015/909 on the modalities for the calculation of the cost that is directly incurred as a result of operating the train service, whereas: A need for accelerated renewal or maintenance resulting from a more intense use of the network may be taken into account for the purposes of calculation of direct costs, provided it is ensured that only costs directly incurred as a result of operating the train service are included; Infrastructure managers are under the obligation to operate networks whilst they face restrictions hampering efficient management and cost control [1].

In according to previous statement European commission defined parameters which may allow the infrastructure manager to modulate the average direct unit costs to take into account the different levels of wear and tear caused to the infrastructure according to one or more of the following parameters: train length and/or number of vehicles in the train; train mass; type of vehicle, in particular its unsprung mass; train speed; traction power of the motorised unit; axle weight and/or axle numbers; recorded number of wheel flats or the effective use of equipment to protect against wheel slips; longitudinal stiffness of vehicles and horizontal forces impacting on the track; consumed and measured electric power or the dynamics of pantographs or contact shoes as a parameter to charge for the wear and tear of the overhead wire or the electric rail; track parameters, in particular radii; any other cost related parameters where the infrastructure manager can demonstrate to the regulatory body that values for each such parameter, including variation to each such parameter where relevant, are objectively measured and recorded.

Based on this knowledge, we got the idea to try with huger specter of the attributes which are also exists in the rulebooks. Usually, the rulebooks are divided in several chapters for the maintenance, whereas: preventive maintenance of tracks, preventive maintenance of construction works, preventive maintenance of track ballast, preventive maintenance of signalization facilities, preventive maintenance of catenary, preventive maintenance of power equipment of electrified lines, preventive maintenance of electric power installations, and preventive maintenance of telecommunications facilities.

In this case we take into account follows attributes: length of track, train speed, number of the trains, traffic load, traffic load of dangerous goods, type of traffic, axle load, integrated functional safety, age and quality, alternative route, time constrains, type of track, type of sleepers, and type of switches. In total we consider 14 attributes for generated data and 5 for real data. For real data attributes are: Traffic load, train speed, number of trains, number of trains with dangerous goods and traffic load dangerous goods.

The data are generated on real parameters, for example: train speed is taken from the network statement of Dunkerques port [2], as volume of the traffic load, and traffic load of dangerous goods [3]. The age of the switches is max 30 years [4]. Average rail age: 4,4 - 39 years [5].

3. TABLES, CLUSTERING APPROACH

Cluster analysis or clustering is the task of grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar (in some sense or another) to each other than to those in other groups (clusters). It is a main task of exploratory data mining, and a common technique for statistical data analysis, used in many fields. Clustering is a powerful tool for automated analysis of data.

Among many criteria used for cluster analysis, the minimum sum-of-squares is one of the most popular since it expresses both homogeneity and separation. Minimum sum-of-squares clustering (MSSC) consists in partitioning a given set of n entities into k clusters in order to minimize the sum of squared distances from the entities to the centroid of their cluster. A mathematical programming formulation of MSSC is as follows:

$$min_{\omega,z} \sum_{i=1}^{n} \sum_{j=1}^{k} \omega^{i,j} \left\| X^i - z^j \right\|^2 \quad (1)$$

Subject to:

$$\sum_{j=1}^{k} \omega^{ij} = 1, \forall i = 1, \dots, n \quad (2)$$

$$\omega^{ij} \in [0,1], \forall i = 1, \dots, n \quad (3)$$

The n entities $\{0^1, 0^2, \dots, 0^n\}$to be clustered are at given points $X^i = (X_r^i, r = 1, \dots, s) \in \mathbb{R}^s \ \forall i = 1, \dots, n$; k cluster centers must be located at unknown points $z^j \in \mathbb{R}^s \forall j = 1, \dots, k$; the norm $\|.\|^2$denotes the Euclidean distance between the two points in its argument, in the s-dimensional space under consideration. The decision variables ω^{ij}express the assignment of the entity 0^i to the cluster j. Regarding computational complexity, minimum sum-of-squares clustering in the Euclidean metric for general values of k and s has been shown as NP-hard [6].

We applied clustering approach on 75 elements, which are in this case trucks, with generated network. For making the generated network we used the spanning tree algorithm. And for real data, the network has 11 elements (trucks).

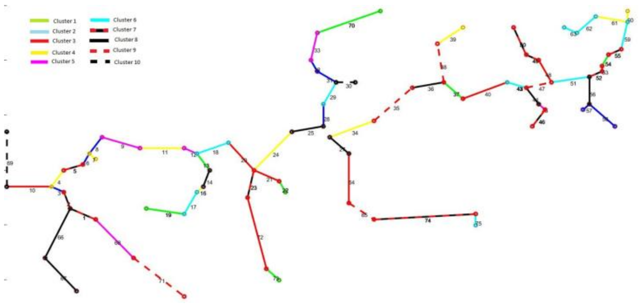

Fig.1. Clustering solution for the 75 elements' set

4. METHODS FOR CLASSIFICATION

VNS is a metaheuristic, or a framework for building heuristics, first time proposed by Mladenovic and Hansen (1997) [7]. It is based on the systematic exploration of different neighborhood structures within a local search routine. There is a change of neighborhood each time when the local search algorithm stops (i.e, when the local optimum is reached). This avoids the algorithm to be trapped, given that a local optimum may not remain optimal for another neighborhood structure [8, 9]. VNS is a flexible framework for building heuristics to solve approximately combinatorial and global optimization problems. It exploits systematically the possibility of changing the definition of neighborhood structures within the search for a globally optimal (or near-optimal) solution. VNS is based on the following simple observations: (i) An optimum for one neighborhood structure is not necessarily optimal for another neighborhood structure; (ii) a global optimum is a local optimum with respect to all neighborhood structures; and (iii) empirical evidence shows that for many problems, all local optima are relatively close to each other. The first property is exploited by using increasingly complex moves in so-called Variable Neighborhood Descent (VND) in order to find local optima. The second property suggests using more neighborhoods if the local optima found are of poor quality. Finally, the third property allows, once a local optimum is reached, to exploit this information to find a better local optimum in its vicinity.

5. RESULTS OF CLASSIFICATION EQUATIONS

The eight local search methods (e.g. K-means, K-means+, H-means, J-means, VNS: J-means, VNS: J-H-K-means, Variable neighborhood descent (VND): K-H-means and VND: Nested J-H-K-means), are compared on the basis of equivalent CPU times, i.e., each local search heuristic is restarted until a given time elapses.

Clustering was done with 75 elements (75 tracks) and tested between 5 to 10 clusters. All methods are re-run (multi start) many times within the same cpu time t_{max}. All heuristics are coded in FORTRAN 77 and run on a zHPnotebook core i7 45104, 8Go RAM, 256 Go SSD.

The best result is with 10 clusters. Numbers of elements (tracks) in clusters are 2, 5, 8, 9, and 10.

6. MODELING FOR PERIODIC MAINTENANCE

In the last part of this paper, we will apply our clustering approach to scheduling maintenance problem. Reason why we decided to apply on the problem of scheduling maintenance is because in scheduling exist time limitation when you have to do maintenance. To determine maintenance schedule such that total costs are minimized. The cyclical scheduling maintenance activities under a certain given cost-structure assuming a fixed cycle length [10].

In a such problem, it is also assumed that there is a number of machines m (or infrastructures) and a time interval *T*. During each period of the time interval *T*, at most k machines can be serviced. When machine *i* is serviced, a given non-negative servicing cost of b_i is incurred, regardless of the period. In each period *t*, a machine *i* not yet serviced is in operation; this incurs an operation cost of $a_i \times g_i(t)$, where a_i is a given positive integer, and $g_i(t)$ is the number of periods elapsed since the last servicing of the machine *i*. The problem is now to determine a maintenance schedule such that total servicing costs and operating costs are minimized.

Based on the results of clustering and available data we determine optimal maintenance schedule for clusters (which present the groups of tracks with similar attributes) over 24 time period horizon. At each time period at most one cluster can be serviced. For any cycle, all the clusters must be serviced at least once. In period k × n + t (k ∈ Z, t ∈ T), the same cluster as was serviced in period t will be serviced again (n-number of periods (24), K=1, ... i). To each cluster is assigned maintenance cost with different sceneries.

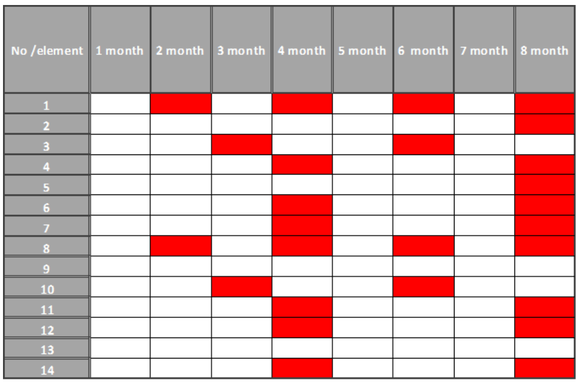

Fig.2. Maintenance schedule before clustering

The maintenance cost is calculated as $a_i \times j_i(t)$, where a_i is a given positive integer, and $j_i(t)$ is time elapsed since from the last service of cluster i. The objective is to find schedule that minimizes the total cost!

For the real data, we have information about the maintenance costs. Thereare 14 elements (tracks) and a period of 8 months. First schedule of the maintenance is presented in Figure 2 and it is done for all elements separately. The maintenance cost, of this schedule, was 18 082 (Unit of costs). After applying cluster approach to the 14 elements, we get 4 clusters. For these 4 clusters, we get a new schedule for the maintenance activities, as in Figure 3. Now, the maintenance cost is 14 710 (Unit of costs). We get a saving of 22% of the total cost.

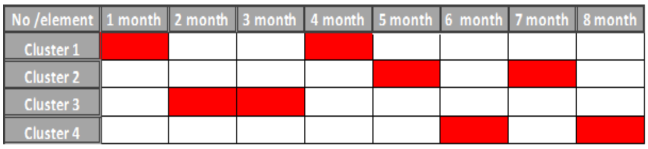

Fig.3. Maintenance schedule after clustering

7. CONCLUSION

This paper presents a clustering approach for the maintenance of a capillary railway network. The idea is to cluster tracks, considering elements of railway infrastructure as attributes. Once railway tracks are clustered in groups with similar attributes, then the maintenance can be organized more efficiently. We develop a mathematical model for the minimum sum of squares clustering problem. We use Variable Neighborhood Search (VNS) metaheuristic to solve it. Finally, based on the results of clustering and available real and simulated data, we compare two situation of the preventive maintenance scheduling problem (PMSP), first without clustering and the second with clustering. We report 22% savings in maintenance scheduling cost for clusters.

As main conclusion, we could notice that the clustering is beneficial, we save on costs, it is possible for the case of the capillary railway network and we develop a VNS metaheuristic to solve it. By this approach, we present a new direction of the maintenance philosophy in railway system. This approach takes not only into account the rail infrastructure characteristics but also the maintenance parameters, maintenance strategies, the organizational issues and regulatory ones. The research reported in this paper was concentrated on a specific organization working in railway maintenance.

ACKNOWLEDGEMENT

If the paper is done within a framework of a project it is necessary to provide the name of the project and the institution that provided the funding at the end of the paper.

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IMPLEMENTING THE GOOGLE MAPS API TO IMPROVE VEHICLE ROUTING PROBLEM: DISTANCE/TRAVELTIME MATRIX

Teodor Berov [1]

Abstract – *This article presents the possibilities of applying the Google Maps™ network data for the vehicle routing problems (VRP) - road distances and travel times for urban areas. This data can be used for "what-if" analysis in systems aimed at generating optimized vehicles routes, related to possible changes to input parameters such as vehicle capacity, maximum driving shift time, seasonal variations of demand, network modifications, etc. The proposed approach copes with route scheduling and the distribution of cargo units from the distribution center (Intermodal Terminal) to geographically dispersed customers in urban areas by a fleet of vehicles.*

Keywords – VRP, Google Maps API, Intermodal Transport.

1. INTRODUCTION

Effective distribution is the main target of the companies, that striving for excellent customer service with minimal investment and operational costs. Therefore, vehicle routing and scheduling is an important problem. The costs related to transportation operations constitute a significant part of logistics costs for most firms: fuel consumption, personnel wages, equipment acquisition, maintenance and others.

The base characteristic of Intermodal Transport Chain (ITC) is the integration of more than one transport mode into a transport chain. In regional intermodal system (Fig. 4), there are three main parts, which form the transport chain: road transport (for first mile picking and last mile delivering), rail part and transshipment. The rail part is a quite fixed part, which has stable delivery frequency and time schedule, with low cost and high capacity.

The Vehicle Routing Problem (VRP) is a well-researched problem in the Operations Research. The VRP consists of designing vehicle routes of least total cost and: each starting and ending at the depot, such that each customer is visited exactly once; the total demand of any route does not exceed the vehicle capacity, and the length of any route does not exceed a preset maximal route length. Although using road distances (instead of air distances) doesn't impact the NP-hard nature of a VRP much, it does result in a few extra challenges.

An important property of real-world street networks is the availability of many multiple routes between points. Routing algorithms [4] to find the optimal route between points may be used, and each journey may have criterion such as time, distance and predicted emissions. When multiple routes exist, some routes may have differing criterion.

In recent years, has seen an increase of the availability of online Graphical Information Systems. The three most commonly used are Google Maps™, Microsoft Bing Maps, Open Streetmap Project [3] and OpenRailwayMap [8] for Rail Transport. All of these systems allow the user access to street network data. With access to the street network data, additional information about the journeys is available, such as individual roads and average speeds and distance for each journey segments.

The aim of this document is implementing the Google Maps™ and Google Maps Api for the calculation of distance/traveltime matrices for VRP.

2. PROBLEM DESCRIPTION

The term Regional Intermodal Transport refers to a combined transport system, which includes at least two different transport modes in regional distribution. The modern regional intermodal transport management not only focuses on goods transport and logistics, but also concentrates on responses from marketing and business strategy.

For effective distribution, the shipper and distributor can make a process of the analysis for regional intermodal transport. In this process, many elements could be taken into account, such as regional transport policy, the design of transport network

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(nodes, route, terminals, etc.) and transport mode choice.

Obtaining better solutions for real-world VRP's requires a thoroughly elaborated data basis. Even the best solution techniques are of no use for practical applications. Essential input data for real-world routing problems by using Geographic Information Systems (GIS) is gathered. Whereas most researchers use Euclidean distances between customers and depots for their optimization algorithms, a GIS can provide real distance information derived from a digital road network.

In terms of the urban environment, in the calculations must take into account the specific characteristics of: one-way streets, intersections-signalized or un-signalized, banned turning or movement and/or reverse bends, etc.

In general, there are a few basic conclusions when are analyzing urban movements:

- Transport cost C_{ij} between two points (i,j) is directly proportional to: time in congestion (tc_{ij}); distance (d_{ij}); constant factor (F_k), which is defined by some fixed parameters;

- Inversely proportional to the travel speed (V_{ij}).

$$C_{ij} = f\ \{F_k,\ d_{ij},\ tc_{ij},\ (1/V_{ij})\ \}, \qquad (1)$$

The throughput of the streets is a function (and depends on) of time interval of the day. The whole time interval will be divided conditionally on $\boldsymbol{T}$ time zones with constant characteristics. The obtained solution is a sequence of typical points $\boldsymbol{V'}=\{0,1,2,..,\boldsymbol{n}\}$, and arcs $\boldsymbol{E'}$ between the points $\boldsymbol{V'}$, forming part of the street network. A point $\boldsymbol{i} \subset \boldsymbol{V'}$ is characterized by coordinates $\{lat,\ long\}$. Between two adjacent points $\boldsymbol{i}$, $\boldsymbol{i}+1$ is limited arc with length $\boldsymbol{l}(\boldsymbol{e}_{i,i+1})$, km. For each arc have average speed $\boldsymbol{v}(\boldsymbol{e}_{i,j},\boldsymbol{\tau})$, $\boldsymbol{\tau}=1...\boldsymbol{T}$, km/h, in the moment of time $\boldsymbol{\tau}$, where $\boldsymbol{\tau}$ – discrete time (specifying the number of time intervals). The number of the intervals $\boldsymbol{\tau}$ is defined as a function of time $\boldsymbol{\tau}=\boldsymbol{\tau}(\boldsymbol{t})$, where $\boldsymbol{t}$ – the current time. The arcs $\boldsymbol{e}_{i,i+1}$ represent elements of the street network, including and intersections. Let $\boldsymbol{K'}=\{0,\ 1,\ ..,\ k\}$ are points of $\boldsymbol{V'}$, belonging to the intersections. The travelled distance and time can be expressed:

$$l_{0n} = \sum_{i=0}^{n-1} l(e_{i,i+1})\ ,км \qquad (2)$$

Where l_{0n} – traveled distance between two vertices of the street network; $l(e_{i,i+1})$ – length of arc between points i , i+1.

$$t_{0n}^{време} = \sum_{i=0}^{n-1} \frac{l(e_{i,i+1})}{v(e_{i,i+1},\tau)} + \sum_{j=0}^{k} t_j^{зак}\ , min \qquad (3)$$

Where $t_{0n}^{време}$- traveled time between two vertices of the street network; $l(e_{i,i+1})$ – length of arc between points i , i+1; $v(e_{i,i+1},\ \tau)$ – traveled speed for the arc between points i , i+1 and time interval τ; $t_j^{зак}$ – delay time for the specific item j, (for example intersection).

3. A PROPOSED GOOGLE MAPS API BASED FRAMEWORK

Google Maps™ is a desktop web mapping service developed by Google. It offers tree main services (for VRP problems): Users can search by location. Users can ask for directions (i.e. driving, public transport, etc.); Users can add their own data to the card, but only through API (**A**pplication **P**rogramming **I**nterface) for Google Maps.

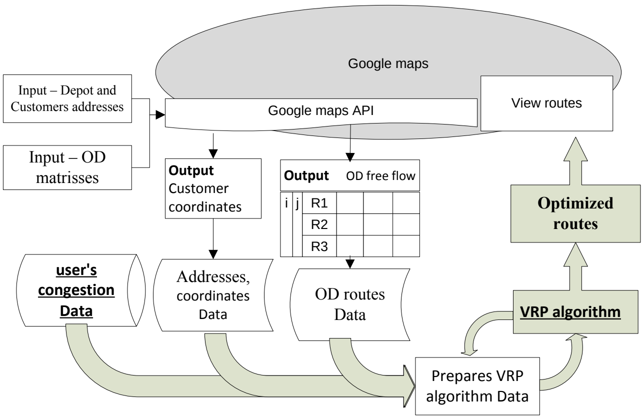

Fig.1. Component diagram of the approach for using the Google Maps API for VRP

Google developed the Google Maps API (GMApi) to access the resources of technology [7].

Some advantages are - Open-source software (available at http://code.google.com/); Very detailed road network; Intuitive vehicle routing: Preference for freeways/arterials, Includes roadway characteristics in "free-flow" travel time calculations; Additional features allow for selecting customers and plotting routes; etc.

The GMApi offers good directions for routing point (x, y), and offer multiple waypoints and TSP optimization [5].

Google maps offers the Distance Matrix API method which, given a set of multiple starting locations and multiple ending locations, returns a matrix of distance and estimated travel time between each. [6]. The Google Maps Distance Matrix API is a service that provides travel distance and time for a matrix of origins and destinations. The information returned is based on the recommended route between the start - end points, as calculated by the Google Maps API, and consists of rows containing duration and distance values for each pair.

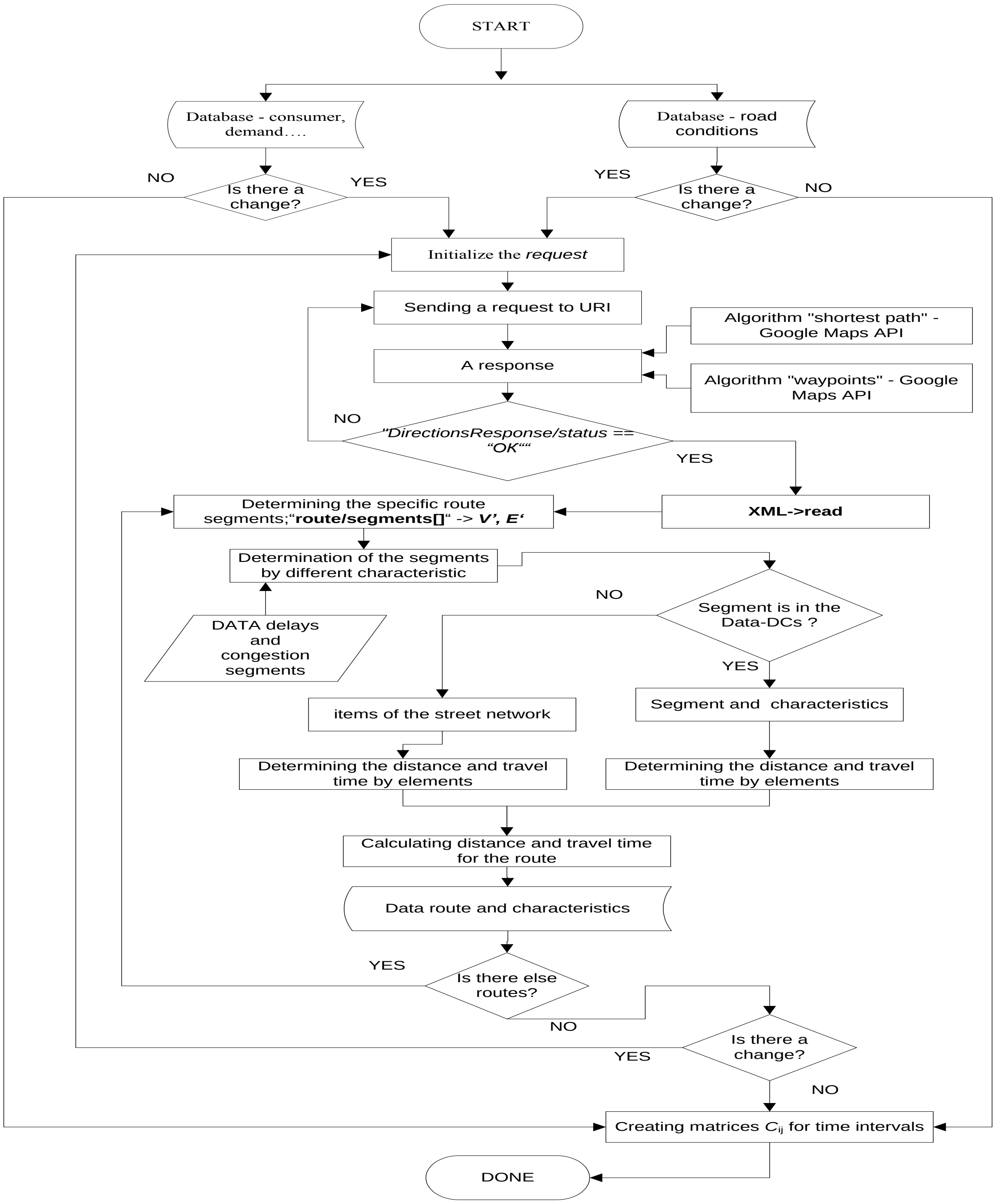

Fig.2. Flow Chart for the System

In this article is not used the Distance Matrix API method.

Interfacing with the Google Maps API

By using the appropriate programming language is applied mainly:

- URL -> WebRequest;

-If there is a response – ("DirectionsResponse/status == "OK"");

- Extract the required information from the response (json, xml).

In response of the query for routes between two vertices of the street network can receive up to three possible routes (figure 1).

Due to the fact that they are "free-flow", by using an appropriate algorithm can be determined the duration of trip for different time intervals.

For example, figure 3 shows the response to a request "Directions": (http://maps.google.com/maps/api/directions/xml?origin={0}&destination={1}&sensor=false", origin, destination) between two points of the urban street network respectively with coordinates (42.7153614, 23.2769640) and (42.7181967, 23.3143616). When using the appropriate API function is receive a response – distances and free-flow travel times:

- route 1 5.6 км. 9 min. ul. "Adam Mickiewicz" end ul. "Khan Kubrat";
- route 2 5.0 км. 9 min. bul. "Slivnitsa";
- route 3 6.1 км. 10 min.bul. "Slivnitsa"

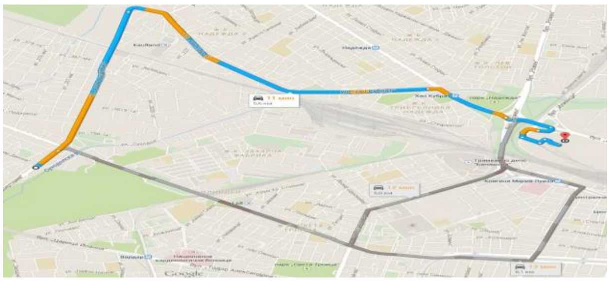

Fig.3. Roads between two points obtained from

Thus the proposed routes typically have different travel time depending on the different time intervals. The analysis of the results found that the differences come mainly from delays at intersections and areas where travel speed is reduced, unaccounted from this version of the API function. This requires an approach for determine the predicted travel time for the street network depending on traffic [1].

It should be noted that is also provided option for preparing a travel time depending on the traffic (*durationInTraffic*) in *URL -> WebRequest*. This feature is particularly useful for VRP tasks, but is available only for "*work*" users.

4. CONCLUSION

The problem of distributing – collecting of cargo, viewed here, is described as a variant of VRP in which a truck visits up possible nodes until return to terminal.

Composition: The process of assembling and consolidating freight at a terminal that offers an intermodal interface between a local distribution system and a regional or long-distance distribution system. In a business logistics, it refers to the "first mile" which assembles loads of freight from different suppliers.

Decomposition: When reaching a terminal close to its destination, a load of freight has to be fragmented and transferred to the local freight distribution system. Commonly referred as City logistics, also known as the "last mile", and often represents one of the most difficult segments of distribution.

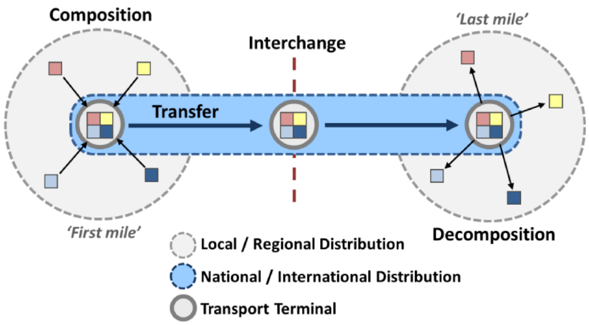

Fig.4. Typical structure of ITC [2]

In this paper, the aim is to construct reliable and efficient routes by means of the realistic travel distances and times for urban street network. The proposed model used Google Maps API, given the amount that the API will do (e.g. finding routes and allowing the visualisation of results).

This approach, by taking into account the specifics, may be applied to rail network by OpenRailwayMap.

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RAIL TRAFFIC FLOW OPTIMISATION BY KRONECKER ALGEBRA FOR IRISH RAIL

Andreas SCHÖBEL[1]
Jelena AKSENTIJEVIĆ[2]

Abstract *– Within the by H2020 founded project DESTination Rail, a task is dedicated to the development of a tool for rail traffic flow optimization in terms of maintenance work. On a single track line priority is set for as much work as possible to be done in one time slot between two trains. Sometimes, the timetable is even modified to allow more efficient maintenance work. On a double track line all traffic has to run over the remaining track, where typically a slow speed zone is established to protect working staff. For this bottleneck section, it is very important to have an efficient usage of capacity. Therefore, it is necessary to optimize the speed profile of approaching trains to let them pass the bottleneck section exactly at the allowed speed limit to keep occupation time as short as possible.*

Keywords – Kronecker algebra, rail traffic flow optimization, rescheduling

1. INTRODUCTION

Rail infrastructure managers are responsible for safety measures and investments within the infrastructure network. Their choices are usually not only based on poor data availability, but also on the visual assessment of infrastructure conditions. Unfortunately, there is enough evidence that visual analysis shows indications for needed actions very late in the deterioration infrastructure process, or not at all. Consequently, the objective of the EU project DESTination RAIL [1] is development of a Decision Support Tool, which relies on reliable data, for rational decision making of infrastructure managers to offer safer, reliable and efficient rail infrastructure. The idea of developing a flexible decision support tool enables possibilities to use it across a range of asset classes, such as: bridges, earthworks, tunnels, switches, and tracks. Rail traffic flow optimization represents a priority in cases of restricted network availability. It is a part of a four-step process, which infrastructure managers face in their decision-making processes. Namely, location and identification of risky assets before they fail, then real-time safety assessment of existing infrastructure; furthermore, evaluation of safety and assignment of scarce resources and finally, choosing the optimal rehabilitation techniques. Using Kronecker algebra, which showed good results in dealing with bottlenecks a case study for optimization of rail traffic flow during maintenance work at Boyne viaduct in Ireland (Fig.1) was conducted. Kronecker product and Kronecker sum form Kronecker algebra. The Kronecker product can be used to model synchronisation while Kronecker sum calculates all possible interleavings. The application of Kronecker Algebra enables a deadlock free railway operation [2].

Fig.1. Boyne viaduct, Irish Rail

2. RAIL TRAFFIC FLOW OPTIMISATION TOOL

The focus of this paper lays in the fourth stage of the flow optimization, namely, the analysis of the possible infrastructure maintenance or renewal strategies. Application of microscopic simulation of railway operations based upon a physical and mathematical model of the railway system is the state of the art in railway traffic operations. Such tools output indicators for the operational performance (e.g. delays). These have a series of shortcomings, most

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notably that optimisation is typically predefined by the user of the tool and introduced into the simulation. This common practice allows the user to find solutions for bottleneck management and planning of maintenance work. However, it often misses the opportunity to find the optimum solution. It is, therefore, not fully capable of solving dispatching questions or handling headway conflicts. To close this gap in future railway operation with increased traffic flow, algorithms have to be applied which consider all train runs at the same time. Within DESTination RAIL, microscopic simulation tool will assess the impact of maintenance and renewal proposals.

3. DATAFLOW MODEL

The input data used for the traffic flow optimization tool is defined by two components: first, the current characteristics of the rail system will be supplied. Second, the infrastructure manager will indicate a desired assessment of a change in the network. Those two components will be merged using simulation tool OpenTrack [3] for the visualization of the data, and further processed into the concrete syntax of the input files needed by the optimization tool. This workflow is shown in the Figure 2:

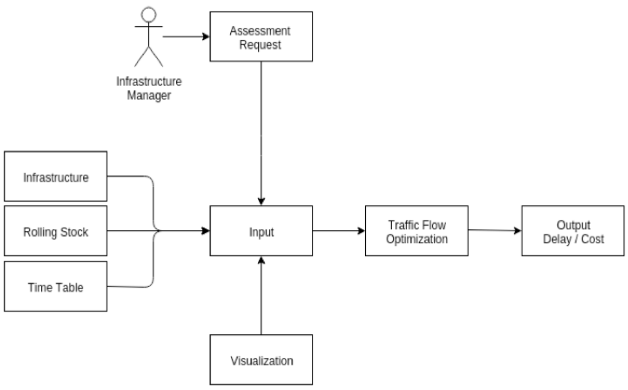

Fig.2. Dataflow model

As it can be seen in the Figure 2, in order for Traffic Flow Optimization process relying on Kronecker algebra approach to deliver Output data, a number of input data is needed. First, and most important, is the set of Infrastructure, Rolling Stock and Timetable characteristics, which represent the base of future calculations. Secondly, infrastructure manager's identification and assessment of consequences of whether it be restricted availability of infrastructure assets, of operational incidents.

4. DATA REQUIRED

The level of details and accuracy directly influences the quality of output. As it can be seen from the Figure 1, two types of sources are used for a complete input data. First represents the crucial elements for the operation of the railway network. Second, the desired change in the network must be indicated. These two components will be merged using lightweight visualization tool before being further processed into the concrete syntax.

4.1. Input Data: Infrastructure, Rolling Stock and Timetable

Infrastructure data comprises information about tracks and operation control points, as well as all related information. The rolling stock data concerns physical characteristics of trains that are part of the traffic system under consideration. The timetable data provides information about planned train routes and their associated time schedules.

4.2. Input Data: Infrastructure Manager Assessment Request

Infrastructure manager can analyze different possible changes in network. First, consequences of restricted availability of infrastructure assets can be assessed. The aim of this is to reduce the impact of restricted availability of infrastructure assets. The incident can be maintenance work on a given track section, which leads to a reduced speed limit for that section or on the neighbouring track, as a protection measure for the staff. Furthermore, consequences of operational incident can be assessed. An interruption event can be a result of the broken down train or unavailability of the track section due to external factors, for example, flooding of a bridge. For both above mentioned cases, the following data has to be provided by the infrastructure manager:

- affected track or track section (reference: infrastructure & timetable input)
- speed change [km/h]
- time period (begin [hh:mm:ss] – end [hh:mm:ss])
- thresholds for delays of affected trains [hh:mm:ss]
- costs of delay per minute for different train categories (regional, intercity, freight) and for the passenger transport information about differences in costs depending on the day of the week.

Finally, there is a possibility of assessment of benefits from infrastructure enhancement. Examples of infrastructure enhancement can be the construction of an additional cross over on a highly frequented line or construction of an additional bridge. The following data has to be specified by the infrastructure manager:

- location of the planned section and connections to existing tracks (reference: infrastructure input [track::id] and position on the track [meters])
- length of the planned section [meters]
- speed restriction on the selected section [km/h]
- gradient on the selected section (if changed) [‰]
- set of affected trains (reference: timetable)

costs of delay per minute for different train categories (regional, intercity, freight) and for the passenger transport information about differences in costs depending on the day of the week.

5. USE CASE OF IRISH RAIL

Within DESTination Rail project, Irish Rail network, more precisely, the Boyne Viaduct (shown in Fig.1.), is used as a case study for the development and analysis of a rail traffic optimization tool.

OpenTrack [3], a software for simulation of railway operations, offered visualization of railML input data by converting them into graphic representation of infrastructure (Fig.3), where Boyne Viaduct represents the test (maintenance work) zone between Drogheda and Dundalk, obtained from the Network Statement of the Irish Rail [4].

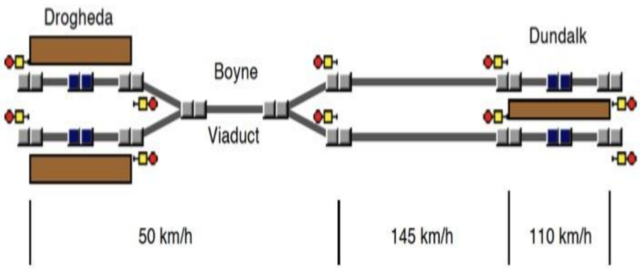

Fig.3. Infrastructure: Boyne Viaduct

Rolling Stock data includes IC and Cargo trains using class 201 and DART traveling only to Malahide. Finally, timetable data (only for passenger trains) is shown in Fig. 4.

		MON-SAT	MON-SAT	MON-SAT	MON-SAT	FRI ONLY	MON-SAT	MON-SAT	MON-SAT	MON-SAT
DUBLIN Connolly	Dep	07.35	09.30	11.20	13.20	14.45	15.20	16.50	18.50	20.50
DROGHEDA MacBride	Dep	08.09	10.06	11.56	13.56	15.27	15.54	..	19.28	21.28
DUNDALK Clarke	Dep	08.31	10.28	12.18	14.18	15.52	16.16	17.48	19.50	21.50

DUNDALK Clarke	Dep	06.59	08.00	09.15	11.47	13.47	15.20	16.05	17.20	19.20	21.20
DROGHEDA MacBride	Dep	07.20	08.22	....	12.08	14.08	15.41	16.30	17.41	19.41	21.41
DUBLIN Connolly	Arr	08.18	09.00	10.05	12.40	14.40	16.20	17.14	18.15*	20.15*	22.15*

Fig.4. Timetable: DUBLIN-DOGHEDA-DUNDALK

Figure 5 shows a train graph, whereas in Figure 6 the optimized train run is displayed, both presenting an output of Kronecker algebra use. Clearly, the optimized train runs do not run at the maximum allowed speed, since Kronecker algebra approach offers solutions for avoideance of deadlocks. Further information and detailed outline of the function of the Kroencker algebra can be find in [5]. The soulution offered by this approach shows the optimal way for passing bottleneck sections at exactly allowed speed and given time, in order to keep the occupation time at the given section as short as possible without unnecessary energy consumption due to, for example, braking for signal.

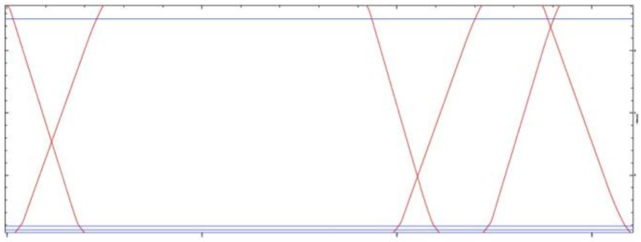

Fig.5. Output from Kronecker algebra: Train Graph

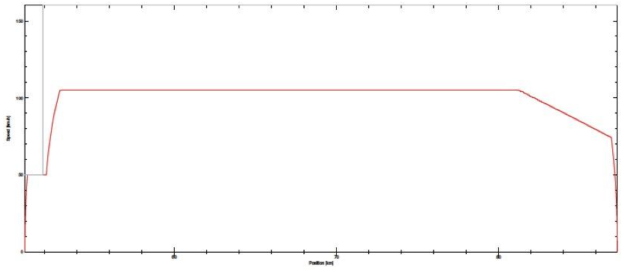

Fig.6. Output from Kronecker algebra: Optimised Train Run

Finally, Figure 7 lists delays and the energy consumption for all trains involved.

- T1 Train1 108000 400000 213 8 210 160 0.85 50786 87318
- T2 Train2 108000 400000 213 8 210 160 0.85 50786 87318
- T3 Train3 108000 400000 213 8 210 160 0.85 50786 87318
- T4 Train4 108000 400000 213 8 210 160 0.85 87318 50786
- T5 Train5 108000 400000 213 8 210 160 0.85 87318 50786
- Structure of output: ID / TrainID / Engine mass / Trailer mass / Train length / No. of wagons / Used engine / max. speed / recuperation rate / start time / stop time

- Train 1 Result 1 of 1 Energy demand: 256.6 Demand complete: 256.6 kWh
- Train 2 Result 1 of 1 Energy demand: 230.1 Demand complete: 486.7 kWh
- Train 3 Result 1 of 1 Energy demand: 256.6 Demand complete: 743.3 kWh
- Train 4 Result 1 of 1 Energy demand: 254.8 Demand complete: 998.1 kWh
- Train 5 Result 1 of 1 Energy demand: 254.8 Demand complete: 1252.9 kWh

- New minimum found: 1252.9

Fig.7. Output from Kronecker algebra: Delay and Energy consumption

6. CONCLUSION

In conclusion, development of rail traffic flow optimization tool enables infrastructure managers to base their decisions on reliable data without output surprises. In other words, optimal solutions will ensure high level of efficient use of, very often scarce, resources and optimal process flow. This tool will enable one to set clear priorities based on reliable date and ensure minimal loss of operations, and more importantly, energy.

ACKNOWLEDGEMENT

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '16

RAILWAY AS A SUSTAINABLE MODE OF TRANSPORT

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Abstract – *Efficient and developed transport sector contributes greatly to the development of the economy, increasing the competitiveness of the economy and its subjects, the greater mobility of people and the development of underdeveloped regions. However, in recent years it is noticeable that the current development trends, approaches and available technologies in transportation have major implications on the environment, human health, and therefore are not sustainable in the long term. Railways as a system of mass servicing, with high energy efficiency and low adverse environmental impact, is the best example of sustainable transport. The main objective of this paper is to indicate the advantages of rail transport compared to other modes of transport in terms of sustainability.*

Keywords – transport modes, railway, pollution, sustainable development.

1. INTRODUCTION

Sustainable development is "a fluid concept" [1]. Definitions of sustainable development point to its fundamental principles: "(i) a commitment that decisions should consider equity and fairness and account for the rights of future generations; (ii) there should be a long-term view that emphasizes the precautionary principle, i.e. "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" and (iii) sustainable development involves understanding and acting on the complex interconnections between its three pillars, i.e. the economy, society and the environment" [2]. All three pillars face the following major challenges: more than 1 billion people are still living in extreme poverty, income inequality within and amongst many countries has been rising, unsustainable consumption/production patterns have resulted in increasing environmental degradation and dwindling natural resources [1] and 14% of greenhouse gas emissions in the atmosphere related to transport activities [3].

Sustainable development has become an overarching objective of the European Union [4]. Currently, the main focus is on limiting the emissions of greenhouse gases, increasing the efficiency of power and natural resources sectors, and increasing the share of renewable energy [5]. Every other sector contributes in reducing emissions of greenhouse gases, except for the transportation sector (Heinrichs et al., 2014) [6]. The transportation sector makes up 25 percent of GHG emissions in the European Union (European Commission, 2014) [7]. Thus, special attention must be paid to the need for decoupling transportation at one side and at other side, greenhouse-gas emissions, as well as emissions of particular matter and ozone precursors. It is expected the share of the transport sector in national total emissions may also increase in the coming years, due to a greater rate of progress in total emissions reductions from other sectors [8].

In the XXI century, there is awareness of the necessity of balanced development of transport in the EU, as well as encouraging environmentally friendly modes of transport. Road transport plays a dominant role in the transport of goods and passengers, although it shows a number of weaknesses relating to air pollution and noise, as well as congestion in cities. About 60% of the total amount of air pollutants in urban areas comes from internal combustion engines. Effects of fuel combustion during operation of automobile engines are the primary cause of high emission of pollutants. Engine exhaust fumes contain harmful substances such as carbon monoxide, unburned hydrocarbons and partially burned matter, nitrogen oxides, sulfur oxides, lead compounds, solid and liquid smoke constituents. Rail and inland waterways have a number of advantages over road

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transport. They are safer and have less negative impact on the quality of environment. Air transport has a significant negative impact on air quality, while sea transport, because of the risk of oil or other fuel spills, can have a negative impact on the quality of environment. Negative effects on environment occur in cases of accidents during transport of dangerous goods. Every mode of transport causes pollution of air, water, or soil, but their negative effects are different. At the same time, each transport mode has a different volume of transport of goods. The volume of transported goods by road shows an increasing trend, while in rail transport it is declining.

The main purpose of the study is to analyze the eco-efficiency of transport modes, starting from environmental indicators. The main objective of this paper is to use data envelopment analysis (DEA) as a support tool to indicate the advantages of rail transport compared to other modes of transport in terms of sustainability in the case of the European Union. The basic hypothesis in the paper is that rail traffic does not have a dominant share in the transport of goods, although its contribution to air pollution is the lowest.

2. LITERATURE REVIEW

The lack of a commonly agreed or exact definition [9] of eco-efficiency can be explained by popularity of various application levels (corporate, sectoral, regional, national or global level) and purposes in using the concept [10]. In general, the authors have utilized the data envelopment analysis concept to measure the eco-efficiency of economics sectors. Although the economic literature deals extensively with this concept, far less attention has been paid to its application for the analysis of sustainability of transport modes.

Leal at all use the concept of eco-efficiency to select attributes for the transportation modal choice for hazardous products. To determine eco-efficiency in the transport sector, they propose a structure based on the aspect, attributes and indicators [11].

Eco-efficiency is a key concept for sustainable development from a business standpoint in that it combines environmental and economic performance [12]. Based on this concept, the eco-efficiency measures can be used to evaluate performance and can choose the best transport modes. We choose only one indicators of service value, combining it with the most representative indicators of atmospheric pollution and GHG emissions.

Data envelopment analysis (DEA) has been proposed as a method for aggregating the impact categories to construct an eco-efficiency index [13]. The first proposal of aggregation using DEA to quantify eco-efficiency according to its definition (economic value added/environmental damage) came from Kuosmanen and Kortelainen (2005) [14]. Nevertheless, researchers have widely applied DEA models to integrate undesirable outputs in measuring the technical efficiency of productive processes [13].

Farelet et al. (1989) were the first to point to the importance of unwanted outputs in efficiency analysis. Today, all authors who analyze eco-efficiency consider that inputs should be the factors that are desirable to minimize, while the output should be a measure of everything that is desirable to maximize [11]. Proceeding from the above, in this paper, we use the concept of eco-efficiency to select transportation modes, following the case of the European Union.

3. METHODOLOGY

Data envelopment analysis (DEA) is a mathematical programming technique that is used to determine the relative efficiency of entities (bank branches, universities, military services, agricultural goods, container terminals, etc.) with multiple diverse inputs used to create multiple diverse outputs. An entity whose efficiency should be evaluated based on DEA terminology is the decision-making unit (DMU) [15]. The creators of DEA method, Charnes, Cooper, and Rhodes, proposed non-parametric approach for the calculation of efficiency, by reducing multiple inputs to a single "virtual" input and multiple outputs to a single "virtual" output, using weight coefficients. They solved the problem of weight assignment by allowing each unit to determine its own weight in order to maximize its efficiency (ratio of weighted sum of its inputs and outputs), with the proviso that these weights must have positive values and that the ratio of virtual outputs to virtual inputs of each unit cannot be greater than 1. They defined this problem as a linear programming task, also known as "CCR ratio model" [16].

In fact, DEA model empirically establishes for parts the linear border of efficiency, to monitor the "conversion" of each DMU inputs into outputs. The relative efficiency of DMU is calculated by comparing production function with an estimated production limit. Therefore, DMU performance is compared directly with the "best" variable or combination of variables. DEA does not require assumption of a functional form relating to conversion of inputs to outputs. Furthermore, inputs and outputs can have very different units. DEA method has become popular and powerful approach largely because of its ability to relate multiple input and output models without *a priori* information about compromises (Zhu, 2003) [17].

The paper used DEA output-oriented CCR model, relying on MaxDEA software. Each mode of transport is treated as a decision-making unit (DMU). The aim is to identify the best, as well as insufficiently efficient or inefficient modes of transport. Then, the

Tab. 1. Inputs, output and efficiency score

DMU	Emissions (Gg - 1000 tonnes)							Freight transport (billion tonnes-kilometres)	Efficiency
	CO	NH3	NMVOC	NOx	PM_{10}	$PM_{2.5}$	SOx		
Road	4831	57.74	575.09	3146.36	115.37	114.14	6.20	1719	**0.433**
Railways	26.96	0.02	9.17	112.05	6.85	4.86	1.35	407	**0.693**
Air	67.41	0.16	8.18	68.54	2.13	1.94	4.43	2	**0.005**
Inland waterways	8.50	0.01	1.39	29.13	6.82	0.99	2.38	152.7	**1**

analysis of the results and comments related to input-output decision-making units are provided.

CCR ratio model calculates the total efficiency, including pure technical efficiency and eco-efficiency, as a result of different scale of operations [18]. It is assumed that constant returns to scale, i.e. that increase in the value of engaged inputs, should result in a proportionate increase in actual output levels. If the value of the objective function is equal to 1, then the k-th DMU is relatively efficient, but, if it is less than 1, DMU_k is relatively inefficient and the resulting value shows percentage by which this unit should reduce its inputs. DMU_k can be considered fully efficient if and only if the results of other DMU do not provide evidence that some of its inputs or outputs could be improved without compromising any of its other inputs or outputs. In output-oriented model, the goal is to maximize output at a given level of inputs, and inefficient unit becomes efficient by increasing its outputs [18].

The work used Road, Railways, Air, and Inland waterways transport as decision-making units. Emission of CO, NH_3, NMVOC, Nox, PM_{10}, $PM_{2.5}$, Sox in Gg (1000 tones) was used as input data, while output data was reflected in the quantity of goods transported by the observed modes of transport in 2013 (billion tones-kilometers). Based on the input and output data (Table 1) and the procedure given in [19], eco-efficient, insufficiently efficient, and inefficient modes of transport are identified.

The result of DEA model is shown in Table 1. Of the analyzed four modes of transport, only one is efficient ($1/\mu = 1.0$); one is fairly efficient ($1/\mu > 0.6$); while the remaining two are considered inefficient ($1/\mu < 0.6$). Inland waterways is efficient, Rail is fairly efficient, while road and air transport are inefficient. The explanation for the high efficiency of Inland waterways and Rail is the connection of a large number of ports with the main railway lines and their proximity, which has a strategic and logistical significance. The biggest cause of inefficiency of road transport is the fact that road transport is the biggest source of pollution in relation to other modes of transport in the European Union. This is confirmed by the data given in Table 1. When it comes to air traffic, the cause of its inefficiency relates to the lack of interest among users of freight transport for these services, because they use services of other transport modes.

This work has a limitation, which is that every mode of transport is treated independently even though a large portion of goods is transported by using multiple modes of transport.

4. CONCLUSION

This paper used data envelopment analysis (DEA) for testing the efficiency of transport modes (Road, Railways, Air, and Inland waterways) in terms of emission of pollutants (CO, NH_3, NMVOC, Nox, PM_{10}, $PM_{2.5}$, and SO_x), relative to the amount of transported goods. The conducted analysis has given the result that Inland waterways transport is efficient and that Rail is fairly efficient, while Road and Air transport are inefficient.

Inland waterways transport, as cleaner mode of transport, as compared to others, has established itself as a natural choice. Natural circumstances give real opportunity to develop this type of transport, and, in Europe, there are more than 30,000 km of canals and rivers that link industrial centers and entire regions. Despite natural advantages, this mode of transport is still insufficiently utilized. The reason for the small share of river transport in the total transport lies mainly in the fact that only half of the EU member states has interconnected waterways.

Another mode of transport that meets the requirements of small amount of emission of harmful gases in relation to the quantity of goods transported is rail transport. Rail is able to use electricity as fuel, and, at the same time, achieve great performance. Railway, as an environmentally friendly mode of transport, particularly at larger distances, and in relation to road transport, should be encouraged. Environmental benefits of rail should contribute to redirection of traffic policy towards the development of rail transport.

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QUALITY OF TRANSPORT SERVICE AT SERBIAN RAILWAYS

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Abstract *– The quality is a term widely used in many different aspect of present-day living. It is common to discuss the quality of any product or service used by people. Since transport represents a special type of service, the quality of the transport is a value that defines the transport itself. The paper is defining the parameters of transport and transport service that identify the quality of the provided service – transport. The quality level is estimated by questionnaire conducted on a certain number of people in European Union's countries. The result show that different nations have different points of view on quality of transportation in railways, they also have major differences in transport needs and habits. The overall conclusion is that the railways provide limited quality both in freight and passenger transport even thou the railway transportation is sustainable, efficient and less expensive than the other transport means. Serbia and its neighboring countries still have a lot to do and improve the quality of the transport service in railways.*

Keywords – Rail transport quality, Quality parameters, Passenger transport, Freight transport.

1. INTRODUCTION

Quality has become a global term – it is a technical and sociological phenomena of the present days, important both for the manufacturer or service provider and for the user or service receiver. The term quality has been expanded from the elementary quality management approach (on products and services) to the total quality management.

Transportation is an important segment of the modern living and therefore is an object of constant investigation and improvement. The White Book 2011 of the European Union's (EU) commission has presented a plan of transportation within EU, with the special scope on the quality of the transportation. The scope of the book is summed as: „The quality, accessibility and reliability of transport services will gain increasing importance in the coming years, inter alia due to the ageing of the population and the need to promote public transport. Attractive frequencies, comfort, easy access, reliability of services, and intermodal integration are the main characteristics of service quality. The availability of information over travelling time and routing alternatives is equally relevant to ensure seamless door-to-door mobility, both for passengers and for freight"[1].

This paper describes the parameters of the transportation service and discusses the grade of railway transportation quality in Serbia and some EU countries considering the transportation volume invested in cargo (freight) and passenger transport.

2. QUALITY PARAMETERS OF TRANSPORT SERVICE IN PASSENGER AND FREIGHT TRANSPORT

The quality is a pure measure of the product's usability – it is a value that shows how much is a system capable to accommodate customers' and market's needs. Therefore, the quality is a synonym for the product's value.

Services are nonmaterial products offered by certain providers. It is a kind of a property considering planning, selling, transportation, training etc.

Quality of a service can be explained as a sum of service's properties that define service's ability to fulfill needs of the customer. The modern way of living and communication demand a certain level of the transportation quality. Transportation and the quality go side by side and a direct product of the qualitative transportation is the number of passengers in a time unit, or the number of cargo units per time, or both [2].

Transportation is a type of service that has a goal

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to fulfill the need for transportation both passengers and material goods (freight). The users of the transportation are not interested in transportation technology, but they are extremely interested in the quality of the provided transportation service.

The literature defines quality of the transportation service over several primary areas [2]: traffic exploitation (vehicles, infrastructure, users etc.), safety and technical exploitation (traffic accidents, vulnerability of persons involved in traffic, resources sustainability etc.), environmental protection (noise, air, water etc.), business economy (expenses, prices, financial gain, investments etc.), social development (reduction of unemployment, regional development etc.).

Some researches [2] show that the most important quality parameters, in the passenger transport, are: transportation rate (time necessary for transportation from start to end location), transportation costs (direct travel passenger travel costs), comfort (wide scale of services available to the passenger with a goal to make transportation easier and more pleasant), safety (risk free traveling), reliability (guaranteed transportation in defined time) and passengers' pleasure (measured as repetitive use of the same transportation mean).

Basic quality parameters of the freight transportation are [2]: reliability, safety (quantity of the lost, damaged or destroyed cargo pieces), security, transportation time, door-to-door delivery system's applicability, adaptability, stability (considering technical and organizational possibilities of transportation), energy consumption, transportation prices, eco-friendly etc.

The user of transportation cannot estimate the quality of the transportation service merely on material senses (for example, noise, taste, color, smell etc.) but also on subjective sense (e.g. environment, politeness of the personnel, hygiene). The quality level is not constant from the passengers' point of view – it has to be measured and corrected continuously.

Transportation service does not have common realization manufacture-sell-consume cycle: the transportation is firstly sold and simultaneously manufacturing and consuming – but it cannot be stored. Transportation service requires constant interaction with the transportation user, even if the user is not present while transportation service is happening. Transport service itself has no significance for the user, because it is an integral part of other activities, from whose successful performance depends on its value.

3. QUALITY OF THE RAILWAY TRANSPORT IN EU

Transport has significant impact to the quality of life. Investigation described in the paper [4] suggests that the most frequently mentioned factors are: access, design, environment, maintenance, mobility, safety, and transparency (communications/planning). Mobility was a top-of-mind category in the discussion of future transportation related needs. Participants would like to see increased travel speed, more free-flowing traffic, less congestion, and reduced commute times [3].

The aim of the European Commission's Directorate General for Mobility and Transport (DG MOVE) is to promote transport solutions that are efficient, safe, secure and environmentally friendly and to create the conditions for a competitive industry, generating growth and jobs. The survey was conducted in order to gather information from European citizens, understand their habits, hear their opinions and analyze their perceptions of transport related matters [4]. Among others, she survey focused to the perceptions of the quality of rail transport over the last five years and the most serious problems affecting this mode of transport.

Investigating the serious problems affecting rail transport, 26865 respondents from 26 countries opinions were collected (table 1). The following parameters were offered: ticket prices, lack of reliable or punctual services, missing railway links (between cities or across borders), rail maintenance, quality of services and facilities on board, lack of high-speed lines, lack of railway stations, security, accessibility, noise pollution, and other.

Every respondent gave the three answers. Almost half of all respondents in EU said ticket prices were the most serious problem for rail transport in their country (46%) – considerably higher than the proportion who mentioned the lack of reliable or punctual services (33%). Missing links and rail maintenance were considered serious problems by at least one in five (21%). On the other hand, accessibility and security (both 10%) and noise pollution (4%) were far less likely to be considered serious problems for rail transport [4].

Data that are related on railway in Bulgaria, Croatia, Hungary, Romania and Slovenia are discussed in this paper. These countries are chosen because these are Serbian neighbors and their rail transport affects to Serbian transport.

It can be concluded that users of rail transport service in Bulgaria, Croatia, Romania and Slovenia consider that the most serious problem is rail maintenance, while Hungarian respondents consider that the most serious problem is ticket prices. A large number of respondents from these countries consider that lack of reliable or punctual services, missing railway links and quality of services are the serious problems.

Tab. 1. Results of the questioning of respondents in some EU countries [4]

	Ticket prices	Lack of reliable or punctual services	Missing railway links	Rail maintenance	Quality of services and facilities on board	Lack of high-speed lines	Lack of railway stations	Security	Accessibility	Noise pollution
EU 26	46%	33%	21%	21%	16%	15%	13%	10%	10%	4%
Bulgaria	14%	20%	18%	36%	23%	24%	13%	32%	7%	3%
Croatia	23%	21%	25%	46%	22%	30%	17%	22%	6%	4%
Hungary	35%	26%	19%	33%	27%	19%	15%	9%	13%	5%
Romania	34%	18%	15%	38%	22%	28%	13%	14%	5%	3%
Slovenia	12%	9%	30%	44%	20%	37%	12%	5%	19%	6%

The conclusions that rely on questionnaires are always relative and the results extremely differ from country to country. It is obvious that passenger habits and technological level of the railway and railway infrastructure imply the answers of the questioned passengers. As a support of such questionnaires, it is necessary to analyze achieved effects of the transport: energy consumption, carbon dioxide emission etc.

Figure 1 shows energy consumption per passenger kilometer in EU in 2000 and 2012, comparing public transportation, railway, bus and personal vehicle transportation (cars) [5]. In average, cars require three times more energy for one passenger-km than public transport (rail transport and buses), and six times more energy than rail transport (trains, metros and tramways).

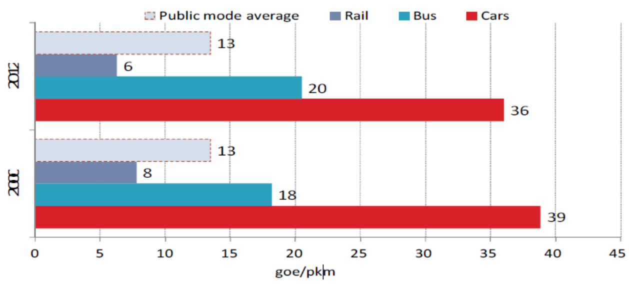

Fig. 1 Comparison of specific energy consumption for passenger transport in EU [5]

The figure 2 shows carbon dioxide emission per passenger kilometer in EU in the time period 1995-2011 [6].

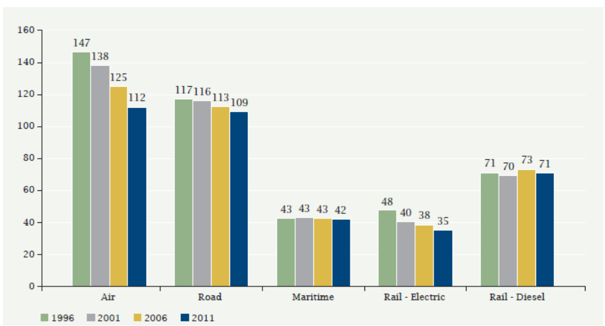

Fig. 2 Carbon emission per passenger transport in EU from 1995 until 2011 [6]

Based on figure 2, air and road transportation means are the greatest polluters while electrified railways has the smallest impact on the environment. This data always has to be analyzed when planning and development of the transportation are done.

4. INDICATORS OF RAILWAY TRANSPORT VOLUME IN SERBIA AND NEIGHBORING COUNTRIES

Road transport is the most developed transportation type and the greatest amount of the passenger and freight transport is done over roads. Railway and water transportations have much less percentage in transportation rate.

Passenger cars accounted for 83.2 % of inland passenger transport in the EU-28 in 2013, with motor coaches, buses and trolley buses (9.2 %) and trains (7.6 %). The share of EU-28 inland freight that was transported by road (74.9 %) was more than four times as high as the share transported by rail (18.2 %), while the remainder (6.9 %) of the freight transported in the EU-28 in 2013 was carried along inland waterways [7].

Tab. 2. Some data on railway transport in Serbia and neighboring countries

Country	Number of inhabitants	Length of railway lines	Rail transport	
			passenger	freight
[-]	[-]	[km]	[10^6 pkm]	[10^6 tkm]
Bulgaria	7,185,000	4.159	1.700	3.439
Croatia	4,230,000	2.974	917	2.119
Hungary	9,835,000	7.942	7.710	10.158
Romania	19,822,000	22.298	4.970	12.264
Slovenia	2,065,000	1.228	620	4.110
Serbia	7,103,000	3.808	617	2.988

There is a great difference in volume of transport (pkm, tkm) among EU countries. This paper is analyzing the statistical data of railway transport in

Bulgaria, Croatia, Hungary, Romania, Slovenia and Serbia. Table 2 gives data about the number of inhabitants and passenger and freight transportation in 2014. The analyzed countries are the countries in the neighborhood of the Serbia.

In Serbia 4223 million passenger kilometer [pkm] was executed in road transport in 2014 [8] what is 7 times greater than transportation in railways, while, at the same time, the volume of freight transport as approximately the same for road and rail transport 2959 million ton kilometer [tkm].

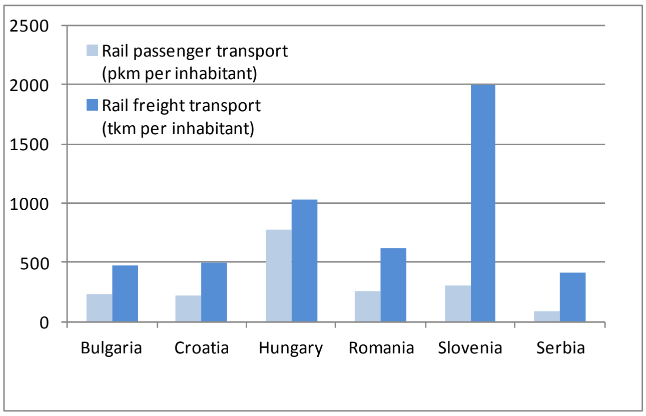

Fig. 3 Rail passenger and freight transport in 2014 per inhabitant

In order to compare the relative importance of rail transport between countries, the data can be normalized by expressing the level of passenger and freight traffic in relation to population, as shown in the Figure 3. Inhabitants of Hungary each travelled, on average, 782 passenger-kilometers in 2014, and the biggest freight transport 1993 tkm per inhabitant was executed in Slovenia. In Serbia 86 passenger-kilometers per inhabitant and 415 tkm per inhabitant were executed in 2014.

5. CONCLUSIONS

Based on the presented quantitative data on transport volume in railways, presented as tkm and pkm, it is obvious that the capacities of the Serbian Railways are not used efficiently, even thou the transportation costs and environmental impact of the railways are much smaller in relation to other modes of transport.

The main reason for insufficient use of the railway transport capacities in Serbia are unsatisfactory quality of transportation services for customers, considered in terms of quality parameters, specified in the carriage of passengers and cargo (e.g. low transport-rate, low level of comfort, lack of reliability and punctuality of trains, too much handling of cargo during loading and unloading, , the inability to transport "door to door", difficulty in planning and implementation of transport due to organizational changes in the structure of the railways, etc.).

The increased quality of the transportation service might redirect the passengers to the railways. In favor of this: the data from the Marketing Sector "Srbija voz" shows that use of the new diesel multiple units (imported from Russia) mainly used in mid Banat has increased the number of passengers and also increased profit. The explanation is quite simple: reliable trains have enabled reliable and punctual time-table and the passenger have started to use the benefits of qualitative and pleasant transportation.

The railway has to increase the quality of the transportation service to become attractive for users and concurrent to the other transportation modes. This might become major strength of the industrial progress in Serbia.

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FUZZY DECISION SUPPORT SYSTEM FOR PLANNING ROBUST TIMETABLE

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Dragomir MANDIĆ [2]
Snežana JOSIPOVIĆ [3]

Abstract *– Reliability and punctuality of railway traffic are among the key indicators of quality of railway service. A way to improve the reliability of the timetable in design stage is by improving the timetable robustness, by adding buffer times, between possibly conflicting events, in order to reduce or prevent delay propagation if the first event occurs with a delay. Buffer times need to be allocated carefully to protect events with the highest priority. In this paper, we consider the problem of increasing the robustness of a timetable by allocation of buffer times on a railway corridor, with assumption that various parameters are represented as fuzzy numbers. According to that, we construct a fuzzy decision system as a helping tool to discover critical points of timetable, at early stage of designing phase.*

Keywords – Buffer times, Timetable robustness, Fuzzy system.

1. INTRODUCTION

Increasing timetable robustness and stability, is carried out by inserting time reserves in it. There are three types of schedule time reserves. Additional travel time, i.e. difference between planned and minimal travel time between two stations, serves to reduce or completely neutralize delays that could emerge during the ride between those stations. Time reserves in headways (buffer time), serves to prevent transfer of delays from one train to another. Time reserves in dwell times in stations, aim to prevent or reduce possibility of delays arising due to passengers' entry or exit.

The more time reserves it contains, timetable is more robust, i.e., lower is the possibility that disturbance can occur in its realization.

In process of timetable projecting, often it is not possible to provide buffer times in all headways, or it is not possible to provide required buffer times amount. Also in early phase of timetable projecting, most often there is no accurate and precise data about time reserves in it. In such cases, the easiest way to describe time reserves in timetable is to represent them as fuzzy values.

This paper will define the fuzzy model, which can serve as an aid in identifying priority points for allocation of buffer times in headways.

2. FUZZY MODEL AS DECISION SUPORT SYSTEM

The basic idea for the formation of support fuzzy model for identifying priority headways to allocate buffer time, is represented through the assumption that all the variables necessary for decision making, as well as the priority allocation of buffer time in the headways itself, can be represented as fuzzy variables.

Although many independent parameters influence the priority allocation of buffer times, in this paper were used tree input parameters:

- Percentage of additional travel times in previous travel time,
- Percentage of additional travel times in succeeding travel time and
- Train rank.

These input parameters are chosen primarily for simplicity of determination ranges of their values, but it must be noted that the decision makers, in every particular case, can use the input parameters according to their own preferences.

Ranges of values for the parameters of percentage of additional travel times are determinate on the basis of a UIC leaflet 451-1 [1]. Although, depending on the type of train, the leaflet lists a number of ways to determine the recommended amount of time reserves

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in travel times, this amount is always around 4% of the minimum travel time. For this reason, the ranges are defined so that the percentage share of time reserves of approximately 4% is considered as an average, and thus further defines a small and a large percentage of time reserves participation in actual travel times. Figure 1. shows percent of time reserves in previous travel time as fuzzy value, and Figure 2. represents percent of time reserves in succeeding travel time as fuzzy values as well.

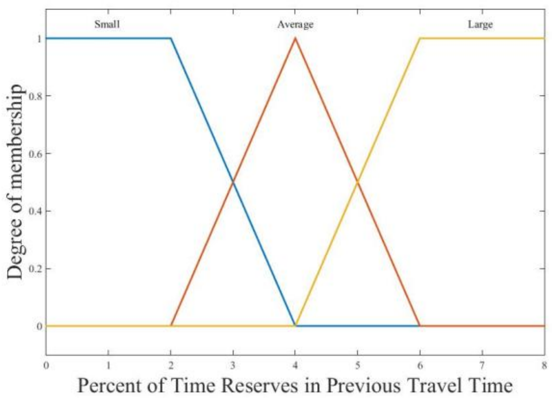

Fig.1. Fuzzy percentage of time reserves in previous travel time

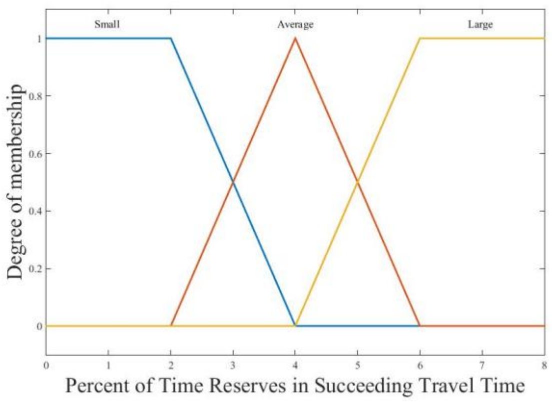

Fig.2. Fuzzy percent of time reserves in succeeding travel time

It is important to note that the accepted forms of membership functions is solely authors' decision, but it is possible to define other forms of membership functions, especially for small and large percentages of time reserves. In addition, as it is evident from the figures, percentages of the time reserves in previous and succeeding travel time are defined in the same manner, without any other conditionings and considerations.

Although represented input parameters are virtually identical, there is a significant difference in way of determining their values. The time reserves in the previous part of the travel times should be determined considering path of the train which comes first in station, because bigger values of these reserves reduce probability of delay at arrival. Thus, probability of delay transfer on a train path, which should be protected, is less. On the other hand, the remaining time reserves on the succeeding travel path should be measured for the train whose route should be protected from delay, because a larger share of these reserves increases the probability that possible delay transfer from station will be reduced or completely neutralized by the end of the travel path.

As the third and final input value, train rank was chosen. Although train rank does not represent fuzzy value in this paper, it was chosen for two reasons. The first one is to show in the simplest manner that any value, even numerical, after fuzzification can be used as input to the model. The second reason is more important, and partly describes the reason why the previous two values were selected, as well. Specifically, intention in the paper was to defined values could be applied to the whole timetable, without having to redefine or another fuzzification process, depending on the characteristics of the timetable, railway line, etc.

Fuzzification of train rank should be implemented depending of the number of different ranks of trains that are intended to operate on the observed railway line. For more precision, to the lowest train rank, we assign number one, and then add one for each category of higher train rank, runs up to the highest predicted train rank. In this paper, it has been used less precise way of fuzzification, because the train rank is also presented in the similar way as the previous two input values, as shown in Figure 3.

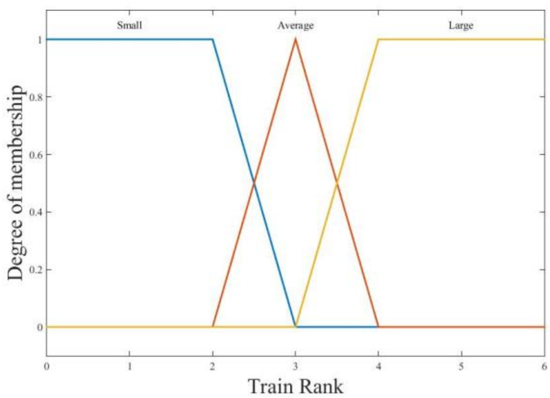

Fig.3. Fuzzy train rank

The described method of determine priority for buffer time allocation, is a different approach to this problem defined in [2].

The output from the model represents the value of "priority for allocation of buffer times" which was also presented as a fuzzy value, shown in Figure 4. For its definition Gaussian membership function was chosen, although it should be noted that it is possible to select form of output function according to the requirements of the specific application.

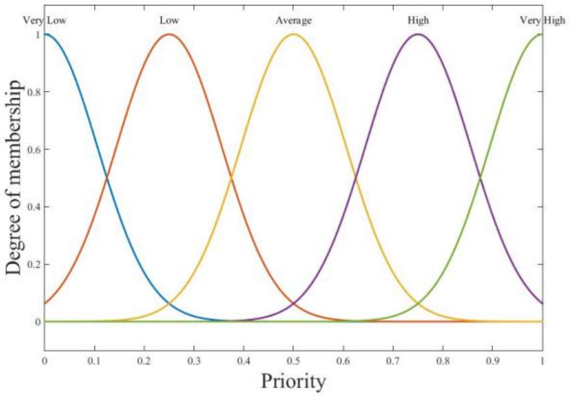

Fig.4. Output fuzzy value "Priority for allocation of buffer times"

Once the input and output values were defined, it was developed 27 fuzzy rules, necessary for fuzzy system to decides the priority allocation of buffer time, for each individual headway.

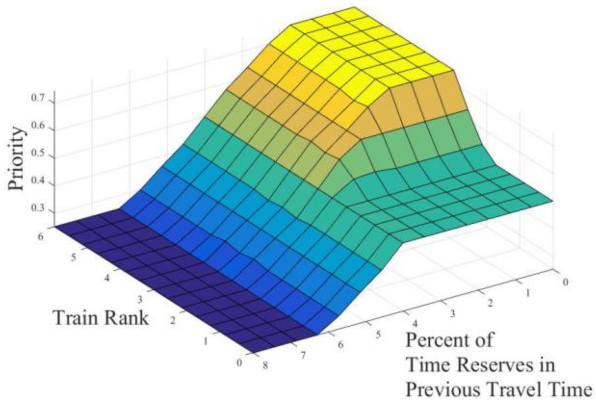

Fig.5. Interdependence of variables Train Rank and Percent of Time Reserves in Previous Travel Time

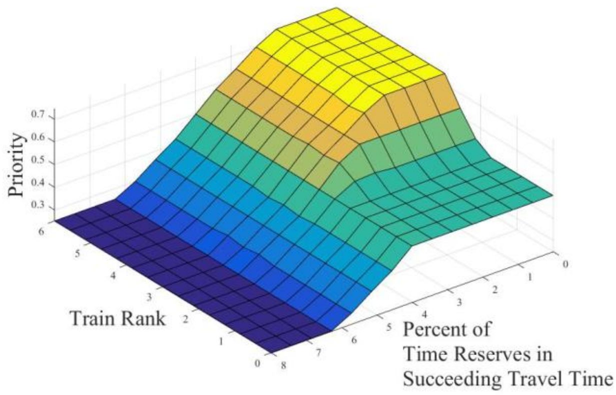

Fig.6. Interdependence of variables Train Rank and Percent of Time Reserves in Succeeding Travel Time

In Figures 5, 6 and 7. is shown their interdependence to the output value.

Identical dependence of percentage part of time reserves on train rank, as well as their mutual symmetric dependence should not be surprising, considering the way of defining fuzzy values.

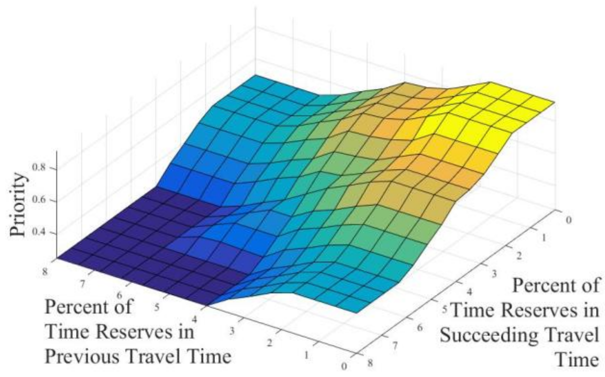

Fig.7. Interdependence of variables Percent of Time Reserves in Previous Travel Time and Percent of Time Reserves in Succeeding Travel Time

Each of the displayed dependences could change, in dependence of the chosen fuzzification process of input values.

A detailed description of the fuzzy systems, and a manner of their uses, are given in [3].

After defining a model, as shown, it is necessary to determine the value of each defined parameter for each headway in timetable. After fuzzification and application of the model, as output we will obtain a priority of buffer time allocation across timetable graph, for each headway.

It is necessary to pay attention to the fact that usually it will be impossible to implement all time reserves into all headways, even not all of those with a very high priority. The reason for this is the limit for their application, represented as available railway capacity on railway line on which increment of timetable robustness was intended. The remaining capacity is limited, often even very close to the upper bound of the maximum capacity. The only way for the application of proposed model is the implementation of the buffer times into the headways, starting from the one with the highest priority, and so on down, until the available capacity is completely exhausted.

In addition, formed model does not take into account the proposed amount of buffer times that should be implemented. These values are not defined for any of the railway administrations, and therefor recommended values are given in [4].

3. APPLICATION OF FUZZY MODEL

To be tested, defined system has been applied to rail section of Swedish railway, between stations Hallsberg and Mjolby. Two-hour period was chosen, in the busiest part of the day. Figure 8. shows the selected timetable. Set of 13 headways-candidates is defined. Five candidates stands out with highest priority, but only four of them can be protected with buffer time, as implementation of the last one, between train paths 4327 and 5368 in station

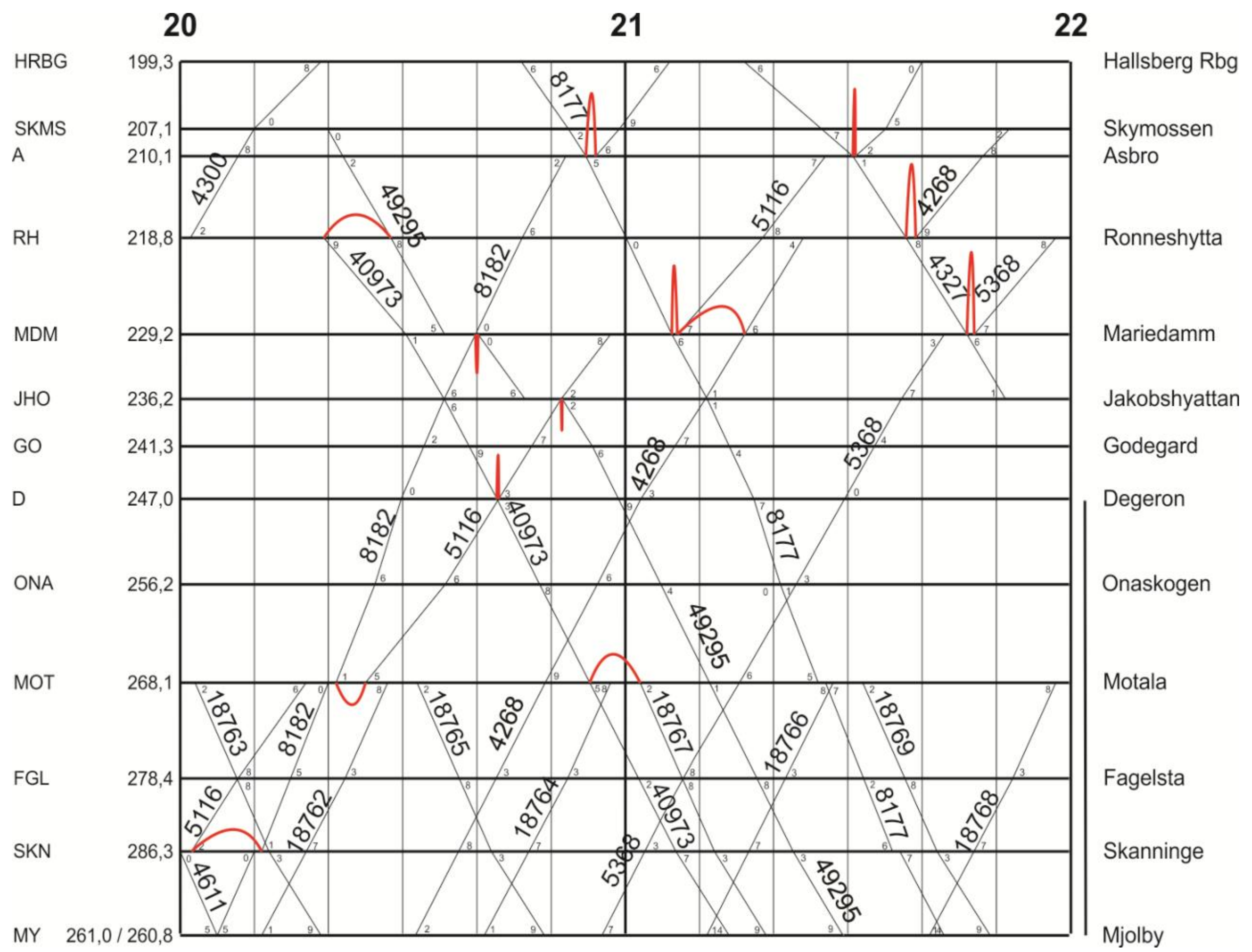

Fig.8. Chosen timetable for model application

Mariedamm, will exhaust available capacity. Candidates for protection are represented with red arcs in the Figure 8. and the resulting priorities for their protection are given in Table 1.

Tab. 1. Results of application of fuzzy model

Candidate	Station	Between Paths	Priority
1	SKN	5116-8182	0.647
2	MOT	8182-5116	0.918
3	RH	40973-49295	0.748
4	MDM	8182-49295	0.591
5	D	5116-40973	0.748
6	JHO	5116-49295	0.748
7	A	8177-8182	0.469
8	MOT	40973-18767	0.918
9	MDM	8177-5116	0.918
10	MDM	5116-4268	0.748
11	A	4327-5116	0.918
12	RH	4327-4268	0.748
13	MDM	4327-5368	0.918

4. CONCLUSION

Defined fuzzy model uses several input parameters for identification of priority allocation of buffer times. As a result, models gives a proposal which train path, in which station, should be protected using buffer time, in order to potential delay of some train minimally affect schedule of other trains at same railway line, which represents a measure of robustness of planned timetable.

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A FUZZY NEW MULTI-CRITERIA METHODOLOGY FOR PROVIDER SELECTION BASED ON COMPARISON OF REAL AND IDEAL PROVIDER'S PARAMETERS

Dragan PAMUČAR [1]
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Abstract – *Transport activities are at the top of the list of outsourcing activities in a number of companies. Provider selection for the implementation of outsourcing transport service is therefore an important issue for managers of these companies. In this paper, we present a new methodological approach to the problem of selection of transport service provider, based on the idea of comparing the ideal and real parameters of alternative providers. F-RIC (**F**uzzy - **R**eal **I**deal **C**omparative) model is a new two-phase fuzzy model that combines the Decision Making Trial and Evaluation Laboratory Method (DEMATEL) with a new method of ranking the alternatives. DEMATEL method is used to evaluate the mutual influence of the criteria of differentiation of alternative providers and thus determine the ideal weighted values of the observed criteria, while in the second phase of the model, these values are compared to the perceived real values of the criteria, based on which alternative providers are evaluated and ranked.*

Keywords – Outsourcing; transport, provider selection, fuzzy multi-criteria model, DEMATEL, F-RIC model.

1. INTRODUCTION

One way of achieving high business performance is to focus on core business activities and core competencies of the organization. This will relieve some organizational resources (funds, material resources, time, energy, etc.), which would otherwise be allocated to supporting, accompanying and other, also necessary, but not crucial processes and dimensions of the organization. Outsourcing approach to supporting processes not only builds up the conditions for the improvement of quality of key organizational competencies and results in corresponding savings, but also implies a potential increase in the quality of implementation processes that are passed on to other organizations. The quality of implementation of outsourcing processes directly depends on the competence of selected external organization – provider.

According to Banomyong and Supatn (2011) "the most outsourced logistics activities are related to freight transportation." Therefore, selection of transport service provider is an important issue in the management of logistics processes in an organization. Due to the conditions of uncertainty, ambiguity and the large number of influencing factors, the methodology of provider selection is extremely complex, with a number of selection models developed.

The problem in selecting a transport service provider is conceptually similar to the provider selection in most other logistic activities. In this sense, when it comes to the models of transport service provider, the relevant studies are those focused on the carrier selection, supplier selection, vendor selection and third party logistic provider selection.

Although there are different views on structuring the problem of provider selection [1,2], as well as on the structure of the selection process [3], when it comes to the nature of this process, there is broad compatibility of attitudes that is multi-dimensional [4]. In regards to this, the use of many methods of multi-criteria decision-making has been proposed for the provider selection.

Besides the advantages, there are certain disadvantages in the use of traditional methods for multi-criteria selection. Some methods require independence of the selected criteria, which are in the context of complex real-world problems difficult to achieve or have numerous limitations and approximations. The others are based on establishing a hierarchy among the criteria, with or without a request for independence, although often the

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hierarchical relationships and influences among criteria at different decision-making levels are not one-way. Such hierarchy or clustering criteria in modeling of real decision-making problems can cause inadequate interpretation of actual relations among the criteria. One of the major problems of multi-criteria decision-making – the problem of assigning relative weights of criteria and sub-criteria should also be added.

A way of overcoming this type of problems is to establish the criteria network structure. Having the present imprecise information and difficulty in evaluating the mutual influence of the criteria and the conditions of uncertainty and dynamics of the environment in which the process of provider selection takes place, the fuzzy logic is also recommended as a suitable approach [4,5].

The rest of this paper is structured as follows. Section 2 contains an overview of the logical course of action in the proposed methodology for the selection and sequence of steps of a mathematical model of provider selection, while Section 3 shows an example of application of the proposed FCRIP model. Finally, Section 4 singles out the main conclusions, advantages and disadvantages of the model, as well as future research topics..

2. FUZZY MULTI-CRITERIA COMPARATIVE I-R PROVIDER SELECTION MODEL

In an effort to develop a model that will correctly interpret connections and mutual influences of criteria and sub-criteria and objectively define their relative weights, taking into account the present imprecise information regarding evaluations and preferences of decision-makers, this paper proposes a new fuzzy multi-criteria model of transport service provider selection, called FCRIP model. The proposed FCRIP model is based on the idea of DEMATEL approach and comparison of ideal and real parameters of alternative providers in fuzzy environment.

FCRIP provider selection model is a two-phase model, whose mathematical representation consists of the following steps:

Phase I: Identification of factors and subfactors and determination of ideal weight

Step 1. Define and choose *K* of the factors affecting the provider selection ($C_k, k=\overline{1k}$).

Step 2. Define and choose *M* of the subfactors affecting the provider selection $(c_t,\ t=\overline{1M})$.

Step 3. Define a set of fuzzy linguistic descriptors $L=\{l_b\},\ b\in\{1,\ldots,B\}$, where *B* is the total number of fuzzy linguistic descriptors.

Step 4. Gather experts' opinion and calculate *the average matrix* $\tilde{Z}$, for factors and subfactors. For each expert, an $n\times n$ non-negative matrix is constructed (*n* represents the number of criteria/subcriteria) as $\tilde{Z}^1=\left[\tilde{z}_{ij}^1\right]_{nxn}$, $\tilde{Z}^2=\left[\tilde{z}_{ij}^2\right]_{nxn}$, ..., $\tilde{Z}^E=\left[\tilde{z}_{ij}^E\right]_{nxn}$.

The process of forming *average matrix* is carried out for both factors and subfactors of provider selection.

Step 5. Calculate *the normalized initial direct-relation matrix* D, for factors and subfactors.

The normalized initial direct-relation matrix for factors (D_{C_k}) and the normalized initial direct-relation matrix for subfactors (D_{c_t}), where value of each element in matrices D is ranged between [0.1], are calculated from average matrices. The calculation is shown below:

$$D_{C_k}=\begin{bmatrix} d_{11,k} & d_{12,k} & \ldots & d_{1K,k} \\ d_{21,k} & d_{22,k} & \ldots & d_{2K,k} \\ \ldots & \ldots & \ldots & \ldots \\ d_{K1,k} & d_{K2,k} & \ldots & d_{KK,k} \end{bmatrix} \quad (1)$$

$$D_{c_t}=\begin{bmatrix} d_{11,t} & d_{12,t} & \ldots & d_{1M,t} \\ d_{21,t} & d_{22,t} & \ldots & d_{2M,t} \\ \ldots & \ldots & \ldots & \ldots \\ d_{M1,t} & d_{M2,t} & \ldots & d_{MM,t} \end{bmatrix} \quad (2)$$

where elements of the normalized initial direct-relation matrix for factors (D_{C_k}) are calculated by the equation

$$d_{ij,k}=\frac{\tilde{z}_{ij,k}}{R_{C_k}}=\left(\frac{z_{ij,k}^{(l)}}{r_{C_k}^{(l)}},\frac{z_{ij,k}^{(m)}}{r_{C_k}^{(m)}},\frac{z_{ij,k}^{(u)}}{r_{C_k}^{(u)}}\right) \quad (3)$$

$$R_{C_k}=\max\left(\sum_{j=1}^{K}\tilde{z}_{ij,k}\right)=\left(r_{C_k}^{(l)},r_{C_k}^{(m)},r_{C_k}^{(u)}\right) \quad (4)$$

and the elements of the normalized initial direct-relation matrix for subfactors (D_{c_t}) by the equation

$$d_{ij,t}=\frac{\tilde{z}_{ij,t}}{R_{c_t}}=\left(\frac{z_{ij,t}^{(l)}}{r_{c_t}^{(l)}},\frac{z_{ij,t}^{(m)}}{r_{c_t}^{(m)}},\frac{z_{ij,t}^{(u)}}{r_{c_t}^{(u)}}\right) \quad (5)$$

$$R_{c_t}=\max\left(\sum_{j=1}^{M}\tilde{z}_{ij,t}\right)=\left(r_{c_t}^{(l)},r_{c_t}^{(m)},r_{c_t}^{(u)}\right) \quad (6)$$

Step 6. Derive *the total relation matrix* T, for factors and subfactors. The total relation matrix T is obtained by utilizing equation $\tilde{T}=\lim_{w\to\infty}\left(\tilde{D}+\tilde{D}^2+\ldots+\tilde{D}^w\right)=\tilde{D}\left(I-\tilde{D}\right)^{-1}$, in which, *I* is an *nxn* identity matrix.

The element of $\tilde{t}_{ij}$ represents the indirect effects that factor (subfactor) *i* had on factor (subfactor) *j*, then the matrix T reflects the total relationship between each pair of factors (subfactors).

Step 7. Calculate the sums of rows and sums of columns of total relation matrices T_{C_k} and T_{c_t}.

The sum of rows and sum of columns of the total relation matrix T_{C_k}, denoted by the fuzzy numbers $G_{C_k,j}$ and $R_{C_k,i}$, respectively.

Step 8. Determine *threshold value α.*

The threshold value α is used to create cause and effect relationship diagrams. The threshold value α, is calculated as the average value of the elements ($\tilde{t}_{ij}$) matrix T , according to equation (7).

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\tilde{t}_{ij}}{N} \tag{7}$$

where N represents total elements number of matrix T .

Step 9. Making of *Cause and Effect Relationship* diagrams (*CER*).

The *CER* diagram is constructed by mapping all coordinate sets of (G_i+R_j, G_i-R_j) to visualize the complex interrelationship and provide information to judge which are the most important factors and how influence affected factors.

Step 10. Establish a *correlation matrix* $A=[f_{kt}]_{C_k\times c_t}$.

The correlation matrix shows the correlation between factors C_k $(k=\overline{1K})$ and subfactors c_t $(t=\overline{1M})$, where

$$f_{kt}=\begin{Bmatrix}1, \ \forall\ c_t\in C_k \\ 0, \ \forall\ c_t\notin C_k\end{Bmatrix},\ (t=\overline{1M},\ k=\overline{1K}) \tag{8}$$

This matrix can be generated by analysts – the decision-makers, as it can be generated on the basis of expert opinion, or application of appropriate methods and techniques.

Step 11. Determine *ideal weights* of factors (w_{C_k}) and subfactors (w_{c_t}).

Ideal weights of factors and ideal weights of subfactors are determined by the equations (9) and (10), respectively.

$$w_{C_k,i}=\left[\left(G_{C_k,j}+R_{C_k,i}\right)^2+\left(G_{C_k,j}-R_{C_k,i}\right)^2\right]^{1/2} \tag{9}$$

$$w_{c_t,i}=\left[\left(G_{c_t,j}+R_{c_t,i}\right)^2+\left(G_{c_t,j}-R_{c_t,i}\right)^2\right]^{1/2} \tag{10}$$

Step 12: Determine the *matrix of ideal weights* (W_{pp}).

Matrix of ideal weights is generated by the equations (11) and (12).

$$W_{pp}=\begin{matrix} & w_{C_k,1} & w_{C_k,2} & w_{C_k,3} & \cdots & w_{C_k,K} \\ w_{c_t,1} & w_{(pp)11} & w_{(pp)12} & w_{(pp)13} & \cdots & w_{(pp)1K} \\ w_{c_t,2} & w_{(pp)21} & w_{(pp)22} & w_{(pp)23} & \cdots & w_{(pp)2K} \\ w_{c_t,3} & w_{(pp)31} & w_{(pp)32} & w_{(pp)33} & \cdots & w_{(pp)3K} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ w_{c_t,M} & w_{(pp)M1} & w_{(pp)M2} & w_{(pp)M3} & \cdots & w_{(pp)MK}\end{matrix} \tag{11}$$

$$w_{(pp)kt}=w_{C_k,k}\bullet w_{c_t,t}\bullet f_{kt},\ (t=\overline{1M},\ k=\overline{1K}) \tag{12}$$

Phase II: Determination of real weights and provider selection

Step 13: Establish a set of potential providers and make their evaluation.

In this step, the set of potential providers is defined first, and then evaluation of each provider by factors and subfactors is performed, wherein a total of P *provider evaluation matrices* are formed (C_i):

$$C_i=\begin{matrix} & C_1 & C_2 & C_3 & \cdots & C_K \\ c_1 & \tilde{l}_{11} & \tilde{l}_{12} & \tilde{l}_{13} & \cdots & \tilde{l}_{1K} \\ c_2 & \tilde{l}_{21} & \tilde{l}_{22} & \tilde{l}_{23} & \cdots & \tilde{l}_{2K} \\ c_3 & \tilde{l}_{31} & \tilde{l}_{32} & \tilde{l}_{33} & \cdots & \tilde{l}_{3K} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ c_M & \tilde{l}_{M1} & \tilde{l}_{M2} & \tilde{l}_{M3} & \cdots & \tilde{l}_{MK}\end{matrix} \tag{13}$$

$$\tilde{l}_{kt}=\begin{Bmatrix}\tilde{l}_{kt}, \ \forall\ f_{kt}=1 \\ 0, \ \forall\ f_{kt}=0\end{Bmatrix},\ (t=\overline{1M},\ k=\overline{1K}) \tag{14}$$

where i $(i=\overline{1,P})$ is ith provider, P is the total number of providers, and $\tilde{l}_{kt}$ corresponding fuzzy value of linguistic descriptor l_b $(l_b\in L)$, which shows the value of the evaluation of *i*th provider by the *k*th factor and the *t*th subfactor.

Step 14: Determine the *matrix of real weights* (W_{sp}), for each provider.

Elements of the real weigths matrix are determined by the equations (15) and (16).

$$W_{sp,i}=\begin{matrix} & C_1 & C_2 & C_3 & \cdots & C_K \\ c_1 & w_{(sp)11} & w_{(sp)12} & w_{(sp)13} & \cdots & w_{(sp)1K} \\ c_2 & w_{(sp)21} & w_{(sp)22} & w_{(sp)23} & \cdots & w_{(sp)2K} \\ c_3 & w_{(sp)31} & w_{(sp)32} & w_{(sp)33} & \cdots & w_{(sp)3K} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ c_M & w_{(sp)M1} & w_{(sp)M2} & w_{(sp)M3} & \cdots & w_{(sp)MK}\end{matrix} \tag{15}$$

$$w_{(sp)kt}=w_{(pp)kt}\bullet\frac{\tilde{l}_{kt}}{B}\bullet f_{kt},\ (t=\overline{1M},\ k=\overline{1K}) \tag{16}$$

Step 15: Calculate provider evaluation scores by subfactors ($O_{(t)i}$).

Provider evaluation scores by subfactors are calculated as the product of the total number of linguistic descriptors (*B*) and the ratio of the sums of elements of real weights matrix (15) and the sum of elements of ideal weight matrix (11), by rows:

$$O_{(c_t)i}=\frac{\sum_{k=1}^{K}w_{(sp)kt}}{\sum_{k=1}^{K}w_{(pp)kt}}\bullet B,\ (t=\overline{1M},\ i=\overline{1,P}) \tag{17}$$

where $w_{(sp)tk}$ is the real weight of *t*th subfactor by *k*th factor, $w_{(pp)tk}$ - ideal weight of *t*th subfactor by *k*th factor, B - the total number of fuzzy linguistic descriptors, i is *i*th provider, and *P* is the total number of providers.

Step 16: Calculate provider evaluation scores by factors ($O_{(k)i}$). Analogously to calculation of the provider evaluation scores by subfactors, provider evaluation scores by factors are also calculated as the product of the total number of linguistic descriptors (*B*) and the ratio of the sums of elements of real weight matrix (14) and the sum of elements of ideal weight matrix (10), but in this case by columns:

$$O_{(C_k)i}=\frac{\sum_{t=1}^{M}w_{(sp)kt}}{\sum_{t=1}^{M}w_{(pp)kt}}\bullet B,\ (k=\overline{1K},\ i=\overline{1,P}) \tag{18}$$

where $w_{(sp)kt}$ is the real weight of *k*th factor by *t*th subfactor $w_{(pp)kt}$ ideal weight of *k*th factor by *t*th subfactor, B - the total number of fuzzy linguistic descriptors, where i is *i*th provider, and P is the total number of providers.

Step 17: Calculate *the overall evaluation score* and rank providers. Based on the matrix of ideal (W_{pp}) and the matrix of real (W_{sp}) weights of provider, using the equation (19), the overall evaluation score for each of P provider (O_i) is calculated.

The total score of each provider depends on its evaluation scores by factors and subfactors, or the sums of ideal weights and the sums of related real weights:

$$O_i = \frac{\sum_{k=1}^{K}\sum_{t=1}^{M} w_{(sp)kt}}{\sum_{k=1}^{K}\sum_{t=1}^{M} w_{(pp)kt}} \bullet B \tag{19}$$

where $w_{(sp)kt}$ is the real weight of *t*th subfactor by *k*th factor $w_{(pp)kt}$ ideal weight of *t*th subfactor by *k*th factor B - the total number of fuzzy linguistic descriptors, i is *i*th provider, and P is the total number of providers.

3. APPLIED METHODOLOGY

FCRIP model of the providers selection was tested in the case of four providers. Ten transportation experts participated in the process of model testing. The experts opinions were used to calculate the ideal ponders of factors and subfactors.

The selection criteria are classified into five classes, called factors $(C_K;\ k=\overline{1,5})$: Total cost, Reliability, Business excellence, Customer service and Green image. Within the defined factors, 15 sub-factors $(c_t,\ t=\overline{1,15})$ have been identified: Competitive charges (c_1), Pricing flexibility (c_2), Quality certifications and IT support (c_3), Time line reliability (c_4), Security and safety (c_5), Equipment availability and condition (c_6), Responsiveness and flexibility (c_7), Geographic coverage (c_8), Experience (c_9), Company stability (c_{10}), Trustworthiness (c_{11}), Complaint handling (c_{12}), Cooperation with customers (c_{13}), Pollution control (c_{14}) and Environment management (c_{15}).

As ten experts were involved in the study, after collecting the questionnaires, a total of ten matrices for factors and ten matrices for subfactors were obtained. After determining the average matrices (Z_{C_k} and Z_{c_t}), the normalized initial direct-relation matrix D is calculated. From matrices D_{C_k} and D_{c_t}, the elements of total relation matrix T are calculated.

Ideal weights of factors w_{C_k} (Table 2) and subfactors w_{c_t} depends on the sums of the elements of matrices T_{C_k} and T_{c_t} by rows and the sums by columns.

Table 2. Ideal weights of factor (w_{C_k})

	$G_{C_k,i}+R_{C_k,i}$	$G_{C_k,i}-R_{C_k,i}$	w_{C_k}
C_1	(2.63,3.82,4.90)	(-0.39,-0.42,-0.46)	(2.66,3.85,4.92)
C_2	(3.15,4.26,5.42)	(0.33,0.22,0.19)	(3.17,4.26,5.43)
C_3	(2.65,3.90,5.02)	(-0.36,-0.34,-0.34)	(2.68,3.92,5.03)
C_4	(1.75,3.01,4.01)	(-0.74,-0.65,-0.7)	(1.90,3.07,4.07)
C_5	(3.02,4.16,5.18)	(1.16,1.19,1.30)	(3.23,4.32,5.34)

Overall evaluation scores are obtained using the equation (19), based on the sums of all elements in the matrices of real and ideal weights, Table 3.

Table 3. Overall evaluation scores and ranking

Provider	Fuzzy score	Crisp score	Ranking
Provider 1	(2.96,3.50,3.94)	3.467	6
Provider 2	(3.07,3.62,4.05)	3.583	3
Provider 3	(3.06,3.61,4.02)	3.561	4
Provider 4	(2.94,3.53,3.94)	3.469	5
Provider 5	(3.27,3.79,4.23)	3.764	1
Provider 6	(2.85,3.40,3.88)	3.378	7
Provider 7	(3.24,3.75,4.23)	3.739	2

Table 3 shows that preference should be given to Provider 5 over Provider 7.

4. CONCLUSION

This paper presents a new fuzzy multi-criteria selection model (FCRIP model), in which providers are differentiated on the basis of similarity with the perception of a desirable (ideal) provider. All provider ratings are based on the evaluation of selected factors and subfactors representing criteria of provider differentiation. The good sides of FCRIP models are reflected in the similarity of its methodological basis with the logic of decision-making in the selection of one alternative from a set of alternatives. Accordingly, this model is adaptive to all the problems of multi-criteria and multi-attributive decision-making.

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ACCIDENTAL RISK ANALYSIS FOR RAIL TRANSPORT OF DANGEROUS GOODS

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***Abstract** – This paper presents the identification and analysis of causal factors that cause accidents in the rail transport of dangerous goods. The proposed model of risk assessment is based on knowledge of the conditional probabilities of events that precede the realesing of hazardous substances from the tank cars. The probability of occurrence of accidents requires the definition of conditional distributions related to the position of the train derailment, the number of derailment wagons, as well as tank cars and tank cars where the releasing occurred. Distribution of conditional probabilities are defined on the basis of statistical analysis of accidents in the software module Analytic Solver Platform V2016-R2, according to the database FRA REA for last ten years (2006 - 2015). A procedure is proposed for the application of the presented probabilistic-statistical model in accordance to the variation of transport conditions, condition of the vehicle and railway infrastructure.*

Keywords – Railway accident, dangerous goods, risk assessment, derailment, tank cars.

1. INTRODUCTION

The intensive development of chemical process industries requires effective engagement of transportation capacity within the system of hazardous materials. Modern conditions of production process are supported with flexible logistics systems where the transport subsystems have the important role. The choice of means of transport is carried out on the basis of technological, transport and economic indicators according to the type (class) of hazardous substances. Therefore, the transport risk is treated as a dominant criterion in the selection of transport modalities.

The comparative advantages of rail transport have influenced to its significant share in the land transport of dangerous goods on medium and longer distances. The safety aspect of these facts should be interpreted in terms of reduction transport risk within individual and socially acceptable limits, and not as the possibility of its complete elimination. For example, transport of liquid nitrogen through rail and road tunnel monitors risk that can not be avoided in an economically acceptable way, but the risk of congestion is slightly lower for the rail transport compared to road for the same type and quantity of hazardous substances and thus becomes more acceptable with individual and social aspects of safety [1]. The main cause that leads to accidents in the rail transport of dangerous goods refers to the phenomenon of derailment [2]. Although the risk assessment of railway accidents, over the past decades, have been the subject of numerous studies, it should be noted that the most significant results have been achieved in recent years, mainly thanks to the FRA REA database [3].

Two basic approaches used in previous research train derailment include simulation models and statistical analysis [2]. The simulation models related to the non-linear dynamic response to the movement of vehicles on specific driving conditions and environments, and are based on a detailed interaction of wheel-rail. Analyzed are also the influence of friction torque due to the traction device, sluggish operation of the brake force and speed of the train to derailment the wagon number. Subsequent studies have conducted the effects of supplementing simulation independent frees movement of wagons due to failure of the towing devices [4-5]. Contemporary trends in the dynamic simulation and analysis of train derailment are based on the use of software packages, such as SYMPACK [6].

Software simulation train derailment due to earthquakes have special significance during transport

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dangerous substances in earthquake areas, such as eg. Japan, California and similar region [7]. Transport accidents of this kind are quite rare events (extremely low frequency of occurrence), but their formation following catastrophic consequences.

Statistical models of risk assessment in the transport of dangerous goods are based on data from extraordinary events occurring due to the derailment of the train taken from appropriate sources (databases). Saccomanno and El-Huge on the basis of truncated geometric distribution developed model estimates the average number of derailed vehicles depending on the speed of movement, the residual length of the train and accident causes [8-9]. Significantly improve the flow of statistical models is carried out through a modification proposed by Bagheri et al. [10]. Using the methodological approach from previous studies, Lui et al. showed that the most common cause of broken rail derailment of freight trains on the main lines of class I in the US [11]. The average number of derailment vehicles due to broken of rails is 14, while in the case of damage to wagons bearing that number is 7. Damage beds represent a potentially serious cause of a train derailment than the ruptured rail, or statistical analysis shows a favorable condition for this causative factor. Previous result is best illustrated by the obvious importance of statistical models compared to the simulation approach, which does not have the adequate techniques to identify these or similar parameters.

Studies by the statistical method to treat a spectrum of development and implementation, such as [8-10] are based exclusively on the use of FRA REA database [3] and therefore the results of such research are limited to US railways. Implementation of statistical methods to countries outside the US require the use of appropriate data bases, but failing that we have very low coverage for most national railways worldwide. It should be borne in mind that the application of statistical methods is not enough only the existence of any database, but it must be designed at least approximately as FRA REA in order to be represented all aspects of the accident (number of derailed vehicles, point of derailment, etc.), and what is not the case with the European database EUROSTAT [11]. In this regard, it should be emphasized that according to the research database of transport accidents in the Iranian railways benefits CRISP-DM methodology to extract the unknown relationship between the available data [12]. The significance of this methodology is reflected in the potential compensating possibly missing data on accidents (eg. doubts about the cause) with the aim of achieving more effective preventive measures.

2. FACTORS OF TRAIN DERAILMENT

The phenomenon of the derailment of the train is a complex problem that requires a systematic approach to the analysis of influencing factors, especially when it comes to the transport of dangerous goods. Derailment are a common type of railway accidents in freight transport in the US [2], which is in respect of dangerous goods initial event for the eventual emergence of a domino effect [13]. Accidental risks of rail transport of hazardous materials is much less favorable compared to the road in the context of domino effect. Therefore, risk assessment must include a process of escalation of accidents which is very pronounced in the rail transport of flammable and explosive substance (petrol, LPG, etc.) and key role in this process has the derailment. A typical example is the railway accident in Viareggio (2009) when the derailment occurred due to an explosion 45 tones of LPG where 13 persons were injured, while material losses estimated at € 32 million [14].

The main parameters that influence the derailment include are: the speed of the train, class track, the length of the train and the point of derailment. Interdependence of these parameters affects the complexity of the derailment which this phenomenon becomes more difficult to identify and adequate assessment of accidental risks. The most pronounced is the dependence between speed and class of train tracks. Smaller classes give the track a larger number of derailment at low speed, while the speed increases we have a tendency of decreasing number of derailment. Number derailment at a higher class track increases with increasing speed.

Practical experience has shown that the larger the length of trains accompanied by greater likelihood of derailment. This hypothesis was confirmed by statistical analysis conducted by FRA REA database. Trains are characterized by small length less risk of derailment, but then brings into question their viability. This is one of the very obvious why the situation does not aspire to the complete elimination of risk, but by reduction to an acceptable level of which has previously been discussed. In this regard, the procedure criteria optimization determines the optimal length of the train derailment that minimizes the risk to an acceptable level.

Previous studies have shown that the first railway vehicle is usually subject to a freight train derailment near. Liu et al. showed that the point of derailment of the train may be best approximated by Beta distribution, using K-S test on a set of common distribution {Normal, Logistic, Weibull, Uniform, Beta, Gamma} [15]. Through this distribution can be identified causes of the train derailment and for frontal position it is mainly broken rails, while unifrom distribution corresponds to failures of wagon.

3. PROBABILITY MODEL FOR ACCIDENTAL RISK ASSESSMENT

Probabilistic models of risk assessment are based on the using of the conditional probability distribution of the events that preceded the accident, which are formed in accordance with the relevant statistical data. The probability of occurrence of chemical accidents due to derailment of a train wagon for heterogeneous composition is given by the conditional probability formula [16]:

$$P(X_l, X_k, X_j, X_i) = P(X_l \mid X_k, X_j, X_i) \cdot P(X_k \mid X_j, X_i) \cdot P(X_j \mid X_i) \cdot P(X_i) \quad (1)$$

The methodology to define the conditional probability is completely independent from the literature with the same probabilistic framework and source of statistical data. This allows obtaining indifferent results for identical or nearly the same input parameters in relation to recent studies [15]. The importance of this approach is the result of existing verification and identification of latent risk factors related to the derailment.

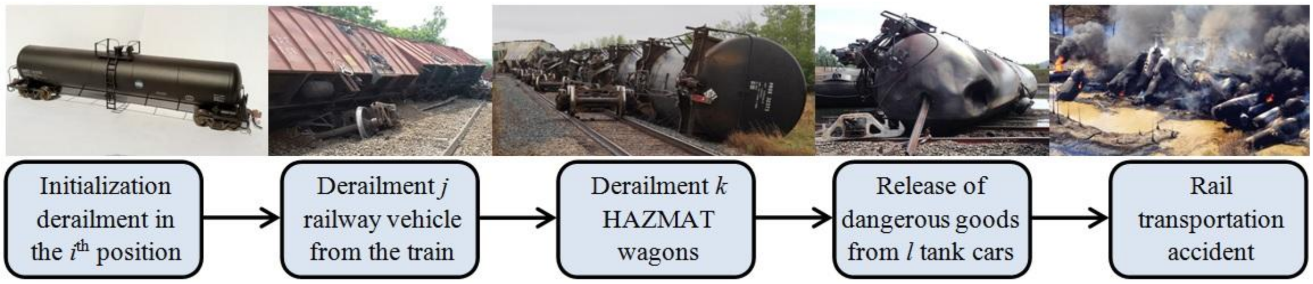

Fig.1. The causal dependence of events that precede the railway accident involving hazardous substances

Discrete random probability distribution are:

X_i – derailment initiated in the i^{th} position of the train,
X_j – derailment of j railway vehicles 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 vehicle,
j – the total number of derailed the cars $(0 < j \leq n)$,
k – the number of derailed the tank cars $(0 \leq k \leq j)$,
l – the number of tank cars exposed to release or leak dangerous substances $(0 < l \leq k \leq j \leq n)$,
n – total number of railway vehicles $(n \geq 2)$.

The outcome of the chemical contamination depends on the potential emergence of sequential events that precede it (*Fig. 1*) and are interpreted through the mathematical probability of partial with the following meanings:

Discrete distribution $P(X_l \mid X_k, X_j, X_i)$ is related to conditional probability of occurrence of chemical accidents provided that the derailment was initiated on the i^{th} position of the train and if there were k tank cars from a total of j derailed railway vehicle. Discrete distribution $P(X_k \mid X_j, X_i)$ is the conditional probability of derailment tank cars provided that the derailment was initiated on the i^{th} position of the train causing the derailment of j railway vehicles. Discrete distribution $P(X_j \mid X_i)$ is the conditional probability of derailment j railway vehicles from the composition of the train provided that the derailment was initiated on the i^{th} position. Discrete distribution $P(X_i)$ is the probability initialization derailment in the i^{th} position of the train.

The formation of discrete distributions referred to in (1) is carried out according to data from FRA REA database for the period 2006-2015. Generating conditional probability distribution is done in the software module Analytic Solver Platform-V2016 R2.

4. RESULTS

Distribution of conditional probabilities of (1) are given in Fig. 2-5, and representing a sequential series of events preceding the occurrence of in rail accidents.

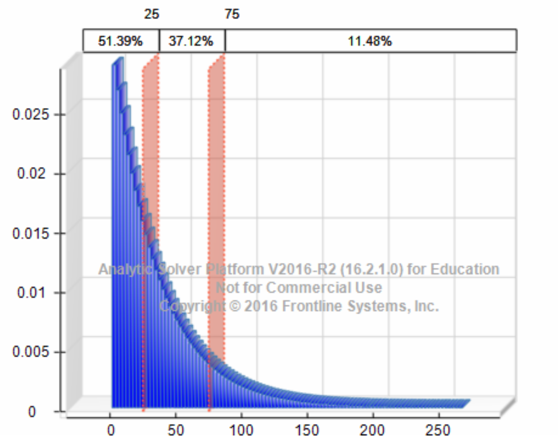

Fig.2. The distribution of derailed train position

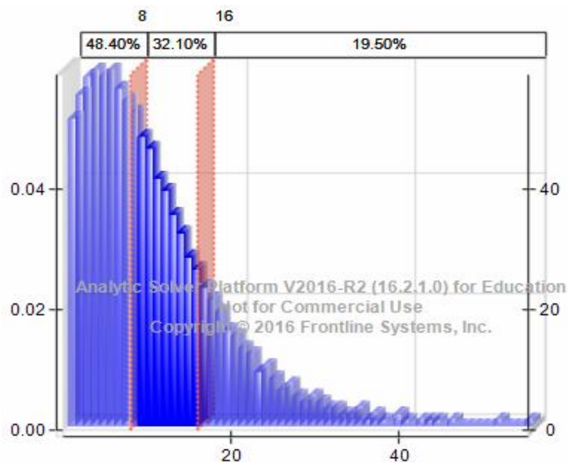

Fig.3. Distribution of the number of derailed cars

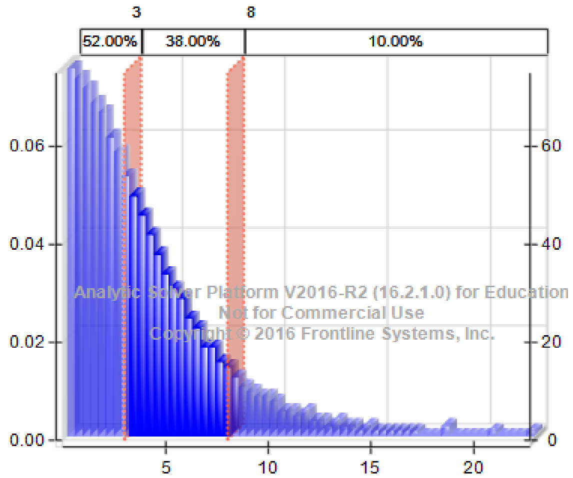

Fig. 4. Distribution of derailed HAZMAT cars

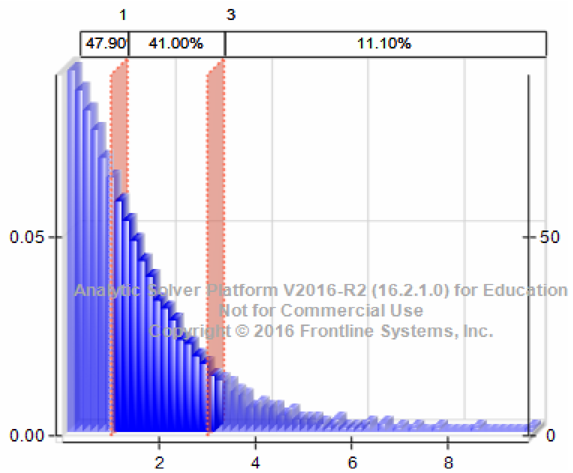

Fig. 5. Distribution of tank cars with releasing

The probability of rail accidents during transport HAZMAT is obtained from (1) under the conditions of *Fig.* 2-5 and eg. for $P(X_2, X_6, X_{10}, X_1)$ is $1{,}23 \cdot 10^{-5}$.

5. CONCLUSION

Derailment plays a significant role in transport accidents, while the presence of flammable and explosive substances affect to their escalation. Their mutual influence of the parameters of derailment is not enough identified, so the latent factors contributing to greater uncertainty about the potential occurrence of accidents or affect the higher level of risk. Adequate risk assessment requires the integration of simulation techniques, statistical analysis and QRA model in the methodological framework for posterior updates of the level of risk. The development of such methodological approaches requires the improvement of existing statistical and probabilistic model and its implementation for specific exploitation conditions.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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APPLICATION OF FUZZY AHP METHOD FOR PROFIT ANALYSIS OF RAILWAY OPERATORS WITH PSO

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Abstract *– Performance analysis of operators of passenger traffic in the RS showed that the volume of passenger transport is in constant decline for 10 years, it also showed that the offer, over the number of trains, has been drastically reduced as well as the quality of services. It is particularly important that the operator from year to year records a negative balance of business with the average annual loss of 6.5 million KM. The way out of the current unfavorable situation in the sector of passenger traffic is the use of OJP based on Regulation 1370/2007. The methodology of solving the problem is based on: an increase in revenues from agreements on OJP and direct ticket sales, as well as reducing expenses, and operating costs. In order to solve the problems seven realistically possible variants were identified. They are based on a combination of these methods. The paper defines the criteria for selecting the best varieties and the criteria of pricing model weight coefficients. Decisions were conducted using the extended AHP method, ie. Fuzzy AHP comparing criteria based on fuzzy triangular numbers determining the normalized weight coefficients of the criteria.*

Keywords – operators of passenger traffic, increase revenue, fuzzy AHP, railway of Republic Srpska.

1. INTRODUCTION

Multi-criteria methods for decision making are used to resolve a large number of problems in all spheres of business, and they represent an area that is developing rapidly, primarily due to a large number of methods that have been developed, particularly within the last decade.

There are numerous examples for the application of Multi-criteria decison methods (MCDM) in traffic and transport. A wide range of application of MCDM methods can be seen in the models for optimal pedestrian crossing [1], measuring of the passengers service quality [2], the prioritization of the investments in transport infrastructure [3], and model for creating a design and construction of railway infrastructure [4].

2. PROBLEM IDENTIFICATION

The analysis of the passenger traffic subsystem showed the following characteristics:

- from 1996 until today the number of passengers has been in constant decline,
- the number of passenger trains has decreased in domestic traffic by 28 trains (63%), in inter-entity transport by 18 trains (20%), , and by 8 trains in international transpor (11%),
- The railway fee for the infrastructure in domestic services amounts to 4,176,295 KM (66%), in inter-entity transport amounts to 601,836 KM (9%), and in international transport amounts to 1,603,022 KM (25%).
- number of passengers 634.397,
- revenue 1.971.574 KM,

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- total cost of traction 8.403.657. KM,
- total loss 6.432.082 KM

2. PROBLEM SOLVING METHODOLOGY

The problem solving methodology is based on: increase in revenue from direct ticket sales and increase in revenue from agreements on OPT, reduction in expencing, i.e. operating costs.

The expected result of the mentioned activities according to the given methodology should be sustainable business operations. The aim of the problem solving is to bring RRS as the operator in passenger traffic into the domain of positive operations, thus providing the necessary conditions for successful operation at a liberalized transport market. In Figures 1 and 2 shows the proposed plan of operations for the solution of the problem, that is characterized by the approach to problem solving based on real costs and potential revenues from the mode of action.

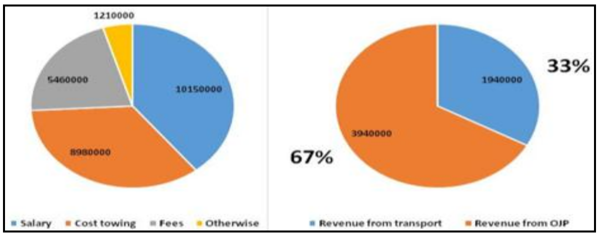

Fig.1. Business Plan for solving problems (cost and revenue)

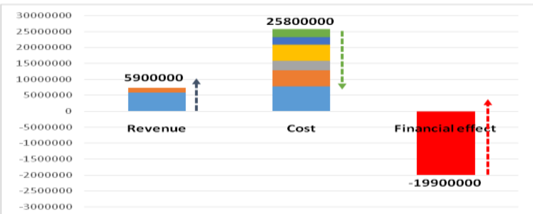

Fig.2. Problem solving methodology

3.1. Variant solutions of the problem

In order to resolve the problem, seven realistically possible variants, have been identified, namely:

- Variant 1: Reduction in operating costs

Variant 1 is characterized by the reduction of operating costs to the level of acceptable negative financial balance sheet, or even to the level when costs are almost equal to revenues which do not substantially change compared to the current situation. Essentially, the aim of this function is to minimize the function of the costs:

$$T = f(T_1, T_2, T_3, \ ..... \ , T_n) \rightarrow \min. \qquad (1)$$

- Variant 2: Increase in revenue from ticket sales

Variant 2 is characterized by the increase in revenues from the sale of tickets, while subsidies, i.e. income from the execution of transport services contracts based on OPT as well as the expenses are unchanged compared to the current situation. The aim of this function is, essentially, to maximize the function of the revenue of the first group (ticket sales):

$$P_1 = f(P_{11}, P_{12}, P_{13}, \ ..... \ , P_{1n}) \rightarrow \max. \qquad (2)$$

- Variant 3: Increase in ticket revenue and reduction in operating costs

Variant 3 is characterized by the increase in revenues of the sale of tickets, while subsidies, i.e. income from contracts on OPT remain unchanged compared to the current situation, and the operating costs are reduced. The aim of this function is to maximize the function of the revenue of the first group (ticket sales) and to minimize costs:

$$P_1=f(P_{11},P_{12},P_{1n}) \rightarrow max \wedge T=f(T_1,T_2,T_n) \rightarrow min \qquad (3)$$

- Variant 4: Increase in revenue from OPT services

Variant 4 is characterized by the increase in revenue from subsidies, i.e. from transport services contracts based on OPT, while the revenues from ticket sales as well as costs remain unchanged compared to the current situation. The aim of this function is, essentially,to maximize the function of the revenue of the second group (from OPT services):

$$P_2 = f(P_{21}, P_{22}, P_{23}, \ ..... \ , P_{1n}) \rightarrow \max \qquad (4)$$

- Variant 5: Increase in revenue from OPT services and reduction in operating costs

Variant 5 is characterized by the increase in revenue from the execution of transport services contracts based on OPT; revenues from ticket sales are unchanged compared to the current situation, and operating costs are reduced. The aim of this function is to maximize the function of the revenue of the second group (from OPT services) and to minimize the costs:

$$P_2=f(P_{21},P_{22},P_{2n}) \rightarrow \max \wedge T=f(T_1,T_2,T_n) \rightarrow \min \qquad (5)$$

- Variant 6: Increase in revenue from ticket sales and OPT services

Variant 6 is characterized by the increase in revenue from ticket sales and subsidies, i.e. increase in revenue from the execution of transport services contracts based on OPT while the costs remain unchanged compared to the current situation. The aim of this function is, esentially, to maximize the sum of functions of the first group and the second group.

$$P_1+P_2=f(P_{11},P_{12},P_{1n})+f(P_{21},P_{22},P_{2n}) \rightarrow \max \qquad (6)$$

- Variant 7: Increase in revenue from ticket sales and OPT services and reduction in costs

Variant 7 is characterized by the increase in revenue from ticket sales and subsidies, i.e. by the increase in revenue from the execution of transport services contracts based on OPT, with accompanying reduction in costs. The aim of this function is that difference between revenue function and costs function should become positive.

$$P_1+P_2-T=f(P_{11},P_{12},P_{1n})+f(P_{21},P_{22},P_{2n})-f(T_1,T_2,T_n)\geq 0 \quad (7)$$

All variants are shown in Figure 3.

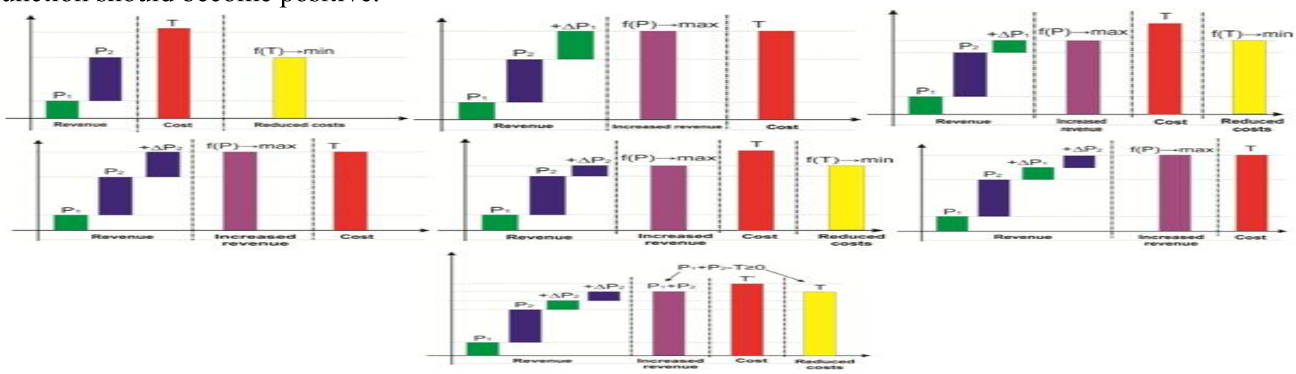

Fig.3. All possible variant

3.2. Identification of evaluation criteria

Criterion is a measure that shows just how adequate is each variant for achieving the goal. Accordingly, it is necessary to determine the criteria based on which we can select the optimal solution that shows advantages compared to other solutions.

The selection of an optimal variant depends on many factors. A number of factors can indeed be quantified. However, a number of relevant factors are not measurable or their quantification is rather complex. Further, a large number of criteria means that the optimization process becomes very complicated.

When defining these criteria, we must take into account only those that exert real influence on the choice of the optimal variant. Therefore, in the development of this methodology as the criteria adopted following sizes:

1. **To what extent is the proposed variant feasible:** This criterion significantly influences the choice of the best variant. The solution depends on many factors, but it also depends on a number of actors in the implementation of the Plan on Public Transport Services (PPTS) using the PSO system. Operators and socio-political community function in the market represented by passengers and their requirements. The interests of these actors are often contradicting. Because of this, it is the reality of the feasibility of the proposed variant that often plays a decisive role in determining the strategy for dealing with the problem.

2. **Public authorities – the budget size**: Essentially, this criterion applies to the most important actor in the PSO. It defines the scope of the application of PSO, as well as the desired level of quality of service. However, often the wishes and requirements of the operator are greater than the real possibilities of the budget, so there arises the problem of under-compensation which negatively affects operator's business activities, quality of service, competition in the market (private operators avoid to participate in public procurements for PSO). This is not a rare case even in the economically most powerful countries of the EU.

3. **Operators's ability**: This criterion shows to what extent the operator is able to face all the challenges that arise in the implementation of PSO. On the one hand,this refers to the rational and efficient operations at minimal cost, and on the other hand it affects the ability to increase the number of passengers offering attractive and high quality services which increase direct revenues from ticket sales. Together with the budget possibilities of public authority for whose interest PSO is actually implemented, these two elements mostly influence the technical and technological, organizational and economic aspects of the implementation of PSO.

4. **The effect of realization:** As a criterion, the effect of realization can be viewed from several aspects. The first aspect concerns the point of view of financial interest, mainly the operator's interest, but it also concerns the socio-political community whose interest is that PSO is performedby a technically, technologically and financially stable company. Another aspect concerns passengers or residents of the region in which the PSO system is organizedbecause of a reliable, high-quality and financially acceptable (according to ticket price) public transport. Further, there is the interest of public authorities, businesses and even the population due to increased accessibility of the region, as well as other side effects.

5. **The period of realization:** In the given circumstances, certain variations may represent a common interest, e.g. of public authorities and operators, but it might take unacceptably long for these variations to produce results. In such circumstances the operator's position in the market is threatened, and the public (passengers) might become dissatisfied with the transport system. This means that it is necessary to seek different strategic decisions (other varieties) in order to solve present problems.

3.3. Fuzzy AHP method

The theory of fuzzy sets was first introduced by [5], the application of which enabled decision makers to effectively cope with uncertainties. In general, the fuzzy sets use triangular, trapezoidal and Gaussian fuzzy numbers. According to [6], fuzzy set is a class of objects characterized by membership functions, in which each object is given a degree of membership on the interval (0.1). When it comes to decision making by using fuzzy AHP methods, different approaches have been developed as an expanded fuzzy AHP method, which is based on triangular fuzzy numbers [7], fuzzy preference programming [8], logarithmic fuzzy preference programming, originating from the above mentioned approach by its expansion, developed by [9]. Fuzzy AHP method applied in this paper consists of four steps that are defined in [7].

3. EVALUATION CRITERIA

For the possibility of of variation the impact of certain criteria were introduced weights. Under conditions where the coefficients have the same impact on the selection of optimal variants of their weights must have the same value. A higher value ratios mean higher impact criteria.

Each criterion is assigned a relative weight ratio. This relative weighting coefficient is practically defines the importance of each criterion. The sum of weights must be one. The criteria are compared with each other on the basis of linguistic stage of the scale defined in [7].

Tab. 1. Comparison criteria by three experts

		C_1	C_2	C_3	C_4	C_5
C_1	E_1	(1,1,1)	(3/2,2,5/2)	(5/2,3,7/2)	(1,3/2,2)	(2,5/2,3)
	E_2	(1,1,1)	(1,3/2,2)	(2,5/2,3)	(1,3/2,2)	(5/2,3,7/2)
	E_3	(1,1,1)	(1/2,1,3/2)	(3/2,2,5/2)	(1,3/2,2)	(2,5/2,3)
C_2	E_1	(2/5,1/2,2/3)	(1,1,1)	(3/2,2,5/2)	(1/2,2/3,1)	(1/2,1,3/2)
	E_2	(1/2,2/3,1)	(1,1,1)	(1,3/2,2)	(1/2,1,3/2)	(2,5/2,3)
	E_3	(2/3,1,2)	(1,1,1)	(1,3/2,2)	(1/2,1,3/2)	(3/2,2,5/2)
C_3	E_1	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(1,1,1)	(1/3,2/5,1/2)	(1/2,2/3,1)
	E_2	(1/3,2/5,1/2)	(1/2,2/3,1)	(1,1,1)	(1/2,2/3,1)	(1,3/2,2)
	E_3	(2/5,1/2,2/3)	(1/2,2/3,1)	(1,1,1)	(2/3,1,2)	(1/2,1,3/2)
C_4	E_1	(1/2,2/3,1)	(1,3/2,2)	(2,5/2,3)	(1,1,1)	(3/2,2,5/2)
	E_2	(1/2,2/3,1)	(2/3,1,2)	(1,3/2,2)	(1,1,1)	(2,5/2,3)
	E_3	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,1,3/2)	(1,1,1)	(3/2,2,5/2)
C_5	E_1	(1/3,2/5,1/2)	(2/3,1,2)	(1,3/2,2)	(2/5,1/2,2/3)	(1,1,1)
	E_2	(2/7,1/3,2/5)	(1/3,2/5,1/2)	(1/2,2/3,1)	(1/3,2/5,1/2)	(1,1,1)
	E_3	(1/3,2/5,1/2)	(2/5,1/2,2/3)	(2/3,1,2)	(2/5,1/2,2/3)	(1,1,1)

Fuzzy importance of criteria is calculated through the geometric mean of the responses of experts [10], as shown in the following table.

Tab. 2. Fuzzy important weight of the criteria calculated by taking geometric mean

	C_1	C_2	C_3	C_4	C_5
C_1	(1,1,1)	(0.909,1.442,1.957)	(1.957,2.466,2.972)	(1,1.5,2)	(2.154,2.657,3.158)
C_2	(0.511,0.693,1.101)	(1,1,1)	(1.145,1.651,2.154)	(0.5,0.874,1.31)	(1.145,1.71,2.241)
C_3	(0.336,0.405,0.511)	(0.464,0.606,0.874)	(1,1,1)	(0.481,0.644,1)	(0.630,1,1.442)
C_4	(0.5,0.667,1)	(0.693,1,1.587)	(1,1.554,2.08)	(1,1,1)	(1.651,2.154,2.657)
C_5	(0.317,0.376,0.464)	(0.446,0.585,0.874)	(0.694,1,1.587)	(0.376,0.464,0.606)	(1,1,1)

Applying the steps of fuzzy AHP method defined in [7] are obtained following results.

W=(0,41;0,24;0,05;0,27;0,03)

4. CONCLUSION

According to the methodology applied in this work the most important criterion for the evaluation of the defined variants is the first criterion, ie. reality presentation of the proposed variants, while the period of realization takes second place and can significantly influence the selection of the best varieties. Future research related to this work represent the application of some of the methods for decision making in combination with fuzzy logic for evaluating and ranking proposed variants thereof.

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TIMETABLE INTEGRATION ON THE BALKANS

Kornél NAGY [1]

Abstract – *According to a CER report, 31,6% of train tickets were sold through innovative sales channels (websites, mobile apps)in 2013. Today online sales makes more than 60% of ticket sales in Europe. This tendency is more expressed in case of disruptive transport businesses like the renaissance of long distance bus transport in Western Europe. They build their strategy as low cost land transport operators implementing the cheap airlines model for internet ticket sale. Europe is converging to the market set up where competing bus companies take a large share in transport business so far reserved only for railways. Blablacar the successful French ride sharing service provides its service all around the world exclusively online and in most of the countries like in Serbia, for free of charge. Where are the railways in our region on the passenger market? What is their answer for a completely changed market set-up? These are the questions, this paper would like to address using smart IT tool for modelling timetable, tariff and reservation data integration in a multimodal environment.*

Keywords –Timetable, Ticketing, Data integration, Journey planner, Polazak.rs

1. INTRODUCTION

Today we have less technical barriers on railways in heavy infrastructure term than in their soft infrastructure, like IT systems. As an example, technically speaking, any average electric locomotive in the region could drive a Budapest - Nis route. However to purchase a Nis-Sofia ticket online is a bigger challenge then to pull through a diesel loco between these cities. Fragmented traffic management and distribution systems still maintain those barriers which were aimed to be destroyed by heavy infrastructure investments. It is not because railwaymen do not use smartphones and do not use journey planner applications, it is exactly because they do and they understand them very well. Incumbent railway companies do not want to share what they had not to –ever in their history. As people until the second millennium mainly purchased their tickets on railway stations, railway companies had never had to pay big amount of commission to third party ticket vendors. Between national railways companies there were and still there are established compensation schemes in international ticket sale, but we are currently in the third decade of internet era where consumption patterns have been completely changed and the business is not based on odd compensations mechanism but on direct revenue management.

It is easier today to book a Warsaw-Singapore flight ticket from Horgos, than to buy a Paris – Beograd train ticket at Gare Lille Europe.

How could it happen that heavy machines in the air, consuming tremendous amount of fuel are more competitive than rails, and make their 90% of turnover on international routes – even competing with trains, while railways are rarely able to perform 10% of international traffic sale in their global operation. Railways often say their business is in domestic transport and international connections have no priority. It is not always true. There are successful companies and services like Eurostar, Thalys, Thello… focusing on highly frequented capitals on expensive infrastructure with expensive rolling stock. Eurostar`s success is as much in its railway excellence as in its distribution management - being even visible in air booking GDS systems.

Well, what can we do in the region to create our star service on existing infrastructure in given conditions?

Let`s take as an example the Beograd-Moscow train line with its Bar and Varna direct coaches. We can`t book online any Bar - Budapest or Sofia-Warsaw ticket, not to mention the regular Beograd-Moscow connection. Timetables are already available in any of the involved RUs but one thing is common, there is no ticket sale for any above mentioned routes. Railways don`t feel the need because anyway they are not well positioned in the google internet. They keep their internet domains as virtual stations without marketing and even without commercial functions, like international ticket sale. There is no real intention to develop international rail routes as their operation in current circumstances is complicated and not competitive with alternative transport modes. As long

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as railways cannot come out with commercial offers like online air booking systems, there will be an under used massive infrastructure with less and less passengers. New generations are connected to their electronic gadgets more than ever. If your routes are not listed in the huge competition of air and bus services, your lines are invisible. Teenagers today first access to internet with mobile devices and they apply behaviour patterns what is completely different than those generations who experienced internet first on personal desktop computers.

Where our trains are in the mobile era and how can Railway Undertakings capture a market share on the exclusive shopping area reserved by big online ticket distribution platforms?

2. WHAT IS THE PURPOSE OF TIMETABLE INTEGRATION?

EU regulators want to see Tallinn-Lisbon single train ticket purchased on centralized railway booking platforms, where anyone can purchase train tickets as we do it for flights. For one it might seem still like a naïve dream in current circumstances, but it is not anymore the future but the present day when success is depending on smart solutions for distribution. Railways have the traffic operation excellence but they need to acknowledge they failed in distribution in the digital era.

Railways have intelligent tools in place like the UIC hosted timetable database MERITS [1], where all European railways feed their data with an access to the global timetable data set. The only problem is that this database is accessible only for UIC members and not for third parties, like ticket vendors. The same is applicable for Prifis [2], which is the database for ticket prices and tariffs. These systems so remain hardly accessible for newcomer ticket vendors and their disruptive technologies. If railways want to keep pace with air and bus competition simply they have to be present on those market places where these competitors generate their biggest turnover. Timetable, tariff and reservation data need to be integrated and accessible for the whole business ecosystem in distribution, as it is regulated by TAP TSI[3], in order to provide easy accessible connections, prices and booking options to all interested customers, as it is required by the Passenger Rights Regulation [4].

3. WHAT IS TIMETABLE INTEGRATION?

3.1. TIMETABLE DATA INTEGRATION

We have to differentiate timetable data integration from timetable integration.

In first case we speak about timetable data delivered by different railway undertakings for the same railway line, like the mentioned Moscow-Beograd train. Data integration is needed to correct all incorrectness occurring in the timetables of participating railways. These mistakes concern mainly the departure/arrival times on border crossings and third countries, train composition marking and in some cases the days of traffic. During data integration, it is essential to properly indicate the train numbers in different sections of the journey as some journey planners could treat different train numbers as separate timetables and so indicating those as journey with interchange.

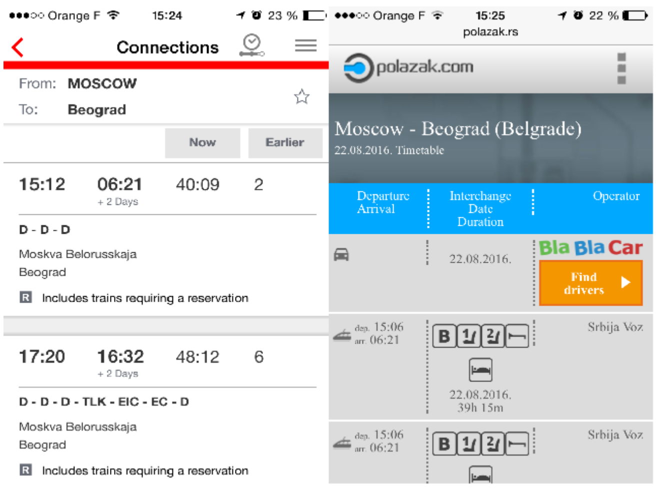

Fig.1. Results of the same search requests in DB journey planner (the only direct train is not indicated) and Polazak.rs (indicating as a direct train after train number integrations)

This is a very technical integration phase, visible only for those experts who deal with the problem, however essential for potential customers. Timetable data integration is more visible for average customers when it comes in multimodal environment.

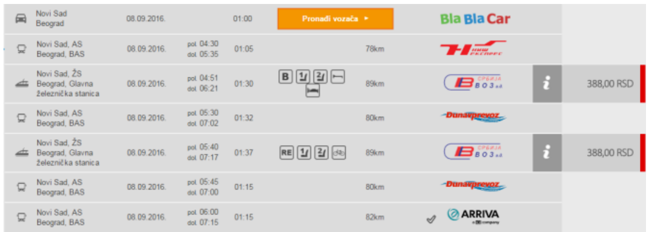

Fig.2. Results of a search request for Novi Sad – Beograd on the multimodal platform Polazak.rs (offers for ride-sharing, bus and train)

In this context data integration means to put together timetables of different transport modes in order to list them according to selected principle (departure/arrival time, length of trip, direct line, price... etc.). It means timetables have to follow the same standard and form to be displayed in journey planners. This data integration not only gives full offer on a selected route to customers but it is a useful tool to develop transport services for all those who are involved into transport planning.

3.2. TIMETABLE INTEGRATION

Timetable integration is already the phase when operators or public authorities plan connecting services or agree on common ticketing principles. Through ticketing provides plenty of possibilities to extend existing services without any infrastructure and rolling stock investments. Connecting different transport services of the same operator can significantly extend the number of available connections.

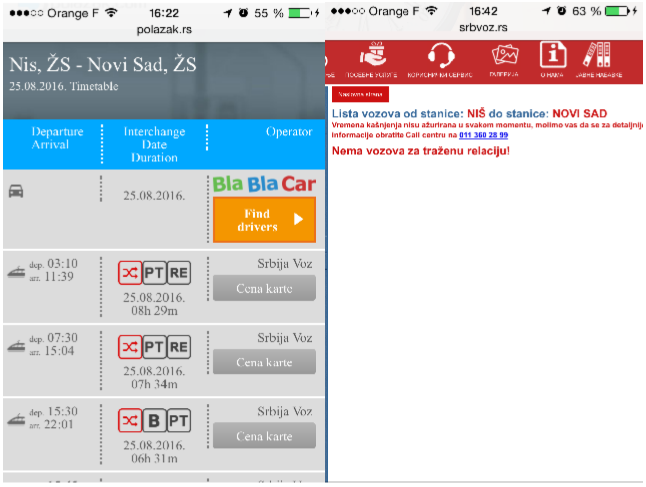

Fig.3. Results with interchanges for Search request Nis-Novi Sad on Polazak.rs and Srbijavoz official website

Connecting transport services of different operators can multiply the number of destinations. The point is that this level does not require any operational activities but to define minimum connection times and ensure solutions for missed connections. To connect different transport services even it is not necessaire to involve participating operators if the passenger has adequate insurance for lost connections. Captaintrain successfully implements it in its own strategy remaining liable, so taking full responsibility for missed connections.

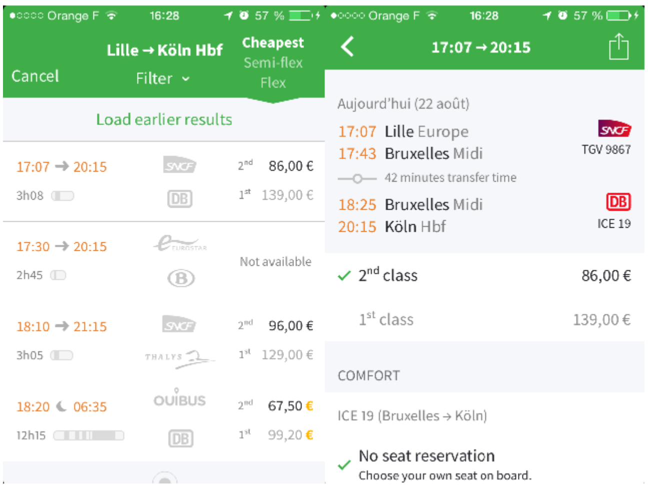

Fig.4. Search results for Lille-Cologne in Captaintrain application with shopping options for connecting services of different train operators

This generous approach helps to gain new customers while the costs of reimbursement of lost connections are marginal in the whole amount of ticket sales.

4. OPPORTUNITIES IN DATA INTEGRATION

Is it possible to book online a night train service from Munich to Zagreb? Can we arrive to Budapest from Belgrade in a business time by public transport? How to travel from Nis to Bratislava? These are the main questions we would like to evaluate and demonstrate in this chapter.

Buses are not anymore only competitors for railways but a new market segment to gain revenue with established traffic management and distribution infrastructure. Despite all the criticism of this paper, we cannot underestimate the already existing offline network of ticket sale and supporting operational systems of railways. This is a huge potential which needs to be adopted to the expectations of today customers and technologies. Buses can be easily integrated to the rail network when they can provide feeder services or in some cases simply substituting not competitive railway alternatives. Today few remembers that the first DB IC bus line was introduced to substitute a not competitive Nuremberg-Prague train on a degraded infrastructure.

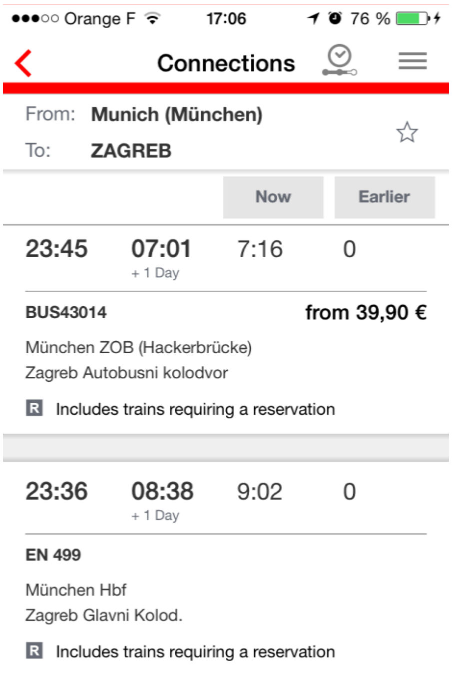

Fig.5. DB application does not provide online booking for EN499 overnight service

DB, since the German bus market liberalization became one of the biggest bus operator in the country. Now in some routes it is easier to book a DB bus ticket than a train ticket. Operating buses by train operators in Western Europe became must do in order to keep competition in the price sensitive market segment. In our region still train ticket prices are lower than bus tickets, however it should not be obstacle for integration and cooperation where there are potential synergies. The Beograd-Vienna train service easily could be extended by feeder bus services to almost all towns in Vojvodina and to cities like Sabac, Obrenovac, Smederevo, Pozarevac. It would mean only tariff and timetable integration on selected municipal and intercity bus services. Passengers would have a one stop shop application to manage their bookings together with clear instructions about interchange. All this work would be mainly organizational and administrative, exploiting existing infrastructure, rolling stock and bus fleet without any additional investment needed to expensive roads, stations and tracks.

Another business opportunity lays in the potential of Beograd-Budapest overnight train service to provide a high class accommodation to business people. Thanks to the cooperation with RZD this route provides high quality service in the new Siemens coaches. Single and double cabins with private bath room and toilette can attract not only leisure travellers but business too. The problems are that it is not advertised and general public does not know about this service, there is no online ticket sale and there is the arrival time issue. The train leaving Beograd main station at 21:50 and Novi Sad at 23:20 is an ideal option for an eight our night journey. However just one small detail in the timetable and so in the operation can ruin this offer for business. Namely, it is the arrival time to Budapest Keleti station at 5:46. As this train continues its journey to Moscow with departure at 8:22, this train could be easily advertised as the most convenient connection to reach Budapest sleeping all the journey and leave the train at 8:00 in the city center. Currently the service is not marketed to business at all and there are no possibilities for online ticket purchase.

If Nis will be connected by Ryanair to Bratislava it should mean there is a market to travel to Vienna and to the Czech and Slovak capitals. However flying is not the most convenient and cheapest option when there are bigger belongings. During summer time, Serbian bus operators send several buses to serve their each departures from Western European cities. People are keen to travel even 24 hours instead of a total 6-7 hour flying time if it is about their luggage. Therefore even low cost airlines cannot compete in a market segment which is more sensitive on the size of personal belongings than on journey time. The most important is to put on the market alternative solutions and if it is visible it will attract its own customers. Currently there are seasonal departures from Nis to Moscow via the main Central European cities, what is barely visible even in the involved railway undertaking`s websites.

5. CONCLUSION

This paper has no aims to give comprehensive understanding of the technicalities in the timetable integration domain. The focus is to serve with existing smart tools to give a hint about the potential of railway business even in a region where last decades have devastated infrastructure and rolling stock. Railways always could build better tracks, bridges and bore tunnels than to build timetables which really fits to their customers.

It is never late to catch up with modern technologies and finally to place railway services on adequate position in the digital world.

ACKNOWLEDGEMENT

This paper is made in the frame of the Polazak.rs project, which since 2010 works on Serbian inter-city bus timetable integration and digitization. During this time all bus timetable data – together with location and operator data have been processed in Serbia and Montenegro, extending the scope of the projects by timetable and tariff data set of Serbian Railways (Srbijavoz) and Railways of Montenegro (Željeznički prevoz Crne Gore). The work included to design and develop an IT tool for data processing and lot of work to manually process data, available only on hard copies. From last year, the project provides e-ticketing solutions for transport operators. The project is available for the public, it serves as a one stop shop for journey planning and ticket purchase. Its android application "Red Voznje" is the most popular application in its category with more than 60.000 downloads.

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Infrastructure

A NOVEL DESIGN OF CATENARY MAST SYSTEM

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Jan RÖHL[3]

Abstract *– Catenary systems in railways supply electric power from substations to railway trains, trams and trolleybusses. In the railway electrification system, it is demanded to supply energy with steady performance and without interruption. Therefore, railway operators are forced to select an efficient and fast working methods during the installation and maintenance of a catenary system, at the most possible minimum cost. Besides satisfying the proper steady function of the catenary system, the railway operator and the system manufacturer should assure the safety of people and other structures in the surrounding. This paper presents a novel catenary mast system that is developed and tested, in a collaborative research project between Ing. Karl und Albert Kruch Gesellschaft m.b.H. & Co. KG and the Carl Ritter von Ghega Institute for Integrated Mobility Research, St. Poelten, Austria.*

Keywords – Overhead lines, rail traction, rail power lines

1. INTRODUCTION

The railway electrification system supllies electric power to railway trains, trams and trollybuses. A catenary system is used to transmit electrical energy from the fixed installation of an electric railway to the moving traction unit. In order to fulfill the required standards of safety and functionality, the overhead line systems are designed in accordance with the requirements of standards. These standards are given in the technical specification for interoperability (TSI) [1], Eurocodes: [2], [3], [4], [5], [6], where nation specific parameters are laid down by respective european country. In addition, there exist recommendations of the International Union of Railways (UIC) for the system.

Masts used as supporting elments, do perform various functions, where they are classified as tensioning, intermidiate suspension, midpoint and mid point anchor masts. For the details and graphical description of these masts, the reader is refered to [7].

EN 50119:2001 defines the components as: (i) mast: mainly vertical structure to provide support, and tensioning of the overhead contact lines, (ii) cantilever: support consists of one or more transverse members from a mast, (iii) cross- span, span wire: wire or cable, normally electrically insulated, placed across the track and used either to support one or more overhead contact lines (headspan) or to carry lateral force (cross-spann), (iv) foundation constructions, usually of concrete or steel, completely or partly buried in the ground on which the support is mounted. The foundation shall provide stability to all loads carried by the support.

Overhead line masts are exposed to various loads that are permanent and variable. Especial attention is paid to the prevailing load, wind. Wind is one of the most important factors of those variable loads on the catenary system [8]. Besides satisfying the safety and serviceability of the catenary system, the railway operators and system manufacturers should assure the safety of people and other structures in the surrounding.

1.1. Safety requirements

Because of the possbile higher risks related to the operational restriction and system failure; the catenary systems are constructed in such a way that an adequate safety and serviceability under all loads acting on the supports are considered. Those loads are derived from (i) the weight supporting components, and the equipment and insulators fitted to the support, including any additional loads applied during installation, (ii) tensile loads drived from the attached conductors, (iii) the wind and ice loads acting on the conductor and transmitted to the support as well as

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(iii) loads derived from wind and ice acting on the support. In addition the dynamic loads from pantograph interaction are considered. The loads from environmental effects such as wind, snow, ice, humidity etc. are usually be derived from country specific standards and regulations that depend on regional locations. Wind forces are computed from wind velosicites that are dependent on time and location. The computation moreover takes the prevailing direction of the wind, the surrounding condition and relevant heights into consideration. The wind loads that are acting on the components of the system are summed up to detemine the total wind load. Furthermore, temporary or exceptional loads originate from the temporary actions caused by methods of erection, maintenance or component failure i.e broken wire are treated.

In dimensioning the system allowable buckling stresses is considered. Moreover, deflection limitations are defined with respect to various loading and boundary conditions. The system is designed so that there are no limitations due to deflection in the use under service conditions. In this regard, according to [2] the calculation for stability shall be supplemented by a calculation of deflection of the support. This assures safety under the action of non-permanent loads, e.g. those derived from wind pressure, horizontal displacements of the overhead contact line incompatible with good current collection shall not occur.

Furtheremore, the design of the foundation should safegaurd that the specified deviation of the grooved contact wire shall not be exceeded by the deflection of the mast and/or the movement of the foundation. In Austria this safety proof is done based on [2].

1.2. Installation processes

In case of the commonly used catenary masts; the mast is supported by the foundation where the foundation provides stability to all loads carried by the mast. The selection of the type of foundation depends on various factors: the load bearing capacity of the construction site, geographical conditions, type of masts used, the available technology and costs [9] among others. The construction of the selected foundation is followed by installation of the masts that in conventional process is performed by using crane on construction vehicle and a wagon on which masts are loaded. If the mast is delivered on a road, a semitrailer with crane is demanded. When many masts are installed, rail bound mast installation machine is used. This machine has two heavy-duty cranes.

The cantilevers are for either new installation or replacement of the damaged ones; will be delivered to the construction site and mounted to the installed masts. First, the fastening elements are fixed to the mast then the cantilevers will be mounted. The installation in this manner demand overhead wiring maintenance vehicles and/or elevating work platform. The demand for the machines is indispensable during both the installation of the cantilever as well as fitting of wheel tensioner, X-auxiliary cable and overhead wire installation.

The cantilever to support the overhead lines in most cases is secured by clamps that are tensed by screws. During the important shift of contact wires to the required height, the regulation of the contact wire position demands a vast range of screws where the cantilever should be displaced and the screws should be tightened again. Those actions make the system laborious and expensive.

2. DESCRIPTION OF THE NEW DESIGN

The technical development of the catenary mast system based on the applicable standards and norms realized an efficient and cost effective system. This modular system of catenary pole and cantilever has low weight and length. It is installed and adjusted by two persons from the ground without any demand for installation and renewal machines. It is stable in design and the cantilevers are mounted without crane. Furthermore, the cantilever height is adjustable at any time.

The mast is constructed as a pair of springs from two formed tubes that are connected about their end. Technically the bending springs provided by a rectangular cross-section are advantageous in terms their favourable effect related to bending.

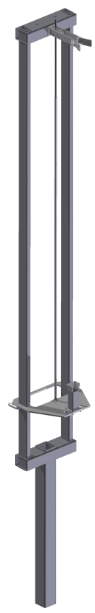

Fig.1. The catenary mast design

In is decisive that the height clearance of the catenary power lines and the selected installation tensional forces are kept constant in all situations during operation. With this new design, the system is arranged in order to make the regulation of the overhead easily accessible than the systems used so far, whereby this regulation can be performed from the ground.

Figure 2 illustrates the complete catenary system of the new design with one of the cantiliver types designed.

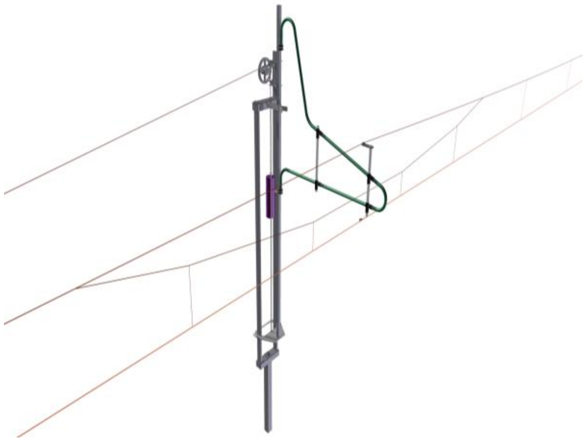

Fig.2. The complete catenary system

The construction is characterised by the fact that two, the so called guides are arranged on a support that is attached to the mast. The support is extended upwards and is movable by unlocking the guides. The middel pole which is inserted in the extended part of the support holds the cantilever. A threaded spindle can be screwed in a nut that is arranged in the upper part of mast and is pivitally connected to the guiding part. The detail of this construction is illustrated in figure 3.

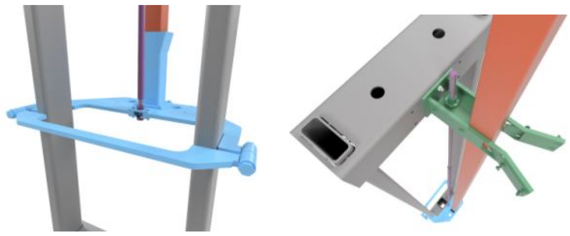

Fig.3. Design details of the guiding parts

This arrangement of the system enables the change of the elevation of the overhead lines by simply rotating the treaded spindle from the ground.

To facilitate the installation of the supporter of the cantiliver on the mast, two guiding parts that are opened outwards like a jaw are attached on the top connection of the mast. Those guiding parts provide a receding as a locking spring once the supporter of cantiliver is pushed in. Hence, the supporter can be inserted between both guiding parts from the outside, where by the locking springs allow the inserting, however inhibit any backward movement. Nuts are arranged between the guidung parts for the treading spindle as it is illustrated in figure 3.

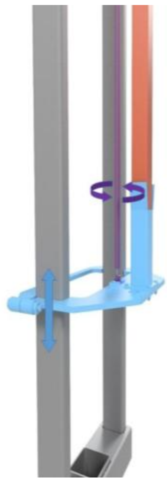

Fig.4. Design details for elevation adjustment

The heights can be adjusted up to 1000 mm.

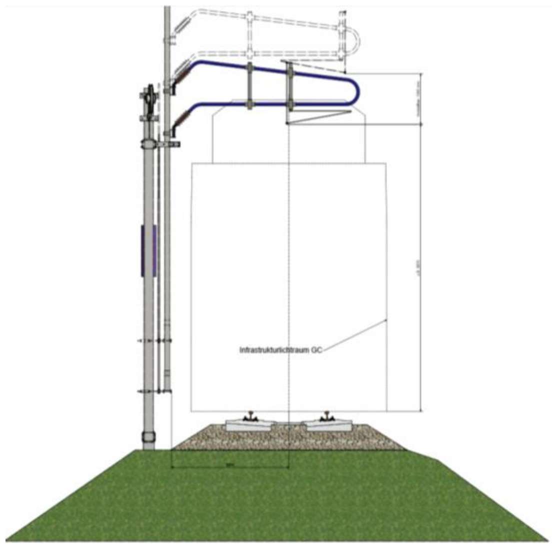

Fig.5. The cross-section of the system

Moreover, there is a possibility of installing tensioning wheel. With this design, one of the two tubes is extended upwards above the connection of the tubes and on the extension a role the tensioning is fixed. The role of the tensioning wheel is fixed on this extended part of the mast as shown in figure 6: (a) the whole assembly, (b) the detail of the tensioning wheel and weight fixture. Through this arrangement the tensioning weight can be kept between the two formed tubes.

Fig.4. Tensioning wheel and weight arrangement

Additionaly, various version of design are planned in reference to the cantiliver systems. The main difference feature is the isolation coordination. The cantiliver can be made of metal tubes or insulated by glass-fiber reinforced plastics. In case of the insulated tubes, care should be taken during the installation of the cantilever to keep the required electric protection and creep distances that vary depending on the applied type of current. In the present design of the looping cantilever resulted in keeping the required creep distances for the power supply with 25kV as well as it enables to adjust the construction height up to 1000 mm. For lower voltages there are smaller construction heights and similar designs with insulations.

3. CONCLUSION

This system avoids clossing of tracks, provides highest possbile work safety and generate cost savings related to work processes during installation, maintenance as well as track closing. Extension of the servic life of the wires can be guaranteed by avoiding damges due to deformaions that can inturn be achieved by proper wire streching and exact positioning of the contact wires.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '16

DETERMINING REACTIONS AT HYDRAULIC EXCAVATOR SUPPORT DURING WORK AND WHILE MOVING ON RAILWAY TRACKS

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Abstract *– Mobile machines perform many functions in the development and maintenance of railway infrastructure. Among them, particular emphasis is on hydraulic excavators. The paper defines a general mathematical model to determine the reaction of support and dynamic stability of a hydraulic excavator during work and while moving on railway tracks. The results of the analysis of support reactions, obtained by the developed software, are given for a hydraulic excavator of 16,000 kg in weight loaded with a backhoe manipulator.*

Keywords –Hydraulic excavators, Railway transport.

1. INTRODUCTION

Size of hydraulic excavators used in railway transport, have a weight of *10,000* to *25,000 kg* and conventional (standard) configuration of the kinematic chain which principally consists of: the support and movement mechanism and manipulators. The support and movement mechanism by conception can be derived from the wheels (Fig. 1). The manipulators are multimember kinematic chains with planar or spatial configuration with the last one changeable member in the form of various tools (buckets, grapples, hooks, magnets, etc.) which directly manipulates with various items. The application of conventional (standard) mobile machines in railway transport is achieved by installing special modules on

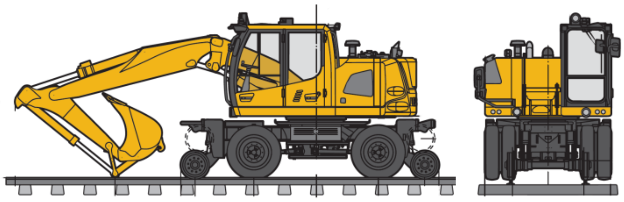

Fig.1. Hydraulic excavators with support and movement mechanism used in railway

the existing support and movement mechanisms, which allow suspension and movement of machines on railway [1].

2. ANALYSIS

Hydraulic excavators on the railway usually perform manipulative tasks related to interruptible transportation during loading and unloading of various materials and goods. Whereby manipulative tasks have cyclical changes of the same operations with very different requirements in terms of the reach of tools and dimensions and weight of load. In such conditions, for the safe operation is necessary knowledge of allowable capacity of tools (hooks, grapples, grips, ...) and dynamic stability of the machine throughout the whole work (manipulative) space.

In the paper [1] was developed mathematical model and software to determine the allowable load capacity of hydraulic excavators in the required number of coordinates workspace of machines in support on the railway.

In this paper, mathematical model and software are developed to determine the reaction of support, and analysis of dynamic stability hydraulic excavators at work and the movement of railways.

2.1. Mathematical model

To determine the reaction on substrate support of excavator with the support and movement mechanism which allows movement of the excavator on rails mathematical model is developed for general configuration of the excavator kinematic chain composed of: the support and movement mechanism L_1 (*Fig.2a*), the rotating platform L_2 and the three-plane load manipulators with: boom L_3, stick L_4

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backhoe bucket L_5, that drives hydraulic cylinder two-way action c_3,c_4,c_5. The support and movement member of excavator is the conventional (standard) movable mechanism with integrated pneumatic modules having a pair of railway wheels with a mechanism for raising and lowering without stabilizers. The position of the members of the excavator kinematic chain is defined by the mathematical model in the absolute coordinate system $OXZY$ with generalized coordinate θ_i (Fig.2a).

Mathematical model of member of the kinematic chain excavator L_i was defined in its local coordinate system $O_i\, x_i\, y_i\, z_i$, geometric, kinematic and dynamic parameters covered by a set size (Fig. 1):

$$L_i = \{ \boldsymbol{e}_i, \boldsymbol{s}_i, \boldsymbol{t}_i, m_i, J_i \} \qquad (1)$$

where: $\boldsymbol{e}_i$ - unit vector joint axes O_i which member L_i linked to previous member L_{i-1} (Fig. 1), $\boldsymbol{s}_i$ - the position vector of the center joint O_{i+1}, which is a member chain L_i linked for the next member of the L_{i+1} (intensity vector is the length of the kinematic members) $\boldsymbol{t}_i$ - the position vector of the center of mass of member L_i, m_i - mass of member, J_i - moment of inertia member. In determining the reaction of excavator substrate support is assumed that the total load that is transmitted to the substrate i.e. rail passing through the center (A, B, C, D) (Fig.2b) rely surface of railway wheels on the tracks. In spatial manipulation excavator comes to eccentric operation of total gravitational and inertial forces and technological load (resistance digging) in relation to the center of the polygon that grade potential rollover lines x-x and z-z.

Reducing the loads of all excavators in the center O_1 rely polygons of the support and movement mechanism , obtained the resulting dynamic force $\boldsymbol{F_1}$ and dynamic moment load $\boldsymbol{M_1}$ substrate support of excavator (Fig.2a)[2][3]:

$$\boldsymbol{F}_1 = \boldsymbol{W} + \sum_{i=1}^{5} \boldsymbol{F}_{ui} \qquad (2)$$

$$\boldsymbol{M}_1 = ((\boldsymbol{r}_w - \boldsymbol{r}_1) \times \boldsymbol{W}) + \sum_{i=1}^{5} ((\boldsymbol{r}_w - \boldsymbol{r}_{ti}) \times \boldsymbol{F}_{ui}) + \sum_{i=1}^{5} \boldsymbol{M}_{ui} \qquad (3)$$

where: $\boldsymbol{W}$ - vector digging resistance, $\boldsymbol{F_{ui}}$ - vector of total force in the center of the mass member L_i, taking the influence of inertia and gravity, $\boldsymbol{M_{ui}}$ - vector of moment of inertial forces members L_i in the absolute coordinate system.

Reactions of substrates in the centers A, B, C, D excavator substrate support in x direction are given in Table 1.

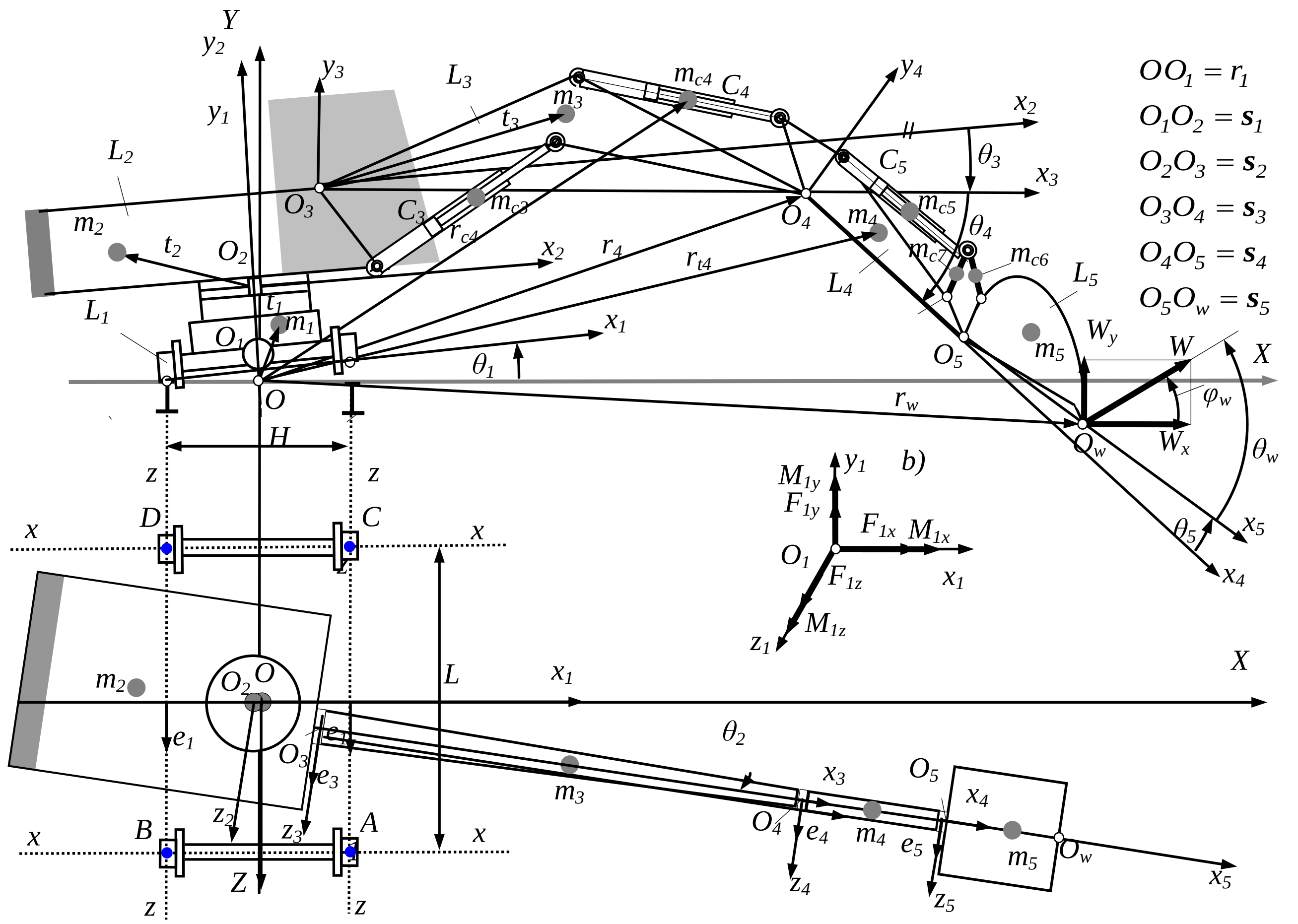

Fig.2. The mathematical model of the hydraulic excavator for determining reaction reliance

Tab. 1. Reactions of substrates F_{Ax}, F_{Bx}, F_{Cx}, F_{Dx}

	$F_{1x} \geq 0$, $M_{1y} \geq 0$	$F_{1x} \leq 0$, $M_{1y} \leq 0$	$F_{1x} \geq 0$, $M_{1y} \leq 0$	$F_{1x} \leq 0$, $M_{1y} \geq 0$
F_{Ax}	$-\frac{F_{1x}}{2}-\frac{M_{1y}}{L}$	0	$-\frac{F_{1x}}{2}$	$-\frac{M_{1y}}{L}$
F_{Bx}	0	$-\frac{F_{1x}}{2}-\frac{M_{1y}}{L}$	$-\frac{M_{1y}}{L}$	$-\frac{F_{1x}}{2}$
F_{Cx}	$-\frac{F_{1x}}{2}$	$\frac{M_{1y}}{L}$	$-\frac{F_{1x}}{2}+\frac{M_{1y}}{L}$	0
F_{Dx}	$\frac{M_{1y}}{L}$	$-\frac{F_{1x}}{2}$	0	$-\frac{F_{1x}}{2}+\frac{M_{1y}}{L}$

Reactions of substrates in the centers *A, B, C, D* excavator substrate support in *y* direction:

$$F_{Ay} = -\frac{F_{1y}}{4} - \frac{M_{1x}}{L} - \frac{M_{1z}}{H} \quad (4)$$

$$F_{By} = -\frac{F_{1y}}{4} + \frac{M_{1x}}{L} + \frac{M_{1z}}{H} \quad (5)$$

$$F_{Cy} = -\frac{F_{1y}}{4} - \frac{M_{1x}}{L} - \frac{M_{1z}}{H} \quad (6)$$

$$F_{Dy} = -\frac{F_{1y}}{4} - \frac{M_{1x}}{L} + \frac{M_{1z}}{H} \quad (7)$$

3. EXAMPLE

On the basis of the previously defined mathematical model, developed software to determine the reaction substrate support excavator, on the basis of the measured size of the state of the kinematic chain excavator at work in operating conditions.

Using the developed software, analyzed the reactions support hydraulic excavator weight *16,000 kg* with a backhoe manipulator volume *0,6 m*^{3} and the support and movement mechanism on pneumatic and additional modules that allow movement and support excavator at railways. The reactions were determined base on measurement value of state working crawler excavator in exploitation conditions, also weight *16,000 kg* width backhoe mechanism volume of the bucket *0,6 m*^{3}, in support and digging land density 1800 kg/*m*^{3} in the exploitation conditions.

For evaluation of dynamic stability of excavator at work and the movement of railway lines needed is an analysis of the character of changes of vertical components of reaction in all the points of support. In the first phase of digging, (t = *3s*) (Fig.3,4) when the bucket begins to catches material, the touch points A and C components of substrate reaction F_{Ay} and F_{Cy} in *y* direction are negative and touch points *B* and *D* positive valuation, which indicates that occurs raising a the supporting wheels *A* and *C* of the railway due to the impact resistance of digging which then has a positive vertical component.

By the end of digging operation (t = *6s*), when a bucket filled with material, the situation will change in the contact points *A* and *C* of substrate reaction F_{Ay} F_{CY} in *y* direction have a positive and touch points *B*

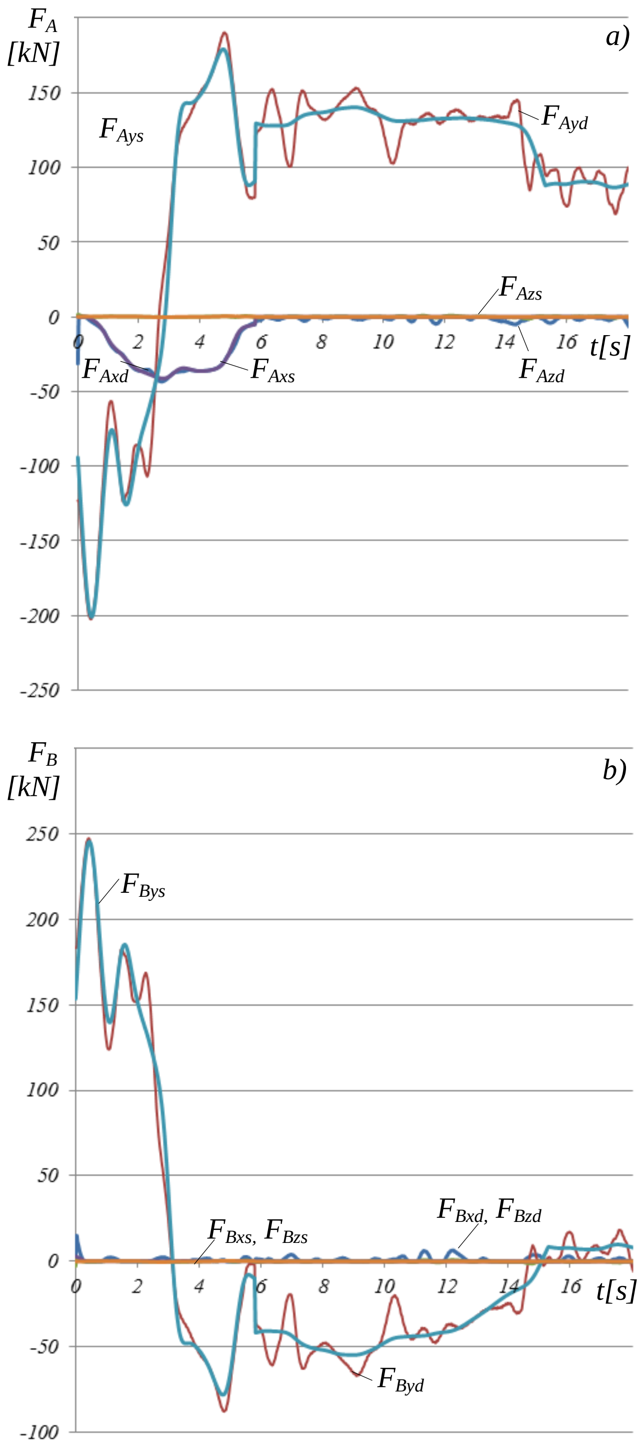

Fig.3. Reaction on substrate reliance of excavator on railway in supports: a) A, b) B

and *D* negative values, which shows that occurs raising of the supporting wheels *B* and *D* of the railway due to the impact resistance of digging, which then has a vertical negative component.

As far as the stability of excavator in digging operation, although in certain phases occur negative values of vertical components of reaction supports, stability is not compromised because the excavator kinematic chain then has closed configuration - support and movement mechanism and bucket excavator are in contact with the ground.

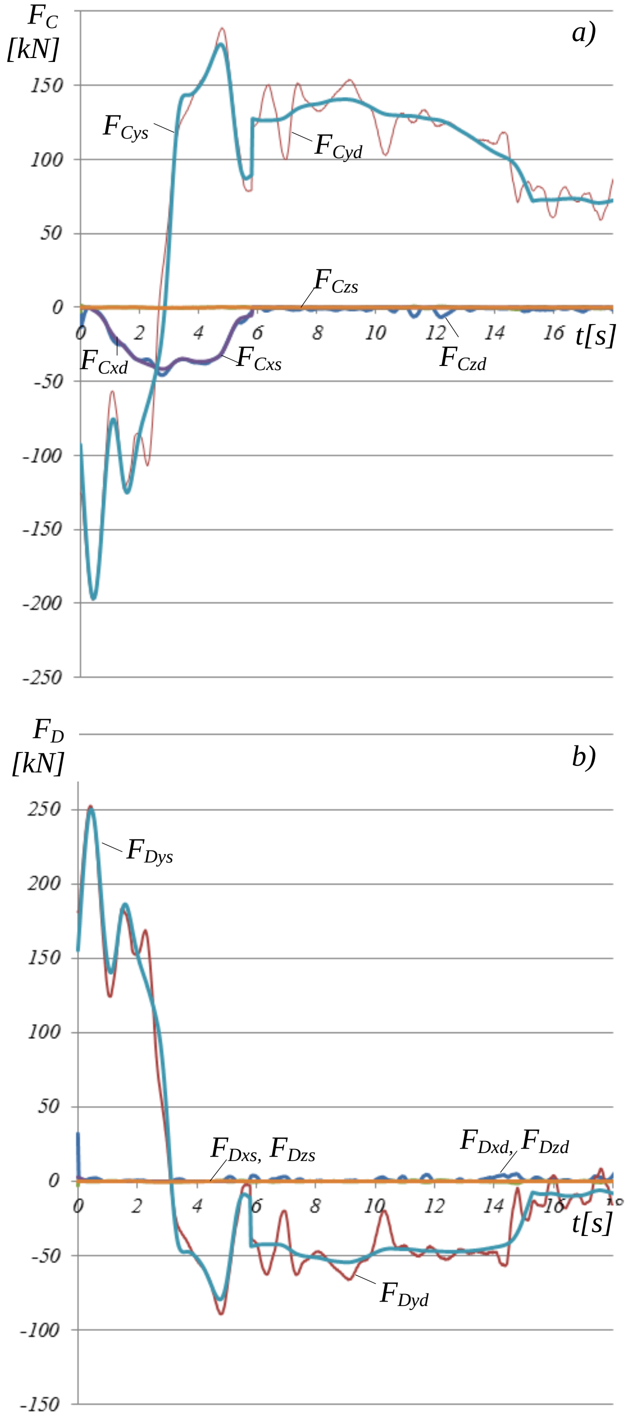

Fig.4. Reaction on substrate reliance of excavator on railway in supports: a) C, b) D

How diagrams (Fig. 3, 4) show below duration of manipulative task, during the transfer material operation from the digging plane in the unloading plane, when kinematic chain excavator has an open configuration, the vertical component of reaction supports have a negative value indicating that the excavator in an unstable condition.

In a stable dynamic state of work, excavator passes only after the operation unloading of materials (*t = 14s*) when the vertical component of a reaction all of supports positive.

Results of the analysis show that the observed hydraulic excavator with a backhoe manipulator, bucket volume of *0.6* m^3 and support and movement mechanism on pneumatic, has unstable work in support on the railway.

On further analysis, with the change of parameters members of the kinematic chains (by reducing the volume of a bucket or stick's length of manipulator), could be determined configuration excavators which satisfy the criteria of a stable dynamic excavator working in support on the railways.

4. CONCLUSION

Defined methods of analysis reaction of support hydraulic excavator on railway is based on static and dynamic model of and measured size of the state of the kinematic chain excavator at work in operating conditions.

Method allows the determination of the reaction of support (railway tracks) on the rollers elements of excavator support and movement mechanism when moving and work on the manipulative tasks of rail transport. Based on the analysis of the reaction can be assessed and dynamic stability of the excavator.

ACKNOWLEDGEMENT

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METHODS FOR DETECTION OF OBSTACLES ON THE RAILWAY LEVEL CROSSING

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Abstract – *Railway level crossing is one of the most dangerous parts of the railway traffic. There, railway and road infrastructure are intersected at the same level, thus it becomes a weak safety point with very often terrible accidents. In addition to motor vehicles, the crossings are not rarely used by pedestrians who are also participants in traffic exposed to the risk. Accidents can happen due to malfunctioning of warning system (flashing lights, warning tones and boom gates) which informs traffic participants that a train is coming. However, even in the case of complete regularity of the warning system, very often fatal accidents happen due to not possessing enough awareness of traffic safety and "traffic culture". Because of that, drivers, cyclists and pedestrians, despite the activated warning system, use the railway crossing. This behaviour leads to the violating of the law, endangering traffic participants and accidents with material damage and possible fatal outcomes. This paper presents actual solutions in the field of detection of obstacles on the railway crossing. The aim of those systems is to monitor the railway crossing with the goal to inform the train driver about possible obstacles existence, and timely response for preventing an accident.*

Keywords – Railway crossing, safety, detection, obstacle, monitoring.

1. INTRODUCTION

The railway is a very important type of transport because of its capacity and infrastructure. However, railway infrastructure is very complex itself, so intersection with another type of traffic (road, marine, pedestrian) additionally complicates traffic flow. In case of intersection of railway and road infrastructure, dependent on the way of the intersection, there are more or less possibilities for accidents. If is an intersection on the same level, known as railway level crossing, that is a weak safety point with very often terrible accidents, because there is an intersection between three types of traffic – railway, road and pedestrian. In addition, many of railway crossings do not have separated parts for road vehicles and pedestrians, which have an effect on increasing of accidents with fatal end.

Railway level crossing accidents and fatalities represents more than one quarter of all railway accidents on European Union railways [1]. So, in the EU, in recent years, on average, every day, beside big material damages (approximately one hundred million euro per year in the EU for all level crossing accidents), one person has been killed and close to one seriously injured on the level crossings in Europe. Pedestrians represent about 40 % of the people killed on the railway level crossings. In the EU, in 2009, there were 641 accidents on the railway level crossings with 411 serious injuries and 332 fatalities, while in 2012, there were 555 with 364 serious injuries and 322 fatalities [1, 2]. Therefore, there is certainly decreasing of the number of accidents, but data about accidents with injuries and fatalities is still alarming.

Generally, cause of the accident can be malfunction of train or/and railway infrastructure, staff incompetence, etc. Furthermore, faulty of the warning system (flashing lights, warning tones and boom gates) on railway level crossings, which has a task to inform traffic participants that the train is coming, and human mistakes in terms of using of the railway level crossing despite the activated warning system, significantly increase risk for accident. However, the existence of any physical object (vehicle, pedestrian, animal, rock, etc.), represents obstacle on the railway, and can cause an accident because, in most cases, it cannot be avoided. This problem can be solved with some system with ability to monitor railway infrastructure and, in case of existence any obstacles that can have an effect on

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railway traffic, inform the train driver about that. Therefore, based on that information, train driver can stop the train on the time and avoid any accident. Monitoring systems, which are using the object recognition principle as infrared, embedded system, multiple lasers, etc., can be installed anywhere on the railway infrastructure and/or train [3-7].

In this paper, some of the actual solutions in the field of detection of obstacles on the railway level crossing are presented. The task of those systems is to monitor the railway crossing with the goal to inform the train driver about possible obstacles existence, and timely decrease possibilities for an accident.

2. CONVENTIONAL METHODS

The most effective solution for decreasing the risk of an accident on the railway level crossing is those that can totally provide safe railway crossing. However, all systems have advantages and disadvantages, so its effectiveness depends on the level crossing construction, the method used by the installed system, weather conditions, costs, etc. Nowadays, there are many conventional methods, based on optical principles, with purpose to detect moving object-obstacle when passing at a particular point on the railway level crossing. Some of them are optical beam, ultrasonic detectors and 3D laser radar.

2.1 Optical beam

Method with optical beam (Fig 1.) is based on several optical emitters that are placed on the one part of the crossing (marked with A in Fig. 1). All emitters emit a directed optical beam, but each one with a defined field of emission. At the other part of the crossing (marked with B in Fig. 1), there are receivers which detect the optical beam from the emitters. If the some beam is intersected (marked with red colour at Fig 1.), there is no beam detection by the receiver, so it means there is some obstacle. Based on field of emission of intersected beam, it is known in which zone is obstacle – away, close or on the railway crossing [8].

Fig.1. Optical beam method [8]

Advantages of this method are easy installation and relatively inexpensive equipment (dependent on the number of emitters and detectors, and compared to the other methods). However, the disadvantages are: it is required to install several emitters and detectors along the crossing for increased safety, traffic needs to be stopped for installation and maintaining, it is weather dependent – unusable in periods of heavy snow, and the most important – optical beam cannot detect pedestrians without the large number of emitters and detectors.

2.2 Ultrasonic detectors

Method, which uses ultrasonic detectors, is based on measuring the time between sent and received ultrasonic signal. This type of system transmits ultrasonic signal towards the roadway. When there is no any obstacle, the signal is reflected from roadway and detected by the system in certain time (marked with green colour in Fig. 2). However, if there is any obstacle, signal is reflected from obstacle and detected by the system in shorter time (marked with red colour in Fig. 2), compared to the case without obstacle [8].

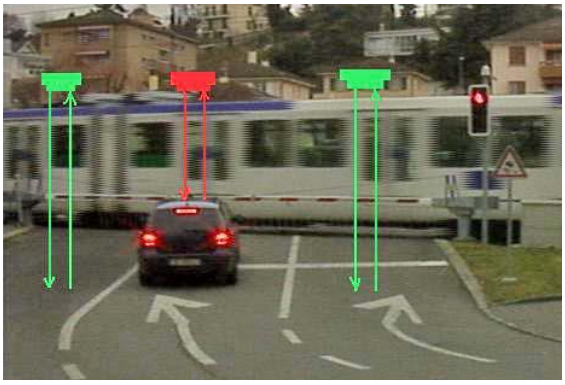

Fig.2. Ultrasonic detector method [8]

Accuracy and determination of vehicle size are dependent on the number of installed systems. The advantage of this method is that system can detect both stationary and moving vehicles. As in the case of optical beam, pedestrians can be detected only in case that there are a large number of installed systems. Disadvantages of this system are equipment and installation costs because of the need for additional supporting structure and extremely sensitivity to environmental conditions.

2.3 3D Laser radar

This method is based on the emitting of a laser pulse to an object by 3D laser and measuring the time that it takes for reflected laser to return to the radar (time-of-flight method), in order to acquire a distance to that object [9]. A laser pulse is emitted so that scans the whole area of railway level crossing in two directions – horizontal and vertical (Fig 3). Based on the laser reflected and returning to the 3D laser radar, 3D coordinate values of each point of the area are measured. The coordinates which is higher than the road surface are extracted, based on the coordinate values of each point. Points which are distributed in close proximity to each other are identified as one group of points. The close proximity of points indicates that there is some object which is a potential obstacle. In order to calculate the positions and sizes of objects, data of these groups of points are processed and analysed (Fig 4). Moving direction and speed of the objects are calculated based on the amount of changes in their positions. Because of pre-defined area, obstacle detection and alarm conditions, etc., if the system detects an object on railway crossing, it generates an alarm.

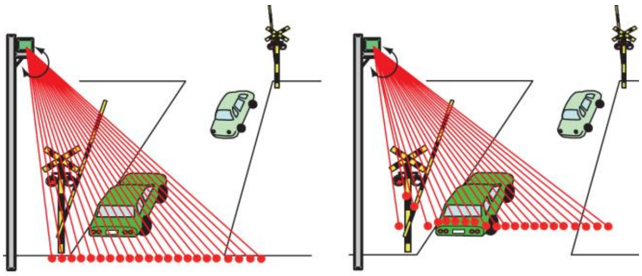

Fig.3. Scanning the area of railway level crossing in two directions – horizontal and vertical [9]

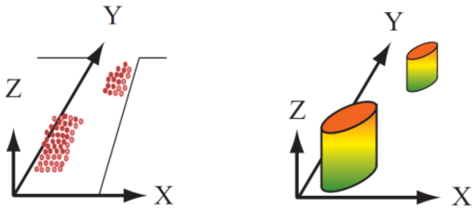

Fig.4. Identified group of points (left) and calculation of object positions and sizes (right) [9]

Advantages of 3D Laser radar method are that operation of this system is relatively independent of the weather conditions (rain, snow, etc.). In addition, it is enough to install only one system for one side of the level crossing, so there is no need for a large number of additional equipment. However, disadvantages are reflected in the operating conditions of the system (vibration, strong wind, etc.) because for system operation, rotation of the 3D laser radar is required. This problem can be solved with high quality equipment, but that effect on increasing on total costs of system installation.

3. IMAGE PROCESSING METHODS

The obstacle detection system on the railway level crossing can use, beside previous named methods, image processing method which is based on cameras. Objects can be detected and tracked in space and time, which enable modelling of behaviour from image sequences. Tracking of the detected objects can provide more relevant information, such as the type of the object (pedestrian, vehicle, animal, paper), and activate alarm in case of potential accident.

3.1 One single camera method

The obstacle detection system on railway level crossing that uses one single camera method has one single camera, which is placed on a certain construction in a corner of the crossing. Objects are detected by image processing, based on the difference between current and background images (Fig 6). Then, 3D positions of the different found objects are computed with knowledge of intrinsic camera parameters, calibration matrix and ground place hypothesis. After that, objects are tracked with an Extended Kalman Filter, and object classification is performed to determine objects as a car, truck, pedestrian, animal, paper, etc. [8, 10].

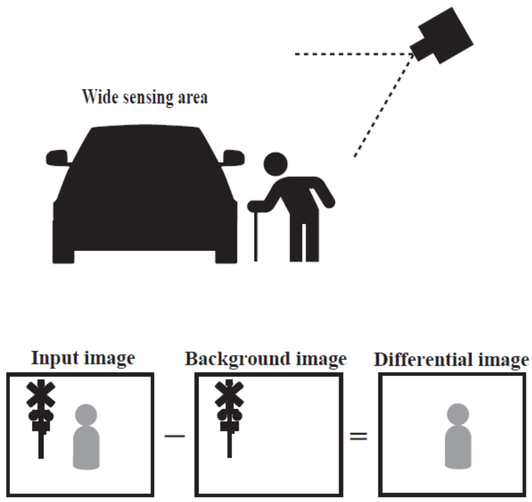

Fig.6. One single camera method [10]

This method shows good results in different positions of camera, bad weather and environmental conditions. However, it is limited in low illumination, because the presence of shadows on railway crossing that come from objects, can activate an alarm although that objects are not obstacles on the crossing.

3.2 Stereo camera method

This method uses stereo camera, which represents, in fact, two cameras placed in one housing. The aim of this method is to determine the 3D shape of the object and the distance between camera and the object. In order to detect an object with a stereo camera, first, the object is projected on each screen with a disparity (Fig. 7) [10].

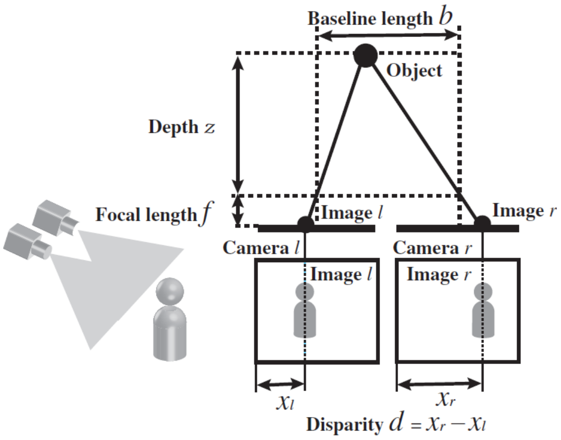

Fig.7. Stereo camera method [10]

Suppose two cameras are placed under a parallel optical axis, consistent horizontal axis and baseline length *b*, the distance *z* between the stereo camera and the object can be calculated by the next formula:

$$z = \frac{b \cdot f}{d} = \frac{b \cdot f}{x_r - x_l}$$

After finishing above processing, a 3D shape of the whole scene is extracted and compared with the background shape. Finally, the 3D shape of the object is obtained as well as distance between stereo camera and object, and can be used in further information processing.

The main advantage of this method is reducing of detection of shadows as objects. That has very big effect on the accuracy of the object recognition on railway level crossings because decreased number of false alarms. Furthermore, a system that uses the stereo camera method, showed the correct results in detection of the object during the day and night under general weather conditions. In addition, this system detected the pedestrians and two wheel vehicles without problems. However, system is extremely sensitive in bad weather conditions, like heavy rain, fog or snow, because a large drop of rain or snowflake can be detected as an object.

4. CONCLUSION

Nowadays, the railway is an irreplaceable type of transport in certain fields, so any interruption of railway traffic has a large effect on people's everyday life and the economy. However, railway infrastructure is often intersected with road infrastructure, which causes occurrence of the railway level crossings. Those crossings are safety weak places with terrible accidents. Cause of accidents and then interruption of traffic can be malfunction of rail, train, warning system, incompetence of staff and using of the crossing despite the activated warning system. Any object, which is on crossing at the moment when train coming, is obstacle and may cause a collision and accident with possible fatal end.

In this paper, the actual methods for object detection on railway level crossings are presented. There are conventional methods, which include use of optical beam, ultrasonic and 3D laser radar. One of the main problems in those systems is operation in different weather conditions and the detection of the pedestrians. However, in presented image processing methods – one single camera and stereo camera method, there are no problems with detection of pedestrians. Disadvantage of one single camera method is false alarms caused by shadows, while a stereo camera method is very sensitive in bad weather conditions, so a large drop of rain or snowflake can be detected as an object. The improvement of all presented systems or designing of some kind of multi-method system should be very important because of increasing of safety on railway level crossings, as well as their integration in autonomous railway that very clearly coming soon.

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RAILWAY INFRASTRUCTURE DEVELOPMENT IN SERBIA - CHALLENGES AND OPPORTUNITIES

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Dragana MACURA [2]

***Abstract** – Railway is energy efficient, environment-friendly and long-term cost effective transport mode. Considering these facts, countries around the world invest in railway infrastructure development and in intelligent transport networks. This paper presents current state of railway infrastructure in Serbia, its challenges and opportunities. With the named railway infrastructure projects and other types of projects, railway system in Serbia will become a relevant actor at the transport market.*

Keywords – Railway infrastructure, Infrastructure management, Investment plan

1. INTRODUCTION

During 2015, 3 new joint-stock companies have been founded, as follows: Infrastructure Railways of Serbia (company for railway infrastructure management); Serbia Voz (company for railway transportation of passengers); and Serbia Cargo (company for railway transportation of goods).

Railway system in Serbia currently operates with these three companies.

The company for management of public railway infrastructure in Republic of Serbia is founded in August 2015, as joint-stock company “Infrastructure railways of Serbia” (IRS). Main activities of this company are:

- Maintenance of public railway infrastructure,
- Organization and regulation of railway traffic,
- Allowing access and usage of public railway infrastructure to all interested railway carriers, as well as legal entities and individuals performing transport for own purposes,
- Safety of public railway infrastructure,
- Investment in development and reconstruction of public railway infrastructure.

A legal document which regulates business relations with IRS is so-called “Network Statement”. “Network Statement” provides all necessary information to potential and current carriers. This document provides basic information about railway network, traffic, conditions for accessing railway infrastructure and fees for usage.

Document “Network Statement” is divided into several sections:

1) General conditions – contains main purpose of issuing Network Statement, legal conditions for regulation of railway infrastructure and transport operations on railway infrastructure
2) Conditions for access and usage of railway infrastructure – a specification of requirements for carriers before they are allowed access to railway infrastructure
3) Overview of technical and traffic characteristics of available railway infrastructure, and limitations in usage – contains description of network managed by IRS
4) Principles, priorities and criteria for assigning infrastructure capacities –contains specification of distribution procedure of capacities and conditions of distribution
5) Types of service – contains specification of services provided by IRS
6) Payment of fees and prices of services, as well as amounts of fees and method of calculation - contains specification of method of calculating fees for usage of railway infrastructure and other services provided by IRS in the network.

This paper is organized as follows. In the second section, as a starting point for further railway system development, the current state of railway infrastructure in Serbia is showed. In the third sections, the vision, mission and objectives of IRS are presented. The next section is dedicated to the current and future projects of IRS. These projects refer to railway infrastructure improvement and providing the rail services of a high quality. Conclusions are given

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in the last section.

2. STATE OF RAILWAY INFRASTRUCTURE IN SERBIA

The railway network in the Republic of Serbia is very old; almost 55 % of railway network built in 19th century.

According to Regulation on categorization of railway lines, categorization was performed as follows:

- Main line (significant for international and national traffic);
- Regional line (significant for regional and local traffic);
- Local line (significant for local traffic); and
- Freight handling line (significant for economic subjects).

In the Republic of Serbia there are: 275,5 km double-track line; 1196,1 km is electrified; on 44 % of network maximum concentrated weight of vehicle per axles is up to 22,5 t/axles; the average age of lines is around 43 years; on length of 66% of lines the maximum speed is less than 60 km/h, and on only 4 % is higher than 100 km/h.

This condition of railway infrastructure in Serbia is the most important factor for the level of quality of transportation services, which are: low commercial speed of trains, long turn-round cycle of trains, increased number and length of speed restricted drive and number of interference in electrical installations.

Tab. 1. Construction railway lengths in network

Total length	***3808,7 km***
Single-track railway line	3533,2 km
Double-track railway line	275,5 km
Narrow-gauge railway line	21,7 km
Non-electrified railway line	2612,7 km (68,6%)
Electrified railway line	1196,1 km (31,4%)

3. VISION, MISSION AND OBJECTIVES OF IRS

A company’s vision identifies what a company would like to achieve. It presents the main purpose of a company business. Mission, based on a vision, defines how to achieve a vision, i.e. desired state of a company. Objectives presents the desired states of a system.

Vision, mission and objectives are in function of a current state of company and market.

Here are presented the vision, mission and objectives of IRS, previously defined by company’s management[1].

Vision: "Modern, safe and market-oriented railway, which means a permanent, continuous and quality maintenance and protection of public railway infrastructure, uninterrupted use of railway infrastructure facilities and other devices for railway traffic, organization and regulation of safe and unobstructed railway traffic while ensuring the protection of the environment in accordance with the law and other regulations."

Mission: "The management of the public railway infrastructure in the Republic of Serbia, organization and regulation of rail transport, providing access to and use of public railway infrastructure to all interested railway carriers and legal and natural persons who perform transport for their own needs, and who meet the prescribed requirements, the construction and reconstruction of railway infrastructure. Establishing business standards, harmonization with the applicable standards and regulations in international railway traffic. Establish standards of conduct for employees and ensuring rationalized, competent and motivated staff."

Objectives: "Based on the defined vision and mission, as well as initiated corporate restructuring railways, certain of the substantial objectives of the Company:

- establishing optimal business structure;
- increasing internal efficiency;
- cost optimization;
- implementation of activities aimed at establishing the principles of market economy;
- raising the quality of infrastructure through the implementation of the investment plan;
- increased profitability."

4. FUTURE STEPS OF IRS

The current conditions of transport market, where the price of petrol is increased, congestion and fuel shortages are present, etc., give the rail a strong role to play, as the backbone of the sustainable transport system[2]. In accordance with this, IRS has the list of completed, active, or future projects, which realization will improve the quality of rail services.

4.1. Active projects or Completed projects

Infrastructure projects in the proces of realization

Slightly over 280km of railways has been already finished (during 2015 and 2016), or it will be completed in 2017. Total value of these investments is about $ 400 millions.

These projects are (Fig.1):

[1] www.infrazs.rs

[2] http://www.smartrailworld.com/blog/2014/01/16/smartrail-speaks-libor-lochman-executive-director-cer

1. Second rail line at section Pančevački most – Pančevo Glavna (Beograd Centar – Pančevo Glavna – Vršac Državna Granica Rumunija) (Pr.1)
2. Reconstruction of north parts of infrastructure objects (Golubinci – Ruma + Sopot Kosmajski – Kovačevac + Mala Krsna – Velika Plana) (Pr.2)
3. Reconstruction and modernization of rail line Gilje – Ćuprija – Paraćin (Pr.3)
4. Construction of the Žeželj bridge in Novi Sad (Pr.4)
5. Reconstruction of capacities for transport management of rail vehicles in rail station Beograd Centar – Phase 1 (Pr.5)
6. Reconstruction of south parts of infrastructure objects, total length 46.5 km (Pr.6)
7. Reconstruction of rail line Beograd – Resnik – Vrbnica – Granica Crne Gore (Pr.7)
8. The Loan Agreement and Guarantee No. 41125 (Pr.8)
9. Project "Beograd na vodi" (Pr.9).

4.2. Future projects

Infrastructure projects in the preparing process - Future projects

Total value of the future infrastructure projects is over $ 700 millions. Over 350 km of rail lines, and some rail stations, are considered.

Projects which are the part of actual investment plan are:

1. Second rail line (rail section Stara Pazova – Novi Sad)
2. Modernization of rail line Beograd-Subotica-State border
3. Rehabilitation of the junction G-Rakovica-Resnik
4. Rehabilitation of rail section Jajinci - Mala Krsna
5. Rehabilitation of rail station Mala Krsna
6. Railway node Beograd and rail sections Stara Pazova-Šid, Resnik-Lapovo and Mala Krsna Velika Plana - rehabilitation of electro-technical infrastructure
7. Mehanization for maintenance of electircal infrastructure
8. Reconstruction and modernization of the BG Voz capacities
9. Reconstruction and modernization of rail line Niš-Dimitrovgrad
10. Construction of one-rail line – railway bypass around Niš
11. Reconstruction of rail capacities on rail line Beograd-Vrbnica-Bar.

In line with infrastructure railway projects, IRS planned some other projects, such as:

- Interoperability of railway system (with applying the Technical specifications for interoperability).
- Installation of electronic signalling and safety systems on the railway stations. These improvements will increase traffic safety, improve the technological reliability of the timetable and the productivity of the railway network and improve the competitiveness of Serbia.
- Dispatching center – the center for online monitoring, management, and regulation of railway traffic in Serbia. The aim is to achieve maximum

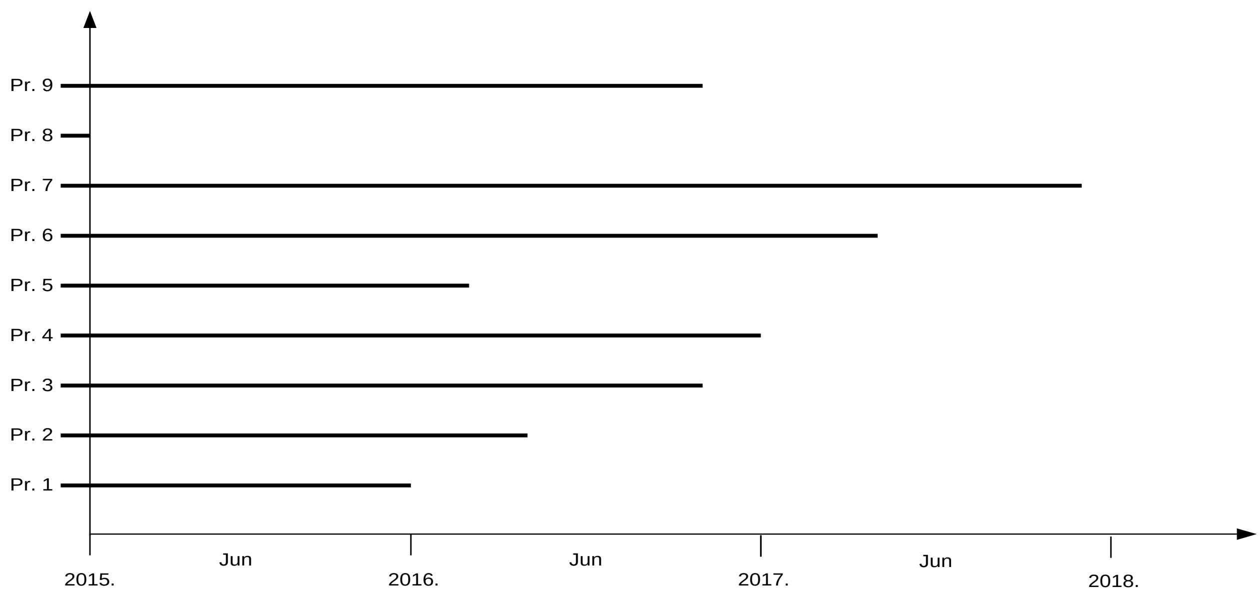

Fig. 1. Time horizon of project's realization

operational efficiency and financial results.

5. CONCLUSION

During the process of restructuring the railway system in Serbia, there are 3 joint-stock companies established.

Infrastructure Railways in Serbia has been operating for a year. This paper presents current state, desired state, and planned activities, which aim is the realization of the desired state of IRS.

There are various risks and external factors, with positive or negative influence on defined goals and objectives. Company management should follow, evaluate and affect these factors, i.e. adjust the company business in order to realize the company’s goals and objectives.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '16

REGISTER OF RAILWAY INFRASTRUCTURE

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***Abstract** – Subject matter of this paper is Register of railway infrastructure (RINF). In the beginning this paper presents legal basis for the establishment and maintenance of the RINF and the obligations of Directorate for railways an infrastructure manager. Scope and purpose of RINF. The basic parameters of RINF with explanation. Description levels of infrastructure: detailed and simplified description. Parameters of RINF that has yet to be determined in Republic of Serbia. RINF system architecture: registries at the national level, central database and common user interface. The implementation plan of RINF in Serbia – steps and deadlines.*

Key words: register, railway infrastructure, parameters, implementation

1. LEGAL BASIS, OBLIGATIONS OF DRIRECTORATE FOR RAILWAYS AND INFRASTRUCTURE MANAGER

Legal basis for setting up of the Register of infrastructure (RINF) is Article 36. of the Railway safety and interoperability law („Official Journal of RS“, no. 104/13, 66/15 and 92/15), which prescribes that Directorate for railways keeps and publishes the RINF.

Infrastructure manager provides necessary data for the RINF and is responsible that they are accurate and updated.

Directorate for railways prepared the Rule book on the common specifications of the register of railway infrastructure, which is fully harmonized with the Commission Implementing Decision 2014/880/EU of 26 November 2014 on the common specifications of the register of railway infrastructure and repealing Implementing Decision 2011/633/EU.

2. SCOPE AND PURPOSE OF THE RINF

The RINF shall cover the entire public railway infrastructure and private sidings connected to it.

The main purpose of the RINF is to provide transparency on the characteristics of the network. The information provided by the RINF is used for planning purposes in designing new trains, for assisting the assessment of compatibility of trains with routes before the start of operation and for use as a reference database.

The RINF enables:

1. designing Rolling Stock subsystems - parameters from the RINF shall be used to identify infrastructure characteristics for the intended use of the rolling stock;
2. ensuring technical compatibility for fixed installations - verification of interfaces for technical compatibility with the network into which a subsystem is incorporated may be ensured by consulting the RINF;
3. monitoring progress of interoperability of the railway network;
4. ascertaining route compatibility for proposed train service - all vehicles in the train must comply with the requirements applicable on the routes over which the train will run and the train as a combination of vehicles must comply with the technical constraints of the route concerned.

3. BASIC ITEMS OF THE RINF

For the purpose of the RINF railway network is divided into sections of line and operational points.

Items to be published for „section of line” related to infrastructure, energy and track-side control-command and signaling subsystems shall be assigned to the infrastructure element „running track”.

Items to be published for „operational point” related to infrastructure subsystem shall be assigned to the infrastructure elements „running track” and „siding”.

Section of line (SoL) means the part of line between adjacent operational points and may consist of several tracks.

Operational point (OP) means any location for train service operations, where train services may

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begin and end or change route and where passenger or freight services may be provided; operational point means also any location at boundaries between Member States or infrastructure managers.

Running track means any track used for train service movements.

Siding means any track within an operational point, which is not used for operational routing of a train.

Within each SoL numerous items are shown, such as:
- name of SoL,
- OP at the start and at the end of SoL,
- length of SoL,
- normal running direction,
- part of a Railway Freight Corridor,
- identification of track,
- TEN classification of track,
- classification of a line according to the INF TSI,
- maximum permitted speed,
- maximum altitude,
- interoperable (G1, GA, GB, GC) and national gauges,
- combined transport profile number,
- gradient profile,
- minimum radius of horizontal curve,
- various track parameters,
- cant deficiency,
- rail inclination,
- minimum wheel diameter for fixed obtuse crossings,
- use of eddy current and magnetic brakes,
- existence of level crossings,
- tunnel parameters,
- start and end of tunnel,
- length of tunnel,
- existence of emergency plan,
- energy supply system (voltage and frequency),
- maximum and minimum contact wire height,
- accepted pantograph heads,
- requirements for number of raised pantographs and spacing between them, at the given speed,
- permitted contact strip material,
- information on phase separation,
- information on system separation,
- current or power limitation on board required,
- TSI compliant train protection system (ETCS),
- ETCS level,
- TSI compliant radio (GSM-R),
- train detection systems fully compliant with the TSI,
- train protection legacy systems,
- other radio systems installed,
- train detection systems not fully compliant with the TSI (track circuit/ wheel detector/ loop),
- minimum permitted wheel diameter,
- minimum permitted axle load,
- maximum sanding output,
- braking distance requested etc.

Within each OP numerous items are shown, such as:
- name and unique code of OP,
- type of OP,
- geographical location of operational point (Latitude + Longitude),
- parameters of running tracks,
- parameters of sidings,
- platform parameters,
- usable length of platform,
- height of platform,
- fixed installations for servicing trains etc.

4. LEVELS OF THE NETWORK DESCRIPTION

The railway network is presented for RINF purpose as a number of OPs connected with SoLs. A line can be described in different levels of details. Directorate for railways, as National Registration Entity (NRE) can choose what level to populate from simple to detailed level.

Fig. 1 below shows several ways of representation from a detailed to a simple one.

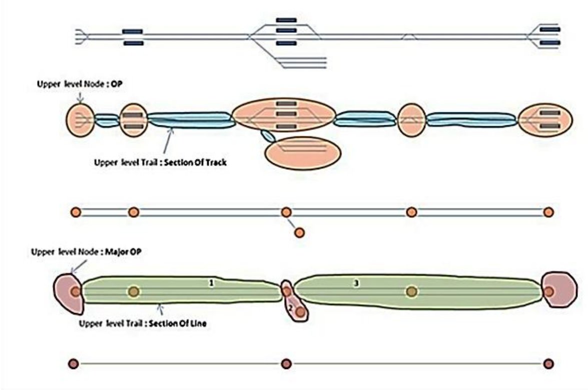

Fig. 1 – Levels of description of the network

5. RINF ITEMS THAT YET NEED TO BE DETERMINED IN SERBIA

Most of the RINF items are already known, but some of them yet need to be determined. Some of them are: unique track identification or unique track number within SoL, classification of a line according to the INF TSI, temperature range, standard combined transport profile numbers, unique tunnel identification or unique number, OP TAF TAP primary code.

6. THE ARCHITECTURE OF THE RINF SYSTEM

The common user interface (CUI) is a web-based application facilitating access to the data contained in the RINF. CUI is managed and maintained by the European Railway Agency.

The architecture of the RINF system is presented in the Figure 2 below.

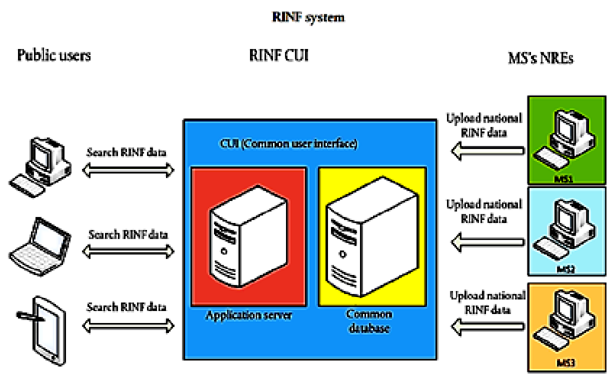

Fig 2. - Arhitecture of the RINF system

The RINF system provides two main interfaces via the CUI:

1. one is used by the RINF of each state in order to provide/upload copies of their full RINF data;
2. the other is used by CUI users in order to connect to the RINF system and retrieve RINF information.

The CUI central database will be fed with copies of the full sets of RINF data maintained at the RINF of each state, in XML format. In particular, NREs shall undertake the responsibility to create files that encapsulate the full set of RINF data available in their RINF. They shall make regular updates, at least every three months, of items that are in their register of infrastructure. One update should coincide with the annual publication of the Network Statement.

Then NREs shall upload the files to the CUI through a dedicated interface provided for this operation. A specific module will facilitate the validation and uploading of data provided by NREs.

The CUI central database shall make data sent by NREs publicly available without any modification. The basic functionality of the CUI shall allow users to searches and retrieves RINF data.

The CUI shall retain the complete historical record of all the data made available by NREs. Those records shall be stored for 2 years from the date of withdrawal of the data.

The CUI shall be available 7 days a week, from 02:00 GMT — 21:00 GMT. The unavailability of the system shall be minimal during maintenance. In the case of failure outside the normal working hours of the Agency, the actions to restore the service shall start the next Agency working day.

7. APPLICATION GUIDE FOR THE COMMON SPECIFICATIONS

The application guide for the common specifications shall be made publicly available by ERA on its website. It shall contain:

1. items and their corresponding data. For each field, at least its format, limit of value, conditions under which parameter is applicable and mandatory, railway technical rules for parameters values, reference to TSIs and other technical documents related to items of the RINF;
2. detailed definitions and specifications for concepts and parameters;
3. presentation of provisions for modelling the network for the purpose of RINF and collecting data with relevant explanations and examples;
4. procedures for validation and submission of RINF data from registers of infrastructure of the Member States to the CUI.

8. CONCLUSION

Setting up the RINF is not just the fulfillment of legal obligation, this will also help railway undertakings to plan the use of their vehicles and trains in accordance with the route parameters and will ease the verification procedure of the structural subsystems serving as a comprehensive data base.

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DETERMINATION OF SLEEPER SUPPORT CONDITIONS

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***Abstract** – Interaction between ballast bed and sleepers significantly influences track dynamic behaviour. Many investigations conducted in the field showed that more than 50% of installed sleepers can be considered as unevenly supported. In addition, investigations showed that unevenly supported sleepers often occur in a row and that this phenomenon leads to significant increase in dynamic forces in wheel-rail contact (increase up to 80% comparing to the sections with regular sleeper support). In current praxis, different methods for determination of sleeper support conditions were applied. This paper considers phenomenon of unevenly supported sleepers and it presents non-destructive determination methods.*

Keywords – track, ballast bed, sleepers, sleeper support conditions, non-destructive methods.

1. INTRODUCTION

Differential settlement of the ballast bed is an inevitable process that often causes irregular support of sleepers. In addition, this phenomenon could occur due to the embankment settlement. On the other hand, unevenly (partly) supported and unsupported sleepers (further referred as poorly supported sleepers) lead to ballast bed degradation and track geometry deterioration.

According to the research presented in [1], more than 50% of the sleepers could be considered as unevenly supported. Research conducted by Li and Sun showed that unevenly supported sleepers usually occur consecutively over 1-4 m of track [2], which was recently confirmed [3,4]. In addition, it was determined that void which occurs beneath the sleepers usually ranges from 2 mm to 4 mm [2,5].

Zhang et al. determined correlation between void height and vertical force in the wheel-rail contact, which applies for cases with up to 6 consecutive unsupported sleepers [6].

Ballast-sleeper interaction contributes significantly to the dynamic behaviour of the railway track [7]. Therefore, one or several consecutive poorly supported sleepers would lead to significant increase in dynamic influence. For example, dynamic forces in the wheel-rail contact could be up to 80% higher comparing to sections with good sleeper support [7]. When the wheel-rail contact force exceed yield strength of the rail steel it could lead to the origination and development of the rail defects due to the rolling contact fatigue [8-11].

Research conducted by Shi et al. considered influence of several cases of unsupported sleepers on the elements of track superstructure and substructure, track stability and ride quality using finite element model of the track. At first, they analysed track with good sleeper support. Afterwards, they used obtained results as a benchmark for cases with one to four consecutive unsupported sleepers. Following impacts were determined [5]:

- increase in the reaction force on the fastener: $R_1=1{,}35\cdot R_0$, $R_4=3{,}20\cdot R_0$,
- increase in the vertical acceleration of the vehicle: $q_2=1{,}35\cdot q_0$, $q_3=1{,}69\cdot q_0$, $q_4=2{,}38\cdot q_0$,
- increase in the wheel-rail contact force: $P_1=1{,}03\cdot P_0$, $P_4=1{,}12\cdot P_0$,
- increase in the stress that transfers to the embankment: $\sigma_{b1}=1{,}01\cdot\sigma_{b0}$, $\sigma_{b4}=1{,}60\cdot\sigma_{b0}$,

where index i=0,1,2,3,4 (R_i, q_i, P_i and σ_{bi}) represents the number of consecutive unsupported sleepers.

On the other hand, irregular cross level leads to uneven stress distribution beneath the sleeper [12], which additionally contributes to the negative impact of poorly supported sleepers.

Research conducted by Lazarević et al. showed that deterioration of the vertical track geometry (longitudinal level) can be correlated with the sections of track with poor sleeper support [3,4].

2. METHODS FOR DETERMINATION OF SLEEPER SUPPORT CONDITIONS

Regarding previous considerations, it is obvious that

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determination of poorly supported sleepers in field is an important task for each Infrastructure Manager.

Determination of sleeper support conditions could be conducted using different methods. In general, these methods could be divided into direct and indirect methods. Direct methods provide the results related directly to the support conditions. On the other hand, indirect methods imply measuring parameters that are correlated to the sleeper support conditions, therefore providing the basis for indirect conclusions.

Regarding the in-field application, determination methods could be divided into continuous and manual (non-continuous) methods. Continuous methods imply application on network level using adequately equipped inspection vehicle. Non-continuous methods imply application on section level using manually propelled or portable devices.

It is important to state that there are pros and cons for each method. Therefore, responsibility of Infrastructure Manager is to choose the method that would provide reliable results, which provide the basis for creating the adequate maintenance plan.

3. DIRECT METHODS

Direct methods for determination of sleeper support conditions imply ballast bed scanning using acoustic waves [3], ultrasound [13], or ground penetrating radar (GPR) [14,15]. These methods could be applied both continuously and manually. For example, there are inspection vehicles equipped with GPR that are used on railway networks in Switzerland and Netherlands (Figure 1).

Fig.1. Inspection vehicle equipped with GPR on railway network in Netherlands

The most commonly used direct method is GPR, which is based on the principle that propagation of electromagnetic wave changes due to the passing from one medium to another. These changes are detected by the antenna, which digitally records the obtained signal.

Data collected using GPR cannot provide reliable results about sleeper support condition. The main problem with GPR is the calibration. On the other hand, electromagnetic waves reflect off the rails, reinforcement in sleepers, masts and similar steel structure, thus providing unreliable results.

4. INDIRECT METHODS

Indirect methods for determination of sleeper support conditions imply measuring sleeper vibration, vertical acceleration, velocity, deflection, or other parameters that could be correlated to the sleeper support conditions.

Kim et al. measured sleeper deflection on three sections of high-speed rail line in South Korea [16]. There were used three measurement methods in this research: a simple vertical deflection sensor, a modified falling weight deflectometer (as in Figure 2), and an optical system for deflection measurement. Analysis of the obtained results confirmed that poorly supported sleepers had larger deflections [16].

Fig.2. Sleeper deflection measurement using modified falling weight deflectometer

The vertical deflection could be determined by measuring vertical acceleration, and subsequent double integration of the obtained signal. This method was applied by Brajović et al. in the research conducted on 'TENT' railway network for coal transportation [17]. Figure 3 shows wireless sensor that was used in this research.

In addition, Brajović et al. investigated sleeper deflections on the same railway network using position sensitive detector fixed to the rail web (Figure 4). Same method was applied in the field research by Pinto et al. on the high-speed rail line in Portugal [18].

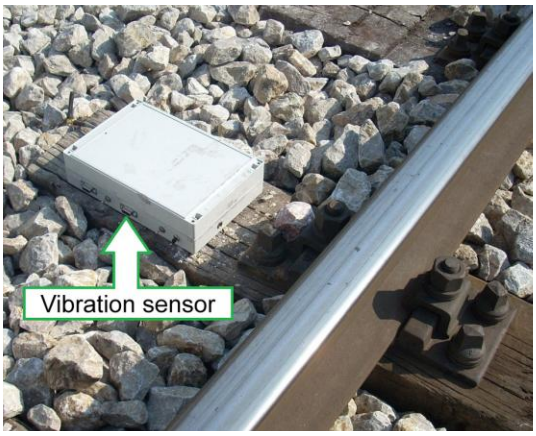

Fig.3. Wireless sensor for sleeper vibration measurements [17]

Fig.4. Position sensitive detector for sleeper vibration measurements

According to the definition of track stiffness [19], increase in the sleeper deflection would lead to the decrease in track stiffness. Therefore, track stiffness diagrams could be used for determination of track sections with poor sleeper support.

There are several types of devices that are used for continuous track stiffness measurements, such as rail-mounted devices (as in Figure 5) or devices that could be installed in the inspection vehicle [20]. These devices usually measure vertical force and acceleration, while deflection is calculated by double integration of the measured acceleration (as in [17]).

Fig.5. Rail-mounted device for track stiffness measurements used in UK [21]

However, it is necessary to state that track stiffness is not homogenous along the track [19]. First of all, stiffness diagrams are recognised by local maximum values that repeat regularly. These values correspond to the track stiffness beneath the sleepers [20]. On the other hand, abrupt changes in stiffness diagrams occur when device passes over track discontinuities, such as fish plate joints, isolated joints, expansion joints, transitions before and after bridges and culverts, switches, etc. Therefore, analysis of the stiffness diagrams and determination of sections with poorly supported sleepers demands detailed data about superstructure and substructure.

Sleeper support conditions could be determined using the analysis of sleeper dynamic response to the naturally or artificially induced excitation. The main idea of this method implies that poorly supported sleepers have significantly higher amplitudes comparing to the evenly supported sleepers [3,4].

Sadeghi investigated response of the railway track system to the artificially induced sleeper vibrations in order to obtain track dynamic coefficient [22]. However, this method is suitable for determination of sleeper support conditions.

The research conducted by Lazarević in 2014. proved the reliability of the measurement system for micro-tremor sampling presented in Figure 6 [3,4]. The micro-tremor contains the continuous ambient micro-vibrations that transfer from the surrounding soil to the railway structure. Therefore, this research implied analysis of sleeper response to the naturally induced vibrations.

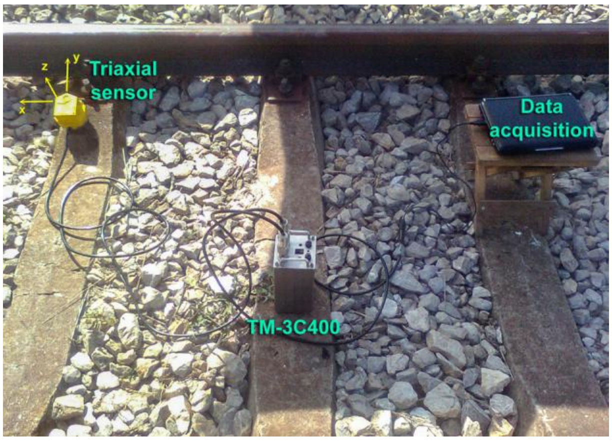

Fig.6. The measurement system for micro-tremor sampling [3,4]

The main advantages of the micro-tremor measurement system are: its portability, ease of set-up and speed of measurements, and it can be used on operational lines [3,4].

5. CONCLUSION

Accumulated traffic load leads to inevitable ballast bed degradation and track geometry deterioration.

Accordingly, it is necessary to define maintenance policy and strategy in order to ensure continuous condition monitoring, thus providing the basis for preparation and application of short term and long term plans of optimal maintenance.

Poorly supported sleepers can significantly reduce the service life of ballast bed, and at the same time negatively influence track geometry degradation. Therefore, these sleepers need to be examined to detect problems, and appropriate maintenance activities performed as early as possible. This approach ensures the possibility of reducing the overall maintenance costs.

This paper reviewed methods that can be used to determine sleeper support conditions. These methods are divided into continuous and manual, depending on the in-field application, and into direct and indirect, depending on the type of the obtained results.

Each method has its advantages and disadvantages related to the field application and reliability of the results. However, Infrastructure Manager has the responsibility to choose the optimal method by considering:

- level of investigation (network or section),
- reliability of the obtained results,
- time to set up and carry out the investigation,
- costs,
- transport to the field and need for the track closure.

ACKNOWLEDGEMENT

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PERFORMANCE REQUIREMENTS FOR RAIL FASTENING SYSTEMS ON EUROPEAN RAILWAY NETWORK

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***Abstract** – In order to realize interoperability of railway system, the reconstruction and modernization plan of railway network in the Republic of Serbia should be harmonized with technical requirements of European railway network. The paper presents hierarchical approach to harmonization of legal and technical regulations in the area of railway infrastructure, with special attention drawn to the rail fastening systems. Performance requirements for rail fastening systems were analysed according to the adopted standard series SRPS EN 13481 and SRPS EN 13146.*

Keywords – track, rail fastening systems, performance requirements, harmonization, interoperability.

1. INTRODUCTION

Harmonization of the technical regulation in the area of railway infrastructure is still in progress in the Republic of Serbia. European Committee for Standardization (CEN) has created a group of standards EN 13481-Railway applications - Track - Performance requirements for fastening systems, which consists of eight parts as listed below:

- Part 1: Definition [1],
- Part 2: Fastening systems for concrete sleepers [2],
- Part 3: Fastening systems for wood sleepers [3],
- Part 4: Fastening systems for steel sleepers [4],
- Part 5: Fastening systems for slab track with rail on the surface or rail embedded in a channel [5],
- Part 6 (European Prestandard): Special fastening systems for attenuation of vibration [6],
- Part 7: Special fastening systems for switches and crossings and check rails [7],
- Part 8: Fastening systems for track with heavy axle loads [8].

The above mentioned parts 1-8 are adopted by the Institute for standardization of Serbia (ISS) [9]. The Serbian standard series SRPS EN 13481 is identical with the European EN 13481 standard series.

Furthermore, the standard series EN 13146 "Railway applications - Track - Test methods for fastening systems" supports the requirements in the EN 13481 series and consists of the following parts:

- Part 1: Determination of longitudinal rail restraint [10] (Fig.1),
- Part 2: Determination of torsional resistance [11],
- Part 3: Determination of attenuation of impact loads [12],
- Part 4: Effect of repeated loading [13] (Fig.2),
- Part 5: Determination of electrical resistance [14] (Fig.3),
- Part 6: Effect of severe environmental conditions [15],
- Part 7: Determination of clamping force [16],
- Part 8: In service testing [17],
- Part 9: Determination of stiffness [18] (Fig.4).

The parts 1-9 of the standard series EN 13146 are adopted by the ISS [19]. The Serbian SRPS EN 13146 standard series is identical with the EN 13146 European standard series.

The adopted SRPS EN 13481 and SRPS EN 13146 standard series are not translated into Serbian language except the Serbian titles and scopes. Significant obstacle to the effective implementation of the adopted SRPS EN standards in engineering practice is the lack of their sense expressed in Serbian technical language.

In this paper, performance requirements for rail fastening systems on rail lines with design speed up to 160 km/h and axle load up to 225 kN were considered according to the adopted SRPS EN 13481 and SRPS EN 13146 standard series.

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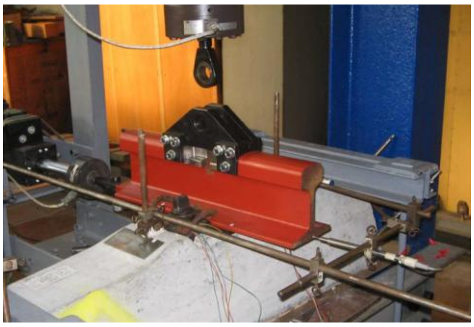

Fig.1. Test arrangement for determination of axial force during the longitudinal displacement of the rail [20]

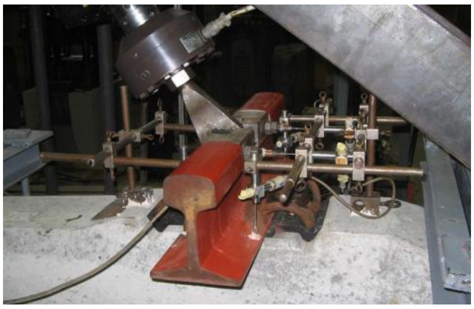

Fig.2. Laboratory test with repeated loading [20]

Fig.3. Determining the electrical resistance in wet conditions, in laboratory

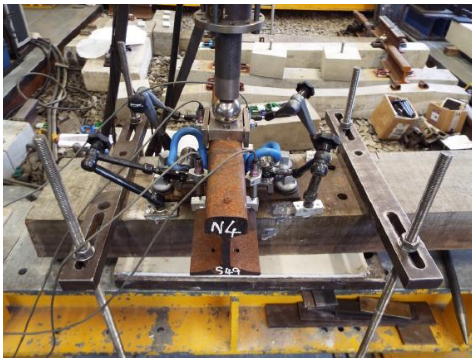

Fig.4. Dynamic stiffness test arrangement for complete rail fastening assemblies

2. PERFORMANCE REQUIREMENTS FOR FASTENING SYSTEMS ON CONCRETE SLEEPERS

The definitions of the terms used in the EN 13481 series were specified in the European Standard EN 13481-1:2012 [1]. In accordance with [1], "fastening system is assembly of components which secures a rail to the supporting structure and retains it in the required position whilst permitting any necessary vertical, lateral and longitudinal movement".

This standard series considers specific requirements for fastening systems depending on the type of supporting structure (concrete sleepers [2], wood sleepers [3], steel sleepers [4], slab track [5]), as well as requirements for special fastening systems (for attenuation of vibration [6], switches and crossings and check rails [7] and for track with heavy axle loads [8]).

Since the fastening systems on concrete sleepers in ballasted track are usually in use, the paper presents the performance requirements for fastening systems in accordance with [2]. These requirements apply to main lines having a radius of curvature greater than 150 m and a maximum design axle load of 260 kN, as well as to light rail systems having a radius of curvature greater than 40 m and a maximum design axle load of 130 kN (Tab. 1).

Tab. 1. Fastening categories in accordance with [2]

Categories of fastening system	Maximum design axle load [kN]	Minimum curve radius [m]
A	130	40
B	180	80
C	260	150
D	260	400
E	350	150
Note: The maximum axle load for A and B categories does not apply to maintenance vehicle		

The requirements apply to direct and indirect fastening systems which act on the foot and/or web of the rail. Further, they apply for the rail sections in accordance with [21] (excluding 49 E4) and with [22]. It should be noted that this standard is not applicable to fastening rigid fastening systems (e.g. K fastening system which is often represented on the railway lines in Serbia).

Performance requirements for fastening systems for use on concrete sleepers in ballasted track include longitudinal rail restraint, torsional resistance, attenuation of impact loads, effect of repeated loading, electrical resistance of fastening system and sleeper, effect of exposure to severe environmental conditions, overall dimensions, effect of fastening system tolerances on track gauge, clamping force, cast-in fastening components, and in-service testing.

Required longitudinal rail resistance depends on the speed limit and the special requirements of substructure. In that sense, the longitudinal rail resistance shall be not less than 7 kN (controlled over the measurement process according to EN 13146-1) on the conventional rail lines and not less than 9 kN on high-speed lines (≥250 km/h).

In accordance with the design of the track supporting structure, the minimum requirement for longitudinal restraint may be reduced by agreement between the purchaser and manufacturer. For example, the utilization of expansion devices to prevent excessive longitudinal displacements and forces on the long railway bridges, is expensive and bad solution in regard to traffic safety and comfort, as well as maintenance costs. Therefore, it can be applied an alternative solution of fastening system with reduced rail longitudinal restraint. Fig.5 and Fig.6 show the PANDROL® ZLR (Zero Longitudinal Restraint) system designed to keep track forces from being transmitted to bridge, to hold the rail vertically in place, to provide lateral restraint and to prevent rail rollover.

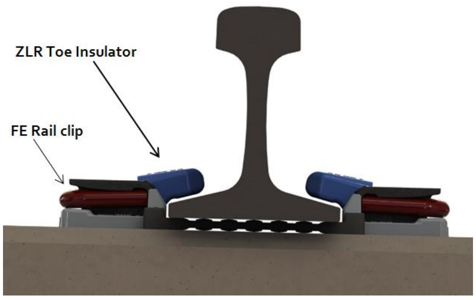

Fig.5. Pandrol ZRL fastening systems with the gap under toe insulator and foot of rail

Fig.6. Installed fastening system with ZLR clips (Pandrol VIPA system) on a bridge

The torsional resistance is measured in accordance with [2] and the result reported.

For fastening systems described as having medium or high attenuation of dynamic loads, test shall be conducted in accordance with [3] and the result reported. Test results for medium attenuation shall be in the range from 15 % to 30 % and for high attenuation > 30 %.

The assembly static stiffness and assembly low frequency dynamic stiffness shall be measured in accordance with [19]. At the request of the customer, the rail pad static stiffness, the pad low frequency dynamic stiffness and the assembly high frequency dynamic stiffness should be measured in accordance with [19] and [2] (loads for measurement of stiffness were defined in [2]).

The effect of repeated loading shall be determined by the procedure defined in [13] using the test loads and positions defined in [2].

In accordance with [13], the following measurements shall be performed before and after repeated loading:

- longitudinal rail restraint (permitted change ≤ 20 %),
- vertical static stiffness change (permitted change ≤ 25 %), and
- clamping force (permitted change for fastening systems which act on the foot of the rail ≤ 20 %).

The electrical insulation shall be not less than 5 kΩ when measured in accordance with [14]. The user may specify a higher value for use with certain track circuits (guidance on traction currents is given in [23] and SRPS EN 50122-2:2011).

Effect of exposure to severe environmental conditions is determined in accordance with [15] based on the salt spray test. After the test, the fastening assembly shall be capable of being dismantled, without failure of any component and re-assembled using manual tools provided for this purpose.

Fig.7 shows the envelope for rail fastening systems (which act on the foot of the rail) for concrete sleepers in ballasted track and rail section in accordance with [21] excluding 49 E4 and [22]. This envelope is necessary to avoid interference with vehicles including track maintenance vehicles.

It should be noted, for web support fastening systems, the minimum flangeway shall comply with national regulations and the envelope of the fastening systems shall be provided by the supplier.

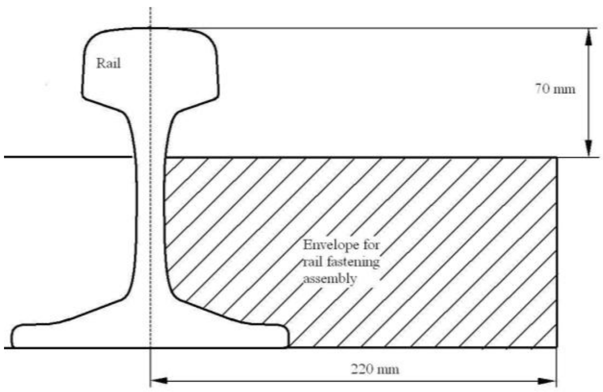

Fig.7. Envelope for rail fastening systems (which act on the rail foot) for concrete sleepers in ballasted track

The manufacturer shall provide a drawing of the interface between the fastening system and the sleeper. The variation in the static track gauge which can arise from the fastening system shall not exceed ± 1 mm.

Clamping force for fastening systems (acting on the rail foot) shall be determined by the procedure prescribed in [16] and the result shall be reported. The requirement for clamping force is not applicable to web support fastening systems.

In-service testing shall be carried out in accordance with [17] at the request of the customer.

Other specific requirements for fastening system must be defined by the customer.

3. CONCLUSION

In this paper, technical requirements for rail fastening systems on rail lines with design axle load up to 350 kN were considered in accordance with EN 13481 European Standard series. It points to the mandatory requirements and according to the European standards and specific requirements according to the conditions of the project.

The paper presents the performance requirements for fastening systems on concrete sleepers in ballasted track since these fastening systems are usually in use.

European standards series EN 13481 and EN 13146 were adopted by the Institute for Standardization of Serbia as the Serbian standards SRPS EN 13481 (Parts 1-8) and SRPS EN 13146 (Parts 1-9). Implementation of SRPS EN standards is difficult because they were published only in English.

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CERTIFICATION OF RAILWAY SIGNALLING SYSTEMS ACCORDING TO EU LEGISLATIVE AND CENELEC STANDARDS

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***Abstract** – In recent years CENELEC adopted a group of standards which define the quality and safety of railway signalling systems, electromagnetic compatibility and environmental impact. These standards are based on the group of IEC standards for the safety of industrial electronic systems - IEC 61508. However, after the above mentioned group of EU norms began to apply in the technical specifications, regulations and other normative acts for signalling systems of individual states, and became an integral part of the technical specifications in the tender documents, many problems has appeared. Most of the problems are related to the ambiguity of the type and quantity of certifying documentation and bodies which issues certificates, independent safety assessment reports and test reports. Failure to comply with the existing procedures at many railways in Europe produced a major systemic problems related to quality, safety and maintenance of the systems. This paper intends to show how CENELEC standards and EU regulations should be implemented in certification process and required tests and how to control the independency of certification bodies that issue certificates and reports with the aim to avoid manipulation in proving the quality and safety of the system.*

Keywords – CENELEC, safety, electromagnetic compatibility.

1. INTRODUCTION

Railway signalling systems have an important role in safety of railway traffic. Signalling system described in this paper are part of Control-command and Signalling (CCS) subsystem. The level of safety that these systems must ensure depends on the quality of their design and production as well as the corresponding documentation proving their safety performance. Certification basically means all measures and actions to be taken in order to achieve all the preconditions necessary for their safe and reliable operation under all conditions of their use. Term certification in this paper also include all necessary documentation including final written decision of the infrastructure manager to accept and place in service such system or any their part that is subject of the certification process.

Main role in certification process has proper implementation of relevant standards but also bodies which issue documents as proof that such standards are correctly implemented. In European Union, as well all over the world, CENELEC and IEC standards are relevant documents and have to be implemented. Some of this standards are mandatory as it is written in Commission Decision on the technical specification for interoperability relating to the CCS subsystems, for example EN 50126, EN 50128, EN 50129 and EN 50159. These standards came out from IEC 61508 standards and basically they are compatible.

2. CONFORMITY ASSESSMENT BODIES

2.1. Notified body (NoBo)

Notified body assesses and verifies conformity of subsystem or it parts and their solutions with relevant technical specifications for interoperability (TSI). Considering that only ETCS system as part of railway signalling systems for railway infrastructure is covered with relevant technical specifications for interoperability, NoBo has important role only when ETCS system is implemented. Other signalling equipment are has no interoperability constituent and only in very small part is covered with mandatory specifications inside relevant TSI.

2.2. Designated body (DeBo)

Designated body assesses and verifies conformity of subsystem or it parts and their solutions with relevant notified national technical rules (NNTR) and for national signalling systems for railway infrastructure still has more important role than

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notified body.

2.3. Common safety method risk assessment (CSM RA)

The Common safety method for risk evaluation and assessment applies when any technical, operational or organisational change is being proposed to the railway system. Bodies which perform such activities are CSM risk assessment bodies.

Generally, assessment body always means the independent and competent external or internal individual, organisation or entity which undertakes investigation to provide a judgment, based on evidence, of the suitability of a system to fulfil its safety requirements.

Assessment body as it is defined in Commission Implementing Regulation (EU) No 402/2013 shall be either accredited by the national accreditation body, recognised by the recognition body, or the national safety authority (NSA) designated by the member state as able to conduct independent assessment.

When member state recognises NSA as an assessment body, it is the responsibility of that member state to ensure that assessment body functions of NSA shall be demonstrably independent of the other functions of NSA. The assessment body shall fulfil all requirements of the ISO/IEC 17020:2012 standard and of its subsequent amendments. The assessment body shall exercise professional judgement in performing the inspection work defined in that standard.

2.3.1. Safety assessment body

According CENELEC standards EN 50126, 50128 and 50129 safety assessment body has the most important role in assessment if some signalling system or its assessing part meets conditions for target safety integrity level (SIL).

For parts of the system to which this standard does not apply, other standards, national technical regulations or principles such as practices and evidence of quality through the use of multi-year (code of practice, grandfathers right) should be applied. Regulation 402/2013 requires a level of safety that only technical solutions by itself in practice may not achieve and it is necessary to include the human factor.

Standard ISO/IEC 17020:2012 determine conditions for independency level of safety assessment body, but only body accredited as type A is real independent body (real third party). Good and objective assessment report is of great help for infrastructure manager because through his SMS (safety managements system), specially maintenance procedure, infrastructure manager can insure safe and reliable work of assessed system or his part. Reason for objective issued report is in fact that relevant standards under some conditions allow that maintenance staff can be involved in preconditions for safe and reliable work of signalling system. This includes periodical testing, measurements, monitoring and other procedures.

It is important to accent that safety assessment report means the document containing the conclusions of the assessment performed by an assessment body.

Some assessment bodies, especially if they are not type A body, for assessment process include external physical person as assessor. At the discretion of the safety authority, the assessor may be part of the supplier's organisation or of the customer's organisation but, in such cases, the assessor shall be authorised by the safety authority. Assessor shall be totally independent from the project team and report directly to the safety authority.

To complete safety assessment report it is mandatory to get certificates and test reports for electromagnetic compatibility and environmental impact issued by accredited testing laboratory. Only in such case safety assessment report is completely and correctly done because orders of standards which cover these areas (EN 50121-4 and EN 50125-3) are contained in standard EN 50129. This standard is basic standard for hardware of safety related electronic systems for railway.

2.4. Documents issued from conformity assessment bodies

Central figure in overall certification process is infrastructure manager, or, in some states, manufacturer of system, as a proposer for authorisation for placing in service of signalling system or some of its part. Before formal asking for authorisation, proposer has to get relevant documents of conformity assessments.

Proposer also means applicant for authorisation for placing in service.

According to Directive of interoperability of the rail system within the European Union notified body (NoBo) issue 'EC' certificate of verification for subsystem or 'EC' certificate of conformity for interoperability constituent.

Designated body (DeBo) issues certificate of conformity or document with similar title for subsystem or its part under assessment (title of document depends on national legislative).

Basic document that confirms target safety integrity level is safety assessment report. Quality of such report often depends on real independency of safety assessment body (inspection body). Safety assessment report is mandatory not only for new signalling system but also for significant changes on existing system.

Declarations of conformity for interoperable constituents issued by manufacturer are covered with EU legislative ('EC' declaration of conformity) but for non-interoperable constituents or parts of signalling systems declaration of conformity are covered with other directives or national legislative.

3. REQUEST FOR AUTHORISATION FOR PLA

In Directive 2008/57/EC on the interoperability of the rail system within the Community is written that until such time as the extension of the scope of the TSIs to cover the whole of the rail network takes effect, authorisations for the placing in service of trackside CCS subsystems on the parts of the network that do not yet fall within the scope of the TSIs, shall be granted in accordance with the national rules referred to in Article 8 of Directive 2004/49/EC, or, where applicable, Article 17(3) of this Directive.

The authorisation for placing in service of a subsystem is the recognition by the member state that the proposer for this subsystem has demonstrated that it meets, in its design operating state, all the essential requirements of Directive 2008/57/EC when integrated into the rail system. In some national legislatives term authorisation for placing in service is translated as approval of use what has different meaning and can caused additional problems in formal procedures.

Authorisation for placing in service from its start was mainly orientated to locomotive and trainsets. For a long time railway vehicle was covered with relevant UIC leaflets (RIC/RIV signs on vehicle). All efforts of EU institution was targeted to possibility for each locomotive and trainset to pass EU country borders without stop and travel safely through all EU railway network.

Procedures for authorisation for placing in service for infrastructure CCS subsystems sometimes can be implemented to their parts i.e. parts of signalling system. If the change on existing system has a potential impact on safety the proposer must decide on whether it is significant or not by using criteria in the CSM RA.

Starting document in this procedure is Commission Recommendation of 5 December 2014 on matters related to the placing in service and use of structural subsystems and vehicles under Directives 2008/57/EC and 2004/49/EC of the European Parliament and of the Council (2014/897/EU). Unofficially this document is known as DV29bis. This recommendation is not mandatory act but can be very useful in overall process of certification.

The following diagram summarises the activities before and after an authorisation for placing in service of an infrastructural subsystem (diagram based on DV29bis).

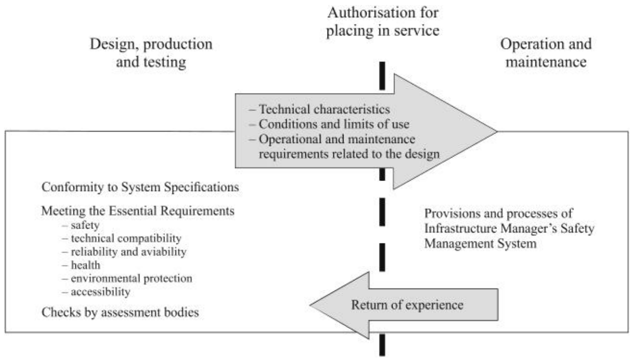

Fig.1. Activities before and after authorisation for placing in service

Based on the results of the application of Commission Implementing Regulation (EU) No 402/2013 and on the safety assessment report provided by independent assessment body, the proposer shall produce a written declaration that all identified hazards and associated risks are controlled to an acceptable level.

When proposer collects all necessary documents from NoBo, DeBo and safety assessment body, sometimes his obligation is to apply additional CSM risk assessment as it is written in article 38. of recommendation DV29bis. This risk assessment refers primarily on safe integration of new signalling system in existing infrastructure or safe integration of some part of signalling system in existing one.

In addition to the basic requirements and by EU regulative mandatory documents, with a request for authorisation for placing in service, proposer has to deliver technical description of system, project documentation, declarations of conformity and other documents which confirm ability of system and personality for his use and maintenance.

Generally, an authorisation for placing in service of fixed installation subsystems should refer to its technical characteristics, including limits and conditions of use. The technical characteristics referred to in the authorisation for placing in service should be declared by the proposer, verified and certified by the assessment bodies, and documented in the technical file accompanying the declaration of conformity.

Authorisation for placing in service of signalling system described above is for new type for infrastructure manager. Once accepted, signalling system or their part especially assessed for generic application, is accepted as a type for implementation on railway infrastructure under one infrastructure manager. Procedure for authorisation for placing in service for second and any further same system is simplified.

The tests that may be required for authorisation, which have to be performed before the authorisation for placing in service and which require the involvement of an assessment body, should be the tests which are explicitly specified in the TSIs, modules, and, where relevant, in national rules, defined by the proposer for demonstrating the compliance with the requirements of the TSIs and/or national rules, defined in other EU legislation, or defined by the proposer, in accordance with the application of CSM RA as described in recommendation DV29bis article 41.

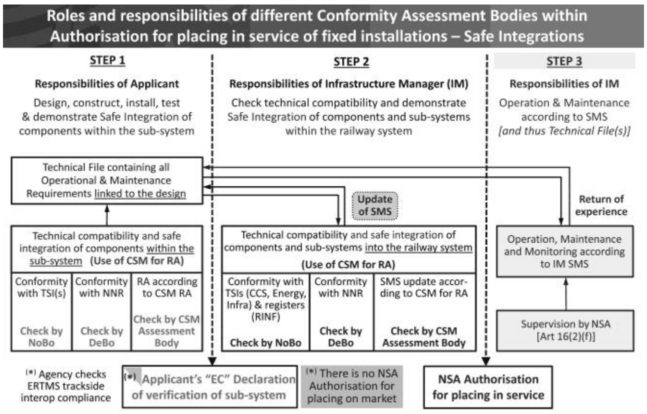

Fig. 2. Roles and responsibilities of different Conformity Assessment Bodies within placing in service (Authorisation of System – Safe Integrations)

Internal checks performed by infrastructure manager are still very important as it is shown in step 2 of figure 2. These checks confirm safe integration of the signalling system or its part within exiting railway system. NSA authorisation for placing in service is possible at the end of step 2.

Declaration of conformity issued by manufacturer should be accompanied by a technical file, including the documentation describing the system or it part, the documentation resulting from the procedures carried out by different assessment bodies and the documentation of the elements relating to the conditions and limits of use and to the instructions concerning servicing, constant or routine monitoring, adjustment and maintenance. The technical file accompanying the declaration of conformity includes all supporting documents needed for the authorisation for placing in service.

It is recognised as a good practice for proposers to engage informally with national safety authorities as early as possible so that the process, requirements, roles and responsibilities, scope of application and limitations and conditions of use are clear and that there are no difficulties at a later stage. National safety authority will be able to decide that, according to national legislative, authorisation for placing in service in some cases is not necessary.

4. CONCLUSION

EU legislative is primarily orientated on fulfilling all conditions necessary for interoperability of the rail system within the European Union. Until there is a full suite of TSIs in place, where there is a gap in the framework – for example if a TSI is under development, member states have their national rules which has to be notify to ensure that subsystems are designed and built to meet the essential requirements.

Some important parts of overall certification of national signalling system is very well covered with relevant CENELEC standards and EU legislative, but for authorisation for placing in service for such systems and specially their part national legislative must be applied. This legislative has some gaps and misunderstandings which basically come from wrong translation and implementing of phrase authorisation for placing in service. Authorisation should not be translated as approval as it is written in some national laws.

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[4] ERA presentation

RELOCATION OF THE NIS - PREŠEVO RAILWAY LINE BETWEEN STATIONS PREDEJANE AND DŽEP FOR THE PURPOSE OF THE CONSTRUCTION OF THE HIGHWAY E75 ON CORRIDOR 10

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Abstract *– European Transport Corridor 10 through Serbia is spatially defined by the railway and highway lines in the same infrastructure corridor, especially in Grdelica Gorge. Due to space constraints the designer planned relocation of the international railway line Belgrade - Mladenovac - Niš - Preševo - State Border between railway stations Predejane and Džep in a distance of 1535 meters. In the beginning, the Public Enterprise Serbian Railways did not give the approval for the relocation of the railway line. New section of the railway line is planned in the major riverbed of the South Morava, so that appropriate measures were necessary to protect the embankment of the new railway line. A particular problem is the operating of the railway during the construction, which is reflected in the dynamics of the construction of the highway because the relocation of the railway is prerequisite for highway construction. After the fulfillment of the technical conditions in the Main design PE Serbian Railways finally gave its approval for the relocation of the railway line. Construction works finally started in October 2015.*

Keywords – infrastructure corridor, highway, railway, relocation, construction

1. INTRODUCTION

Transport Corridor 10 through Republic of Serbia is spatiallu defined bu the railway and highway lines in the same infrastructure corridor. This is a consequence that the main road and rail lines followed the route of the ancient Roman roads, laid in the valleys of major rivers (for example, the VIA MILITARIS road on Belgrade - Niš - Preševo and Niš - Dimitrovgrad road and railway lines). The development of transport infrastructure in Serbia, as well as in other parts of Europe, was such that the railway network was completed first. The construction of highways was begun 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. This can be a significant problem in terms of spatial constrains [1].

The subject of the project is the relocation of the railway on Section Caričina Dolina - Vladičin Han of the Highway E75, which follows the Section Gornje Polje - Caričina Dolina, and continuos with the Section Vladičin Han - Donji Neradovac.

At the beginning of the section , spatial constraints are such that, in a narrow river valley , it was not physically possible to place the railway , highway and alternate path without significant engineering interventions.

In that sense, the designers made the analysis, which were compared three variants highway:

- with the relocation of the railway,
- with the construction of the viaduct road - overpass over the railway and
- with the construction of road tunnel.

The analysis showed that the optimal solution of the highway construction on that section is the relocation of the railway from km 316 + 900 to km 318 + 435, which was confirmed by the report of the Review Committee of the Republic of 28.04.2011.

The main task in the preparation of the project was to give quality technical solution for railroad relocation and reconstruction of the necessary elements of infrastructure with minimal disruption to traffic on the international railway line.

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1.1 Functional and technical specifications

Limitary elements of situational plan and longitudinal profile are not worse than the design elements in the interstation distance Predejane - Džep of the existing lines. The existing railway section is part of the present single-track line, electrified with traction system 25.000V, 50Hz. The minimum radius of horizontal curve over the interstation distance is 300m, a maximum vertical slope is 5 ‰ [2].

Design speed is 65km/h. The alignment of the railway is a minimally displaced toward the South Morava riverbed, it would be possible to build a highway in the area between the existing highway and railway. On the right side of the track, toward the riverbed, the peripheral road traffic for maintenance of the railway infrastructure was build. The beginning of rail transport at the relocated route of the railway is a precondition for the continuation of construction work on the highway.

2. DESCRIPTION OF THE CURRENT SITUATION

From km 316 + 900 to km to the culvert on km. 317 + 200 body of the existing lines is close to the riverbed of South Morava. From km 317 + 200 ie. from the culvert, the Morava river bed is separated from the body of the existing railway line to the west over a distance of 100 to 150 m. From km. 318 + 500 lines nearing the existing highway, so at km. 318 + 253 passes Seliški creek. From the bridge over the Seliški creek all the way to the train station Džep line running along the river South Morava. From km. 317 + 200 to km. 318 + 253, in the part where the Morava moving away from the existing lines , there is a large partially cultivated surface and the surface on which the exploited gravel and logging. This surface can be approached only in conditions when there is no rain, and that from the direction of the railway station Džep, crossing the bed of the Seliški creek.

On this section there are 6 curves with vertices and elements: T32 (R=300, L=30), T33 (R=600, L=50), T34 (R=800, L=50), T35 (R=350, L=50) и T36 (R=300, L=60).

On the existing alignment there is following culverts: arched culvert L=4.00m km. 316+990, plate culvert L=2.00m, km. 317+250, arched culvert L=1.00m km. 317+425, plate culvert L=1.00m km. 317+800.

The existing railway line is electrified at 25kV 50 Hz and secured with the APB system on the regime of remote control.

3. DESCRIPTION OF DESIGNED RELOCATION

According to technical conditions PE "Railways of Serbia"[2] designed relocation was done for the railway line no. 3 Belgrade - Mladenovac – Nis - Preševo - state border from km. 316 + 900 to km. 318 + 435 of the 1st order line. On the line is kept current speed V = 65 km / h on the basis of which it is given and elevation of the outer rail in curves. In this part of the relocation is projected planum width b = 2x3,00 = 6.00m , with rails 49E1 on reinforced concrete sleepers for rail with relevant fittings. Since the market has enough sleepers JŽ 70K with K accessories, the project envisages their installation, which maintains the same superstructure on the entire railway line. Ballast is of crushed stone with the thickness of 30 cm below the concrete sleepers. Due to the conditions of increased ballast the width of the formation of 6.00m is adopted.

Fig. 1: Location before starting the execution of works (photo: Aleksandar Naumović)

On the new designed railway alignment protective layer with thickness of d = 30 cm of gravel-sandy material is provided. The protective layer is applied over the embankment which is made with a slope of 5%. Bearing in mind that the embankment is made of stone material from the quarry Momin Kamen, there wasn't need to install transitional layer resistant to the frost. In the open part of the railway line two sided cross slope of 4% is designed. The existing ruling grade on the line is retained and it does not exceed 0.6%.

In order to consider the reconstruction of the section of railway in the length of L = 1000 m , it was necessary to examine the current state of the line in front of and behind a length of about 500 m, and in this regard the whole situation of the field from km. 316 + 900 to km. 318 + 435 was taken. On the obtained situation of terrain, and on the basis of the main highway project, preliminary project of relocation of the railway from km 0 + 000 to km 1 + 530 is developed. Preliminary design was approved by expert and based on it was made the main design.

From km 0+000 to km 0+405 the current situation is retained where it is done cleaning of ballast adding the necessary amount of gravel. From km 0 + 405 to km 1 + 385 the alignment leaves the existing body of the track , where a new body with a new railway superstructure is implemented. From km 0 + 405 up to km 0 + 485 alignment has been moved by the cross sections and designed levels of rail top are obtained by screening of the existing track. From km 0 + 485 up to km 1 + 340 protective layer with thickness 30 cm is fitted. From km 1 + 340 to km 1 + 385 track alignment is by profiles brought to the projected axis. In this part a new ballast is constructed.

Start of the relocation of km 0+000, is picked on km 316 + 900 of the existing lines and is located on the current direction T_{31} – T_{32}. Existing curves on T32 is retained with the existing elements of R / L = 300 /30 meters. This curvature is fully retained, both in direction and height.

The current direction of T32 - T33 is retained and is from newly designed T1 under the current direction of the length of L = 433,53 m derived curves on T2 with elements of R/L=1000/30m. With the new T2, touches the existing curve in the T36 with elements of R/L = 300/60 m. After this tangent from T2 at the intersection of an existing route T37 - T36 in a length of L = 819,47m there is a new design T3.

End of the relocation is on the KPK at km. 1 + 529.39 on the existing direction T36 - T37.

Checking of the current levels of rail top at the beginning of the section is made on the existing drop gradient at km 316 + 845.00 and finished at the end of the relocation km 318 + 435.00. To prove the correctness of the levels of the existing rail top, the leveling was developed from the km 316 + 435.00 to the next drop gradient to 318 + 606.80.

From km 0 + 000 to km 0 + 236,22 the existing level of rail top is retained with a small slope of 0.64‰ , and from km 0 + 236,22 to km 0 + 423.82 with the slope of 0.5 ‰ and the same is in decline.

In this part the existing level of rail top is retained, as well as existing vertical alignment. At the turn of the vertical alignment at km 0 + 236,22 was designed vertical curve Rv = 20,000 m was designed. The difference of inclination is small, so the vertical rounding is not executed. From km 0 + 423.82 to km 1 + 164.37, at the length of 740.65m, alignment has a gradient of 3.10 ‰. At the turn of km. 0 + 423.82 vertical curve with the radius Rv = 10.000m was made.

From km 1+ 164.37 a length of L = 390.34m alignment has a gentle grade of 0.89 ‰ to km 1 + 554.71 where it retains the existing level of rail top to the drop gradient. At km. 1 + 164.37 the vertical curve with Rv = 10.000m was executed.

Fig. 2: Executing the works on relocation (photo: Aleksandar Naumović)

3.1. Substructure

At the designed line is mainly embankment of varying height from 0-3m. Slopes of embankments have been designed at an incline of 1: 1.5, and the slopes of the cuts in the slope of 1:1.

Bearing in mind that the South Morava river torrential and can at any time to reach the level of century-old water, it had to take account of the security of the track. For flows with probability of Q1% - Q5 % slope is provided by creating a stone lining with thickness of 30 cm, above the layer of sand of 10 cm. Behind the levels of high water at a flow rate Q1 % lining is made 0.50 m below of elevation of vertical alignment of the track. Stone lining on the right side starts from km 0+016.00 – km. 0+485.00 at the length of L = 469,00m where it protects the existing body of track, and from km 0 + 485.00 - km. 1 + 275.00 at the length of L = 790.00 m stone lining laid on the new slope of the embankment.

When determining the position of the culvert on the newly designed railway embankment was not taken into account the position of the culvert on the existing route, but the corresponding position on the future highway construction, to carried water from them safely through the body of railway line and evacuated it to the South Morava.

In this way, in the area where the moving by the cross sections has done the existing culverts was retained with fewer interventions (lining the bottom with the stone, forming the casting structure etc.) while on the part where the body of the railway line was displaced an entirely new drainage culverts executed respecting the conditions of the drainage of the highway.

Especially the existing steel bridge over the Seliški creek at km 318+253 (1+321 to the relocated route) was processed. At this point by the separate project the reinforced concrete bridge with the span L = 6.0 m was executed as an extension of the plate culvert L = 4.0 m at km 887+148 of the highway.

Fig. 3: Temporary turnout (photo: Aleksandar Naumović)

3.2. Superstructure

By the design the relocation of the new railway track laid from km 0 + 405 to km 1 + 385 of the new change, with a length of 980 m, while in other parts of the alignment the matching of the existing alignment with the new alignment of the railway was made.

On the existing line is the superstructure with the rail type 49, on the concrete sleepers JŽ 70 with K fitting welded at CWR. For the superstructure of new track the new material was purchased: rails of profile 49E1 steel grade R260, concrete sleepers 2,40m long (placed on the axle distance of 60cm) with K rigid fastening and crashed stone of volcanic origin (ballast height 30cm).

Finally assemblage of tracks was performed by the mechanical regulation of the track, stabilization and formation of the unique LWR of the existing and new line.

4. CONSTRUCTION WORKS

4.1. Temporary Track

For the purpose of the construction of the superstructure, during the executing of works was built the temporary track, in the total length of 198 m (from the start point of the turnout No.1 to the start point of the turnout No.2). A contraction element of the temporary track was according the regulations for the industrial tracks: width of the formation was 4.50m, rails were old (type 49), sleepers were old, wooden, and the thickness of the ballast (stone) was 0.30 m, and the maximal speed was limited on 5km per hour.

4.2. Access and Parallel Road

For the purpose of the access to the site, was built the access road, also. The width of the pavement was 4 m, with the shoulders of the 0.5m wide and the 0.5m wide gutters. Pavement was made of the crushed stone. The access road, which was temporary, was continued to the parallel road, as the permanent. Width was reduced to 3 meters, without gutters and shoulders.

5. CONCLUSION

The executing of works was started in October 2015. and finished in July 2016. First train was passed the new track on the first of August 2016. Works were executed without the influences on the construction of the highway, which were continued immediately after the relocation of the previous track.

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SPATIAL CRITERIA FOR EVALUATION IN GENERAL DESIGN OF RECONSTRUCTION AND MODERNIZATION OF RAILWAY LINES

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***Abstract** – The process of planning and designing is a research and hierarchically structured process. In addition to the technical design, the design of the infrastructure is an important component of socio-economic and spatial planning. General purpose of the project is to determine the optimal corridor in the defined area, or to examine several variants of both technical and spatial solutions of railroads and other construction-engineering facility, as well as to compare the variants from the point of fitting into the space and the impact on the environment. The aim of the Paper is to show what indicators and criteria used by planners in general projects aimed at the rational use of space intended for the planned magistral railway infrastructure.*

Keywords – railway, general project, spatial planning, criteria, indicators.

1. INTRODUCTION

Preparation of project documentation for the construction of infrastructure facilities includes the development of complete technical documentation required under the Law on Planning and Construction. Design of infrastructure, in addition to the technical design, an important component of socio-economic and spatial planning. The railway as an infrastructure system that is embedded in space has the characteristics of physical systems.

Identification, analysis and diagnosis of developmental potential, possibilities and limitations in a given area planning rail corridors and their implementation in accordance with pre-set goals, basic starting points to assess the implications of spatial construction of railway infrastructure.

General purpose of the project is to determine the optimal corridor in the defined area, or to examine several variants of both technical and spatial solutions stripes and other construction-engineering facility, as well as to compare the variants from the point of fitting into the space and the impact on the environment.

Accordingly, the existing situation and the purpose of the organization of space and the existing condition of the infrastructure system in the corridor research, analyzed comprehensively, which is the basis for the formation of possible solutions.

Spatial implications of the construction of the railway infrastructure in the corridor can be analyzed through: the attitude towards the future route of the settlements, controlled and planned expansion of settlements, the separation of agricultural land from villages and a number of other factors, in order of rational use of space intended for the planned main railway infrastructure.

2. SPATIAL CRITERIA FOR EVALUATION IN GENERAL DESIGN

Indicators assessment of the state of the organization and use of space when it comes to analyzing the current situation of the railway corridor area (referring to the analysis essential for spatial planning) can be grouped into: general indicators of the current situation, indicators of natural conditions and restrictions, limitations of indicators in land use and purpose area (indicators created attitude towards the middle), indicators of traffic restrictions and infrastructure subsystem (indicators of functional limitation).

Indicators limitations of land use and land use planning are defined through the occupation of land under forests, agricultural areas, areas under special purpose zones, construction areas, number of cultural monuments within the study corridor, etc. Based on those essential characteristics are determined in order to then use the pre-set criteria, defined by the level of expression of these traits within the limit values of categories.

Criteria:

1. The ratio of the route line and the existing

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structure of the urban fabric.

2. The ratio of the route line and the occupation of land.

3. The ratio of the new route line and agricultural land and landscapes.

The ratio of the route line and the existing structure of the urban fabric:

• The ratio of the route line to the housing areas

• The ratio towards the route of the railway work zones

• The ratio towards the route of the railway zones recreation

• The ratio of the route line on protected monuments

• The ratio of the route line to protected areas

• The ratio of the location of the railway station and the central zone of other transport terminals

The ratio of the route line and the occupation of land:

• The ratio of the new route line and taking new land - change of use of land

• The ratio of new and existing route line - how the existing route line reserves

The ratio of the new route line and agricultural land and landscapes:

• The ratio of the new route line and agricultural land (according to the soil quality criteria)

• The ratio of new railway route and landscapes (based on a selection of elements of the route (tunnels, bridges, embankments and cuts))

One of the most significant impacts that railroads have created value in the area of the impact on the settlement. In the past, many settlements were formed along the tracks, developed along the railway line on both or one side of the central functions developed around the railway station. The tracks was a positive element in the spatial structure of the settlements in this period of development

With further development of the village, depending on its size and position of the railways in relation to the functional zone, the railway becomes a limiting factor in spatial development. With the development of rail transport, increasing the speed of trains and others, there are negative impacts in the immediate environment of the railway. Relocation of railway tracks imposes itself as the ideal solution to the physical aspect.

In the case where the line is modernized and reconstructed for high speed trains, the relationship between the railway and the settlement is complicated. Ideally it would be that line is not going through, and does not bother the village, where there is no stop for high-speed trains. But such solutions are very rare, because in practice it is often the reconstruction of the existing railway lines for the needs of high-speed trains i.e. a railroad for mixed traffic, which is the maximum fit into the existing corridor.

Based on enlargement corridors, increase speed, inaccessibility corridors, etc., in many villages through which the reconstructed and modernized railway line will carry a variety of influences, regardless of whether the trains to stop or not.

The intensity of the implications will mainly depend on the position of railways in relation to the settlement and functional zones within it. The greatest conflicts we can expect if the railway goes through the central city zone, residential zone of large density or the densely built area.

The main impacts that may occur in the settlement are reduced to changes in the use of building land in the immediate environment of the railway, the vulnerability of residential and working zones of noise and vibration disturbance in the mode of usage of traffic and street network, separation of certain areas such as industrial zones, recreational zone and others.

Therefore, future alignment modernized double-track railway line should retain maximum corridor existing lines. It has a special quality due to the fact that the existing railway lines in this region and this region "live" for more than 100 years. On this fact were based plans for the development of settlements and land use.

In order to ensure harmonious development of railways, towns and cities through which the railroad passes and their economies, as well as other forms of transport it is necessary to take account of the relevant regional and urban planning.

Schedule station on the need to fit the needs of settlements through which the railroad passes, and the economy is connected to the rail through freight terminals and industrial tracks.

Therefore, in the formation of cell complexes in the metropolitan area should be maximally take into account that they do not cause a range of disorders interest in space, which again, later, it is difficult to reconcile and adhere to certain criteria when locating the railway station and the railway in the metropolitan area (these criteria can be applied evaluation of alternative solutions for the location of the railway node) [2]:

1. The decision of the railway tracks and stations that fit into the existing maximum spatial organization of the city, and less disruptive of the existing urban fabric is best.

2. Location of the new railway station in the space provided valid planning documentation is the best solution in terms of the envisaged development of the city in the future.

3. It should give priority to the location at which the possible integration of terminals for rail and bus services, and the establishment of high quality connections with important traffic routes in the city

and the wider environment.

4. Strive for a decision railway junction, which engages at least a new land, and which requires the smallest demolition - a single passenger and freight station is the urban point of view of the smaller town's optimal solution.

5. Railway station, especially the passenger to locate the direction of one of the main roads, the distance of 1 km from the city centers (15 min. Walk), unless established public transport, as is the case with smaller cities or close to the same, with gives a desirable integration of rail and bus terminal.

6. Strive decision railway junction at which the lines and cellular complex is possible from the protected areas so that protective measures are needed.

7. Strive decision railway junction at which the lines and cellular complex is possible from the protected areas so that protective measures are needed.

8. Strive separation of passenger and freight stations, provided that freight station at a certain distance from the village.

9. The optimum location is one of the railway stations and the route of the railway where the costs for the construction or reconstruction of the lowest, and the additional costs that are conditioned or initiated the construction.

3. CONCLUSION

In the case of opting for the retention of the existing corridor, also be accepted by all conflicts of the existing railway had on the organization of the settlements. Relationship lines - the resort is compounded in cases of enlargement corridor, when analysing the benefits and constraints on the part of the corridor through which the proposed route with variant solutions, which is also shown on the map limits. By overlapping of those of conveniences and limitations of existing and planned state gives synthesis constraints, which is displayed on the "Synthesis map of limitations for spatial aspect" in the General Project for rail infrastructure.

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LOCATION OPTIMALITY EVALUATION OF TRACK RADIO STATIONS IN SERBIAN RAILWAY NETWORK

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Abstract *– In this paper we consider location optimality of radio stations of Locomotive radio dispatching system (LRDS) according to the radio field level, which must exceed the requested value throughout the coverage area. The issue of optimality involves antenna directions as well. Actual locations are taken as optimal for economic reasons, while directions and radiation patterns of antennas were considered by comparing old and recent data about. Differences indicate weak points in the system project from this aspect, which needs evaluation. Seasonal measurements carried out recently with modern instruments confirm today's antenna disposal but it is obvious a certain exact criterion should be formulated to theoretically confirm measuring results. It opens a way for further research in finding out a mathematical models for optimal antenna direction which would relate antenna direction and track trajectory, for two cases: flat land and hilly terrain.*

Keywords – Railway radio station, Radio dispatching system, Radio coverage, Antenna radiation pattern, Fading, Radio field prediction.

1. INTRODUCTION

LRDS 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 (0,7m) 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. The whole LRD system is divided into several radio dispatching sections (RDS), each with its own radio dispatching center (RDC). A RDS corresponds to its railway section, 100 km of length, on the average, along which several radio stations (**RS**) are situated, all connected to modulation line. The receiving frequency f_1 is the same at all RS of a RDS, since locomotives emit their signals sequentially, while transmitting frequencies f_2, f_3 and f_4 are assigned to RSs in repeating pattern e.g. f_3-f_2-f_4-f_3-f_2-f_4-... in order to minimize cross-talk or interference between RSs with the same frequency. 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 $\pm$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.

The Draft project of LRDS was issued by Radio industry Zagreb at late 1970. Prior to system accomplishing, extensive measurements has been carried out to verify proposed locations of antennas. In this work we will present measurements and locations just for the railway section Resnik-Mladenovac-Lapovo (R-M-L), length 95,5 km, described in Measurement Report (1982) [1].

It is chosen because of topographic versatility, comprising flat land, valleys, hilly terrain and, hence, tunnels.

2. DISPOSITION OF RS

The Draft project, relying only on theoretical considerations, proposed 15 rail RS along the section R-M-L: (1') Pinosava (17+934 km), (2') Klenje (24+793), (3') Ripanj I (30+515), (4') Ripanj II (31+591), (5') Ralja I (33+704), (6') Ralja II (35+685), (7') Đurinci (43+000), (8') Mladenovac (53+100), (9') Kovačevac (60+000), (10') Ratari (70+300), (11') Glibovac (74+000), (12') Guberaš (82+400), (13')Velika Plana (89+400), (14') Markovac

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(100+400), (15') Lapovo (109+600), which means 6,8 km of average radio stations span.

Theoretical considerations, only, could not give satisfactory disposal of radio stations since, at that time, they could not perceive all factors of EM waves propagation, reflection and interference, producing fading of radio field at moving receiver (locomotive). Only measurement in situ could answer the question of proper (convenient) antenna locations. Hence, the number of stations was reduced to 12, at different locations than in the Draft project, namely: (1) Pinosava (17+934), (2) Ripanj (21+290), (3) „km 27" (26+950), (4) Tunnel Ripanj I (29+987), (5) Tunnel Ripanj II (31+605), (6) Ralja (34+732), (7) Đurinci (41+500), (8) Mladenovac (51+450), (9) Rabrovac (62+900), (10) Sm. Palanka (79+344), (11) Velika Plana (90+383), (12) Lapovo (106+200) [1].

The Table 1 contains geographical coordinates of antennas of these 12 RS whose elevations are presented as terrain elevation at the spot + tower height.

We may notice significant discrepancy between antenna dispositions based on theoretical modeling and measurement results.

Tab. 1. Coordinates of antenna locations

No	Latitude deg/min/sec	Longitude deg/min/sec	Elevat. m
1	44/402/50,00	20/28/36,40	140+20
2	44/39/42,81	20/30/30,47	142+20
3	44/37/21,87	20/32/00,44	184+20
4	44/35/50,02	20/31/56,30	220+5
5	44/34/53,72	20/32/05,62	225+5
6	44/34/06,33	20/33/38,94	227+20
7	44/31/21,55	20/36/47,09	159+20
8	44/27/11,22	20/40/37,80	140+20
9	44/23/05,41	20/46/29,14	110+20
10	44/21/37,20	20/58/07,14	110+20
11	44/19/30,91	21/04/56,52	116+25
12	44/11/11,81	21/06/09,16	107+20

Antennas' geographical locations were taken from Google Earth, except elevations, which were taken from [1].

We may consider absolute antenna (angle) elevations as insignificant in the analysis of this issue because of small track average slope, well below 17‰. So, we consider only tower height on which top antenna is mounted, important for coverage within line of sight. In addition, vertical radiation pattern of antennas is with broad main lattice (over 60 deg) and extensively tolerates vertical directivity deviations. All antenna towers are 20 m high except those at entrances of Ripanj tunnel (positions 4 and 5 in Table 1), which is quite understandable. Another discrepancy is position 11 in Table 1, indicating the fact that the antenna is mounted on 30m-high lighting tower at V. Plana railway station at the height of 25 m.

Before we proceed with presenting measured data from Report let us briefly describe the measurement technique and equipment.

In order to achieve as real conditions as possible, measuring equipment was composed to simulate a real radio system, comprising receiver with registrating appliance, analog and digital paper tape writing devices. Transmitting side of the system included a measuring transmitter, emitting appropriate measuring signal, and antennas, as would be positioned and directed in the real system. It was achieved by a telescopic pole, with two antennas mounted on its top, oppositely directed according to azimuth angles for particular location. With the pole, elevations of up to 18 m were reachable. The earliest version of pole was winder driven by a system of steel cables and wheels. Afterwards came a pneumatic version, much easier to operate (manipulate).

3. RECENT/OLD ANTENNA DIRECTIONS

To make more complete picture of global radio coverage we present parameters of antenna directions and local coverage, comparing data from the Report and the recent data, quoted in licence for 2015 [2], issued by RATEL (Serbian Regulatory Agency for Electronic Communications and Postal Services), which are given in Table 2.

Tab. 2. Antenna coverage parameters

No	Azmth-B deg	Azmth-L deg	Ant type	Beam deg	Gain dB
1	310/310	112/112	A/B	19/70	13/10
2	315/315	**118/145**	A/A	19/19	13/13
3	359/355	175/175	A/A	19/19	13/13
4	–/–	173/165	–/C	–/33	–/12
5	335/335	–/–	C/–	33/–	12/–
6	295/295	**137/115**	A/A	19/19	13/13
7	**320/298**	**138/120**	A/A	19/19	13/13
8	330/330	**150/135**	A/A	19/19	13/13
9	300/300	**101/153**	A/A	19/19	13/13
10	275/270	**120/130**	A/A	19/19	13/13
11	280/–	170/–	B/B	70/70	10/10
12	355/0	180/180	A/A	19/19	13/13

In Table 2, in 2nd and 3rd columns, there are given **recent/old** antenna azimuths in the directions to Belgrade (Azmth-B) and Lapovo (Azmth-L), respectively.

The 4th column indicates antenna types used at RS in these directions and are designated by A, B and C, which means A: K 73 34 2 7, B; K 73 30 2, and C: K 73 51 2 7, producer Kathrein [3].

The 5th column contains beam width of antenna, i.e. the angular width of main lattice of antenna radiation diagram, measured at 0,71 of max value.

Old values are taken from Report [1]. But, one can find different data for the same positions in the Report. For example, antenna type for Pinosava location is K 73 30 2 7 in Report chapter 1 (for location 1), but K 73 34 2 7 in Survey Table.

In the Master Project of R-M-L railway section [4], one can find antenna type K 73 34 2 7, which is today status at this location. For location Ripanj we find in [4] originally K 72 30 2 7 but subsequently corrected to K 73 34 2 7, as it is current status.

The same case is for locations Ralja and Mladenovac.

These differences and corrections indicate intention to improve system performance and they are sign of system evolution during system planning and realization.

After 2005 a new instrument was included in seasonal measurements of radio coverage and the measuring process was automated by computer software [5]. Consequently, additional corrections were made and they are presented in Table 2 by bold font.

The most prominent discrepancy is at location Velika Plana. Instead of K 75 16 2 31 (stick antenna, omnidirectional), as quoted in chapter 11 of [1], or K 73 51 27 (helix antenna with 33 deg and 12 dBi) in Surway Table in [1] and in [4], today we have K 73 30 2 7 (with 70 deg and 10 dB).

These discrepancies indicate weak points of system planning and its realization which call for consideration and evaluation.

4. ANALISYS OF PRESENTED DATA

According to antenna performance given by radio field requested value of 1,9 $\pm$0,2 μV, so-called system range, the distance between neighbouring RS is defined. Taking also into account terrain configuration, responsible for reflection pattern and signal fading, we can get optimal, or better to say, ideal disposition of RS antennas.

For economic reasons:

1. to situate RS in area of railway station
2. to situate RS equipment in existing premises, with nearest reach to signal supplying modulation line
3. to locate RS near roads and power supply, if infrastructure is not available [1],

locations of RS are inherently not optimal. But, neglecting this ideal case, we will treat these, economic, locations as practically optimal.

Therefore, within such working frame, we will analyse optimality of RS locations in respect to antenna directions, or, in other words, optimality of radio coverage.

Discrepancies of antenna directions, given in Table 2, proves an evolution of values during LRDS exploitation, with an aim to attain the best pattern of radio coverage.

The first significant discrepancy one can notice in position (2) of Table 2, location Ripanj (toward Lapovo) with old and today's azimuths of antenna: 118 and 145 deg respectively, for antenna type K 73 34 2 7 (19 deg beam width and 13 dB gain).

The disposition is shown on Fig.1.

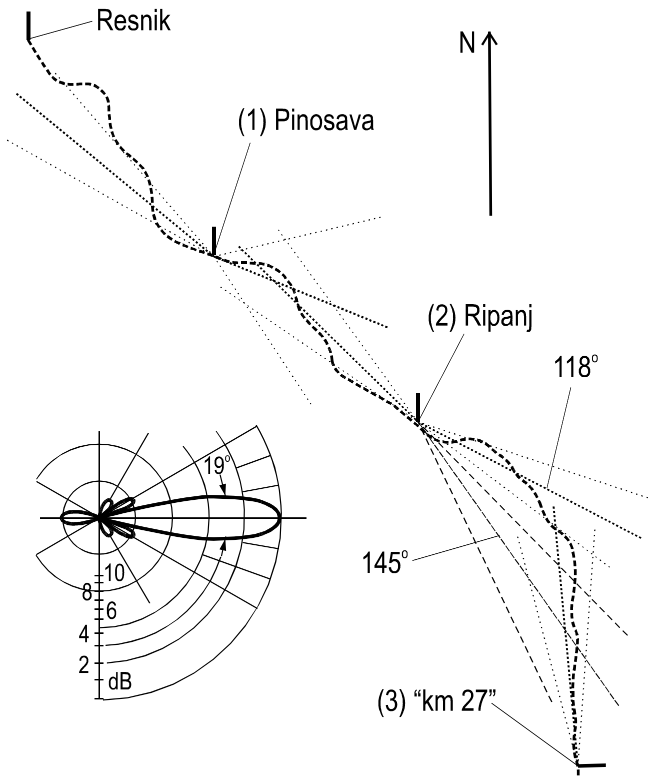

Fig.1. Old (145°) and recent (118°) azimuths of antennas in direction Lapovo. The coverage improvement is obvious. The insert shows radiation pattern of used antennas

Another significant discrepancy is at position (9) (location Rabrovac) where the azimuth value of 153 deg is taken from [1], either from chapter 9 or from Survey Table, and in Master Project [4] as well.

Afterwards, this azimuth value was changed to more appropriate value of 101 deg.

From Fig.1 it may seem that the antenna direction at location (1) Pinosava, toward Resnik is not optimal in covering the section up to Resnik and there is a room for improvement.

If we proceed with other locations we may give an account of analysis which shows, apparently, very good coverage, seemingly optimal antenna directions along corresponding sections of rail tracks.

5. EXACT CRITERIA FOR OPTIMALITY

Nevertheless apparently optimal directions of antennas in these locations one could notice the lack of objective or exact criterion according to which azimuth will be considered as optimal. The values presented in Table 2 are results of antenna adjustments on the base of assessments, stemming from many year experience, and confirmed by field measurements. Measurement is obviously exact confirmation of radio field strength but it does not obligatory means optimality. To say it simple, we can measure acceptable radio field strengths for different antenna azimuths, wherever their values are closed. We should keep in mind the fact that the fading or interference pattern with its maxima and minima manifests rapid changes on each λ/2, i.e. 0,7m/2. So, antenna direction optimality means average field strength along the tracks, which inevitably varieties, but its average value is the highest.

Therefore, further research about this issue will be devoted to formulation of a mathematical model which would interrelate track trajectory and antenna azimuth. It is essentially different case in comparison to [6] where measurements are compared to radio field pattern. In our case we seek for a mathematical expression relating track meandering within sight of antenna main lattice and one value of angle. This is, of course, a two dimensional problem so this model will be applicable to flat land areas, including smooth and broad valleys. Reflection mechanism in such areas is pretty simple and it is reduced to straight rays.

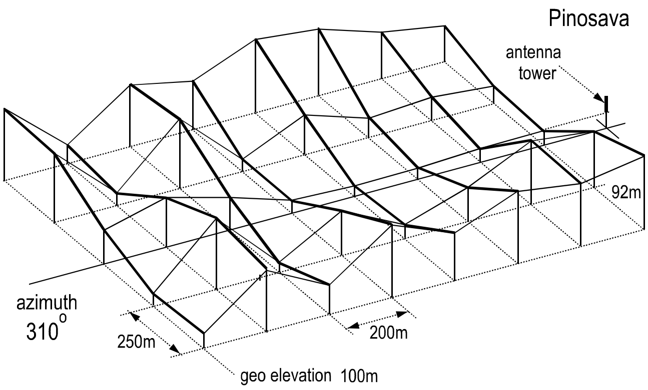

Fig. 2. Terrain approximation of valley from Pinosava to Resnik along antenna azimuth (310 deg) with resolution 250x200m. Geographical elevations are given over the absolute bias of 100m.

On the other hand, on hilly areas, with much complicated reflection picture, with skew rays dominating, this model would not function properly and the problem becomes three-dimensional. The first step in this case is to create 3D mesh model of actual terrain along considered section. It is an approximation of terrain, created as a system of reflective surfaces. Fig 2 shows such approximation of valley from Pinosava toward Resnik, with resolution 250x200m. Of course, much better resolutions are available, this one is given only to get the idea. Such surface system would give rough picture of reflections to find out the radio field strength at desired point. Moreover, from all plain surfaces of terrain mesh we select just those which reflect rays toward specified point of reception.

6. CONCLUSION

In this paper we analysed 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 through optimising antenna directions which would enable better radio coverage. This work gave us an impetus to do so relying on more exact basis which will be the theme for our further research – developing a mathematical model which would exactly relate optimal value of antenna azimuth with the rail track trajectory.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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STRATEGY IMPLEMENTATION IN THE RAILWAY PROJECTS

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***Abstract** – The essence of strategic planning refers to a decision what we want to achieve and how to do it, through respect of dynamic of the environment on which has an influence. Planning of actions include creative thinking about possible actions that can be taken. When we are thinking about desired, the options could evaluate "ad hoc", in different ways. Strategy Implementation of strategy involves managing of resources during monitoring of actions and the Strategy Implementation is oriented towards efficiency and primarily is an operational process. Identification of the most important issues (key issues) and the strategic vision, refer to the priority areas or category of questions that should to be resolved due to the positive economic future. The paper analyzes the process of the Strategy Implementation of all necessary and planned activities through implementation of the railway project for the construction of the railway bypass around Nis. Taking into account the results of the project documentation and procedures in order to move the process of construction of the single-track railway bypass, after a preliminary assessment of the feasibility, the main guidelines of implementation (in terms of budgets, deadlines, scope of work, interoperability, implementation phase, land use, funding, procurement, etc.) will be presented.*

Keywords – Strategy Implementation, the Efficiency, Construction, Railways

1. INTRODUCTION

Strategic planning is a process through which the organization agrees and builds obligations between key stakeholders (stakeholders) about key priorities for their mission, in relation to environment in which they operate. Strategic planning includes the selection of specific priorities - making decisions about the short and long terms goals and means. Strategic decisions are basis, they oriented towards the future and the Strategic plan provides priorities for achieving the next few years.

1.1. The reasons of a strategic plan preparing

Planning for itself does not produce results. It is a means, not a goal.

The plan should be implemented in order to give results. Good plan increases the chances that activities achieve desired results, from day to day. Planning helps that members of the organization are focusing on the right priorities, and that improve the working process of the people who working together on realization of priorities.

1.2. Strategic and operational planning

These two planning approaches involve two different types of opinions.

Strategic decisions are fundamental and oriented towards the future.

Operational planning is a daily application of strategic decisions.

Strategic plan contains priorities which should to achieve in the next few years, the operational plan contains actions which should to take next year, according to strategic priorities.

1.3. Strategic opinion

Meaning of information includes opinions about the changes in technology, economy, market, politics, law, ethics and society, and critical review of strategic capabilities of the organization.

Strategic opinion involves three activities: Providing the meaning of information, Designing the ideas, Planning the actions.

Skills of opinions include forecasting, imagination and visualization as well as critical evaluation as the basis for the strategy implementation of project.

A general accepted method for strategy planning in the communities doesn't exist. Preparation of the Strategy Implementation successfully realized, is the impetus for the development of appropriate economic sector and the social community.

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1.4. Strategy implementation

The strategy defined all the necessary activities, procedures and documents in order to realize the project, within the planned period and funds. Identification of the most important issues (key issues) and a preparation of the strategy vision, are related to priority areas or questions that should be resolved due to the positive economic future.

The key for planning strategy is action for managing of resources on the key questions. The most important phase is the implementation. Successful process of the strategic planning recognizes the needs for the realization monitoring and comparing with the plan, and in that way forming the strategy implementation.

2. THE STRATEGY IMPLEMENTATION IN THE FRAMEWORK OF THE PROJECT MODERNIZATION OF RAILWAYS - BYPASS AROUND NIŠ

2.1. Transport Strategy

In the phase of modernization and construction, the purpose is that the transport system of the Republic of Serbia be compatible with the transport system of the European Union, with a tendency of further modernization [1]. After the implementation of this phase, the Republic of Serbia will be ready to comply with most of the standards of the European Union in the field of transport, the transport chains will be define, and the Republic of Serbia will be competitive in the transport market. Financing of this phase will be provided from EU funds; loans from international financial institutions; domestic funds; funding public-private partnerships etc.

Rational and consistent policy development of particular modes of transport will contribute to economic prosperity, will enable efficient use of funds from the budget of the Republic of Serbia and will provide an increase in traffic safety and instruments for efficient infrastructure management.

Considering that public investment and investment in transport infrastructure significantly affect the environment, some parts of the Strategy transport modes anticipate the measures of environmental protection and sustainable development and ensure their implementation.

Approach to the Transport Strategy based on the following principles

1) Transport Strategy should to focus the quality of life, environmental protection, welfare and mobility of individuals;

3) Active access to the transport has influence on the development of the transport system, and not only responds to demands by adapting to events. Successful and active transport strategy offers interrelated solutions for all modes of transport;

4) Strategy of transport takes into account long-term objectives of the state and harmonizes them with the needs of individuals;

5) The transport strategy is active in the areas where safety, population health or environmental jeopardized by uncontrolled growth of the transport system.

The strategy has the following functions: 1) Provides guidance for decision-making in the field of transport as well as planning documents that include the functionality of all transport modes; 2) Source of information about the state, problems, scenarios, general objectives and goals in particular transport modes and certain measures in the transport sector; 3) Guide and provides information to the Economy and interested citizens; 4) Provides guidelines for decision-making to the state authorities and local self-government.

2.2. Modernization railways – bypass around Niš

The purpose of the modernization and realization of the railway bypass around Niš is to help make rail transport more competitive and to equalize and improve transit times by rail in comparison to road. This project [2] will help divert international road traffic to the railways with the consequent benefits in environmental terms.

The planned Modernization of Railways sets up requirements which will provide answers on them through preparation of technical documentation and forming of opinions, according to the requirements: Spatial - planning requests, Functional –operational requests, Structural requests.

In this project, mentioned requests are the following [3]:

I. Spatial bypass rail corridor is in accordance with the Spatial Plan of the Republic of Serbia and Spatial Plan of Infrastructure Corridor Niš – Bulgarian border. The corridor defined outside the city center of Niš, towards the north. The first stage aims to form a double-track railway of „high performance„ mostly, in the north of Niš and electrification, overhaul, and installation of modern Signaling and interlocking, and Telecommunication devices of the railway Niš – Dimitrovgrad. Preparation of the project documentation for the Modernization of Railways – Project documentation for the railway Bypass around Niš and construction of the line, have foundation in the development of planning documents. That mean, preparation of the Plan of General Regulation for railway bypass around Niš, will be in accordance with the approved General Design, for construction of single-track railway bypass around Niš in the corridor for double tracks.

II. Functional –operational request - General technological requirement is separating railway line from roads in the city area, separating passenger traffic from freight traffic, as well as separating transit traffic from local traffic. These requirements are based on European Agreements, and it is necessary that functional characteristics of the railway bypass fulfill all requests relating to:

a. Application of AGC, AGTC, TSI standards, and within the criteria defined in the SEECP

b. Maximum use the existing century-old rail corridors and railway land. Maximum use of existing railway capacities at existing locations, according to major technological tasks of stations in the node.

c. Compatibility of railway, road and air traffic in the city area and harmonized development of the their infrastructure.

d. Functional solution of the railway bypass, the railway station on railway bypass, as well as adequate functional connection for the new bypass line with the existing infrastructure capacities and with existing and planned connections with industrial tracks.

e. Safe traffic of all types of trains (passenger and freight), in mixed traffic with different speeds.

f. Performing of foreseen technological operations on all types of trains in stations in an efficient, rational and safe manner.

III. Structural requests - The project concerns the construction of a single track railway bypass around Niš, which will consist of a new electrified single track section length defined with the starting point is located at the beginning of the railway siding Niš Marshalling – Crveni Krst, inside the station Niš Marshalling. The beginning of the new railway bypass track has to be designed so that 'the height of the electric-traction contact line does not limit landing of the planes on the runway of the Konstantin Veliki airport in Niš, considering also the new Niš North railway station, which will, among others, serve the near airport. The end is located in Sićevo station. The new line will run, in general, along the alignment of the Corridor X (route E-80). In the entire length of the new railway line around Niš, in the General Design, the space will be foreseen for two railway tracks, and in the Preliminary Design, single track will be designed, which will be built in the construction of phase.

2.3. Effects of railway bypass`s construction

- Effects of construction of electrified railway bypass are:
- Separation of transit traffic from local traffic;
- Separation of passenger traffic from freight traffic on the approaches to the city - release of the city central zone of freight traffic;
- Solving conflict points between airport „Konstantin Veliki“ and railway capacities;
- Continuous passenger railway traffic through Niš without changing direction of travel (head of train);
- Quick passage of trains, passengers and goods through the junction;
- After finishing electrification of railway line Niš – Dimitrovgrad – state border traction units for the trains will not have to be changed in Niš;
- Reduction of shunting movements in Niš station for passenger trains because they retain the direction;
- Reduction of duration for technological operations at stations related to arrival and departure of trains, especially when the traction units are not changed;
- Increased speed and reduced travelling time of transit trains on direction Belgrade - Dimitrovgrad;
- Reduction of damaging influences, pollution and noise level;
- There is no transportation of dangerous materials through the city;
- Higher efficiency and safety caused by proper flows of trains trough the junction without changing direction;
- Increasing traffic safety because of reduced number of level crossings;
- Railway system will better serve to city, its population and economy;
- Improving the position of railway transport in the market in comparison to other transport modes, particularly when it comes to the freight traffic and transport of goods suitable for transport by railway.

2.4. The formation of a strategic plan

Taking into account the results of the project documentation, and the procedures in framework of law regulations, necessary to fulfill at all, to start the process of construction the single track bypass, a preliminary assessment of existing plans and investment strategy was set up. Then, the main guidelines (in terms of budgets, deadlines, scope of works, interoperability, implementation phase, land usage, funding, procurement, etc.) proposed, in order to implementation of project.

Functional requirements and various scenarios of development and implementation periods define the strategic plan. During the project, the final implementation strategy will be verify.

Chart of individual activities, necessary for the completion of the planned railway modernization project, in accordance with the national legislation, is showing Figure 1 and Figure 2.

The Consultant took into account the functionality of realization, including several primary phases:

- Phase I - Preparation of planning and technical documentation, preparation of tender documentation,
- Phase II- Securing funds for implementation,
- Phase III - Land expropriation,
- Phase IV - Conducting of tendering procedure and selection of the Contractor,
- Phase V – Construction.

The scope of work overview for construction of railway bypass and safe traffic organization are very important inputs for the Investor.

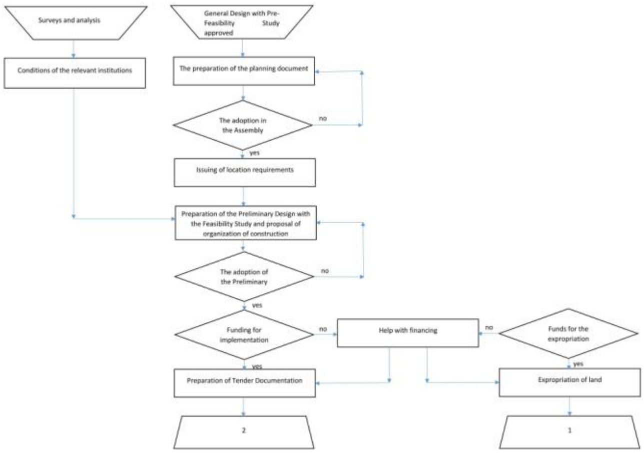

Fig. 1 ENG diagram 1

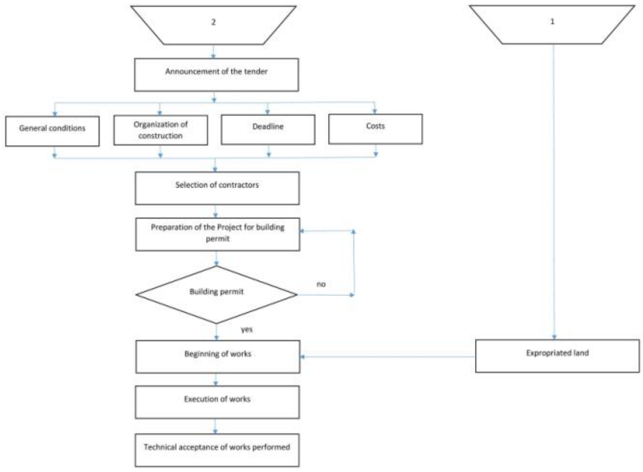

Fig. 2 ENG diagram 2

2.5. The formation of operational construction plan

Proposal of construction given under the assumption, the selected contractor will be able to provide the parallel works in first phase, in order to shorten the duration of construction period and ensure safe railway and road traffic. Below are more precisely listed the main works:

a) Construction of the railway bypass predicts for the observed sections: preparation works, substructure with drainage, superstructure, and works on Catenary wire, Signaling and Interlocking and Telecommunication facilities.

b) Reconstruction of railway lines (largely due to changes in the route of the preparatory work, substructure with drainage, superstructure, works on Catenary wire, Signaling and Interlocking and Telecommunication), as well as facilities which are predicted on the observed section. At places of fitting reconstructed track in existing condition it is necessary to include works of superstructure and catenary wire and also linkage of Signalization and interlocking systems)

c) Road construction and deviations (substructure and superstructure of route)

d) Construction of the station and complete infrastructure (track situation of superstructure, buildings, underpass platforms, installations)

Division in two phases is result from timetable of road and rail traffic. Therefore, it is:

1. First phase of works and its total length is submitted so that the traffic (road and rail) be as long as in function while the construction works are taking place simultaneously in several points, which will of course depend on the availability of jeep on field and contractors machinery.

2. The other phases of the works on the subsections and the length of their work will be in accordance with the proposal of the traffic during the works.

3. CONCLUSION

The Strategy Implementation and preparation of the plan shall detail the distribution of roles and responsibilities between beneficiaries, including requirements for the project management team, relevant specialists and implementation support. Implementation plan will describe in detail the overall procedures and milestone activities such as completion of design documents, communication procedure and define governing documents of the project.

The Implementing Agency should prepare an official Project Implementation Manual for the procedures and detailed arrangements for implementation of the works in the construction of single track railway bypass around Niš. This Project Implementation Manual shall be a living document and expected to be revised and updated as necessary to incorporate the evolving needs of the project and any changes in procedures based on the experiences of project implementation.

ACKNOWLEDGEMENT

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Vehicle and infrastructure maintenance

XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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ACCUMULATION OF CONTACT FATIGUE DAMAGES IN CAR WHEELS WHEN RAILING OVER RAIL JOINTS

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Abstract *– A method for estimating impact influence in a rolling wheel of a train set of cars on rail joints and wheel durability has been worked out. Maximum dynamic forces appearing between wheels and rails depending on percussive and oscillating processes during motion of a loaded car on a railway section with a rail joint have been determined. Contact stress distribution for cases of a wheel contact with rail edge were investigated, and also a dependence of maximum pressures from a normal force in a contact with far enough from the rail splice has been received. Calculation of impact forces arising under rolling the wheel over the rail joints has been made more exact as compared with the results obtained earlier. The methodology of the estimation of contact-fatigue life of the wheels is developed using the experimental curve of the contact fatigue life for wheel steel.*

Keywords – contact-fatigue life of the wheel, rail joints, impact forces

1. INTRODUCTION

The climatic conditions of Russia are characterized by changing temperature in the wide range. It requires the presence of clearances in rail splices in the construction of rail roads. Railway wheels undergo by significant dynamic loads during the rolling over rail joints that is the sources of impacts and following oscillating processes.

Use of long-welded rails allows to decrease a number of rail splices. However, the complete elimination of the rail joints is practically impossible. The part of Russian rail ways with the splices is 60% of the whole stretch of roads. Rolling wheel on a continuous rail was investigated in many papers. At the same time, the movement of the wheel over rail splices is researched much less.

The presented paper is devoted to the study of the wheel state during its motion in the area of rail joints. The aim of the investigation is the development of the methodology of estimation of the influence of impact forces arising under movement of the wheel over rail splices on its fatigue life.

The following problems have been solved to achievement of the goal.

The statistical data for clearance values in the rail joints of the railway is obtained [1].

A railway track model was given allowing to investigate dynamic processes because of wheel pair moving through the rail joint. The model allows to take into account bed of ballast losing in the field of a rail joint.

Dynamic efforts because of accelerated interaction of a wheel and a rail on the joint and also an oscillating process accompanying car movement on sections with a bed of ballast losing in the rail joint zone with various movement speeds, losing depths, section lengths with ballast losing were investigated with the help of a cultivated model [2,4].

The distributions of the contact stresses for the wheel-rail edge contact interactions as well as contact stresses at the far enough distance from the splice are investigated [2].

The method of estimation of the contact-fatigue life of wheels is developed using contact fatigue curves for railway wheel steel.

Some problems solved in this research are mentioned also in conclusions.

1. STRESSES IN WHEEL-RAIL CONTACT

Stresses in the wheel-rail contact are calculated with the help of the finite element method using fragments adjacent to the contact area in the case when the wheel is located over the edge of the rail. The part of the wheel has the following sizes: 60 mm for the lateral and longitudinal sizes and 30 mm for the vertical size. The sizes of the rail fragment are equal to 60 mm, 30 mm and 35 mm correspondingly (see Fig. 1).

The simulation is carried out for the new (not worn) wheel and the rail under the central location of

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the wheelpair on the railway. The following loads acting on the rail from the wheel are considered: 62.5, 110, 150 and 300 kN.

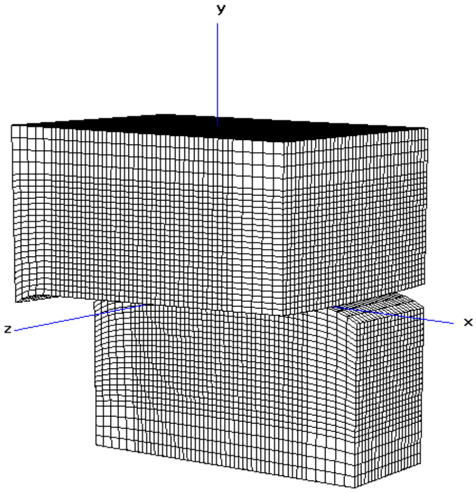

Fig. 1. Finite element model for calculating contact stresses for location of wheel on rail edge

The dependence of the maximal pressure in the contact on the normal force is approximated by the following expression

$$p_0 = 258P^{0,454} \quad (1)$$

The relation between force P and approaching of the wheel and rail is described by the following expression

$$P = \beta\alpha^{1,578}, \quad (2)$$

where β = 1,387·10[11], α is measured in meters, P is expressed in kN.

If the wheel is located far enough from the rail splice, the maximal pressure is calculated based on the Hertz solution:

$$p_0 = 213{,}86\sqrt[3]{P}\,. \quad (3)$$

The value of the normal force P in expressions (2) and (3) is measured in kN, the maximal pressure p_0 is expressed in MPa.

2. DISTRIBUTION LAW OF CLEARANCES IN RAIL JOINTS

The statistical data for clearances in rail splices is obtained for the sections of continuous welded rail track. The total length of the investigated way is 722 km. The measurements are taken on Bryansk-Lgovsk division of Moscow railroad, Russia. In total, 4026 splice clearances have been considered. The clearance values lie in the range 0…25 mm. This range has been divided into 13 equal intervals. It was found that the distribution of the clearance values obeys the Weibull law.

The coefficient values of the following differncial function describing Weibull distribution were obtained

$$f(x) = \frac{b}{a}\left(\frac{x}{a}\right)^{b-1} e^{-x/a}, \quad (4)$$

where a =1,8; b = 7,93.

3. CALCULATION OF IMPACT FORCE

For estimation of contact-fatigue damages, which are accumulated in material of the wheel in the result of passing the splices, the value of maximal impact force should be determined.

When the wheel rolls over splices of the rail, a sudden shift of the instantaneous center of rotation occurs from point A in the end of the giving (previous) section to point B of the receiving (next) one (see Fig. 2).

It leads to instant change of direction of the speed vector of the wheel center of mass due to momentary appearance of the vertical speed vector Vb. As the result, the impact interaction of the wheel with the rail occurs.

In the Fig.2, the surfaces of loaded and free rails are located on the same levels and the clearance between their ends is equal to z.

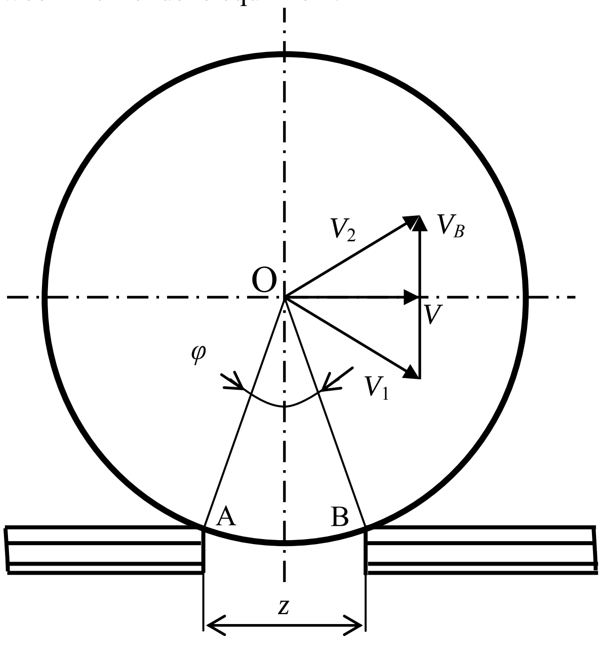

Fig. 2. Wheel on rail splice

The dependence of the vertical speed of the wheel on its translational speed and the clearance value looks as follows:

$$V_B = V\frac{z}{R_k} \quad (4)$$

where V is the speed of vehicle; z is the clearance in the splice; R_k is the radius of the wheel.

The solution to the problem of collision of two rigid bodies is used for calculation of the impact forces arising under passing the splice by the wheel.

In this solution, the impact force depends from the approaching of the bodies α [5]. The approaching is the change of distances between the interacting bodies points locating on the enough length from the contact area. The largest approaching corresponds to the maximum impact force. The approaching speed corresponding to the largest approaching is equal to zero.

The equation of vertical motion of the wheel is written as follows:

$$m\ddot{\alpha} = -P(\alpha) \quad (5)$$

After integration of equation (5) and substitution of initial conditions, the following expression is obtained:

$$\frac{2}{m}\int_0^{\alpha} P(\alpha)d\alpha = V_b^2 \quad (6)$$

Using expression (2) obtained from the solution of the contact problem for the wheel and an edge of the rail [1] and taking into account that the peak impact force corresponds to the maximum approaching of the bodies $\alpha_{\max}$, the following expression can be derived for these values

$$\alpha_{\max} = \left(\frac{1{,}289}{\beta} m V_b^2\right)^{0{,}3878} \quad (7)$$

and

$$P_{\max} = \beta^{0{,}3879}\left(1{,}289 m V_b^2\right)^{0{,}6121}. \quad (8)$$

The final formula for calculation $P_{\max}$ in dependence on longitudinal speed of the vehicle and value of the clearance in the rail splices can be obtained using expression (4) for V_B:

$$P_{\max} = \beta^{0{,}3879}\left(1{,}289\frac{mz^2V^2}{R_k^2}\right)^{0{,}6121}, \quad (9)$$

where m is the mass of the wheel rim; it is equal to 197,4 kg, $\beta = 1{,}387\cdot 10^{11}$, the speed is measured in m/s, the resulting force is in N.

4. CALCULATION RESULTS

The influence of the rail splices on accumulation of contact-fatigue defects in railway wheels has been analyzed.

The contact fatigue curve for wheel steel obtained in paper [6] is used for detection of accumulated damages.

The curve is approximated by expression

$$N = 2{,}682\cdot 10^{11} p_0^{-1{,}729} \quad (10)$$

where N is the number of loading cycles of the test sample by compressive load to appearance of a crack. The normal contact forces exceeding 102,24 kN are the damaging ones if the value of surface endurance limit for wheel steel (p_0) is equal to 1000 MPa.

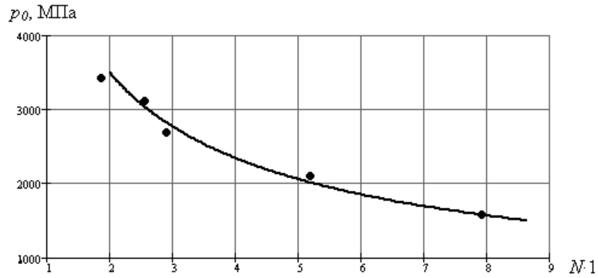

Fig. 3. Curve of contact-fatigue life for railway wheel steel.

The simulation results for the carriage of 80 ton in mass, moving with speed 72 and 90 km/h were used for the estimation of fatigue life of the wheel for movement on the rails without splices. The accumulated damages of the wheel for 1000 kilometers of the carriage running is calculated taking into account the distribution of the contact forces. It is detected using the linear hypothesis of the summation of damages $\sum \frac{n_i}{N_i}$, where n_i is the number of contacts implemented under the damaging normal force P_i, N_i is the number of cycles needed for appearance of a crack under this force. For speeds 72 and 90 km/h, the accumulated damages are correspondingly equal to 0,033 и 0,036.

For 1000 kilometters of the railway, 5576 splices are counted.

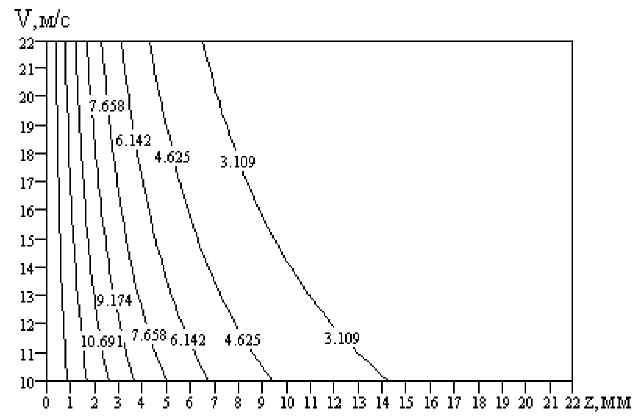

Fig.4. Isolines of number of fatigue cycles to destruction of wheel material (isoline values are miltiplied on 10^{-5})

It was ascertained in the result of analysis of solutions of the contact problems that the damaging stresses appear in the bounds of the area which size in the circular direction does not exceed 30 mm. Then the rolling surface of the wheel can be divided into 100 such areas. The probability of hitting of each area on the splice is equal to 0,01. Then the hit number on 1000 kilometers of the way is calculated as

5576·0,01=56.

The calculation of accumulation of the wheel damages is carried out with taking into account the probabilities of the clearance values in the rail splices because the impact forces depend on them. In Fig. 3, the lines of equal numbers of fatigue cycles for appearance of cracks in the wheel in dependence on the clearance and speed of the carriage are shown.

The accumulated damages due to wheel rolling across the splices along the distance of 1000 kilometres are equal to $17{,}73 \cdot 10^{-5}$ for vehicle speed 72 km/h and $21{,}0 \cdot 10^{-5}$ for 90 km/h. The splices in the railway leads to increasing of intensity of damages accumulation by 0,537% and 0,58% correspondingly.

5. CONCLUSIONS

In the presented research the following problems have been solved.

1. The statistical data for clearance values in the rail joints of the railway is obtained. It is shown that the distribution of the probability density of the clearance values obey the Weibull law. The parameters of the distributions are calculated.
2. The dependence of the impact forces on approaching of bodies is defined more exactly based on the solution of the contact task for a wheel and an edge of rail by finite element method.
3. The dynamic forces are researched which arise due to impact interconnection of wheels with rails on splices and due to oscillations excited under moving the carriage through sections with the subsidence of ballast bed in the area of the rail joints.
4. The distributions of the contact stresses for the wheel-rail edge contact interactions as well as contact stresses at the far enough distance from the splice are investigated. The dependence of the maximal pressure on normal forces in the wheel-rail contact is derived [2].
5. The methodology of the estimation of contact-fatigue life of the wheels is developed using the experimental curve of the contact fatigue life for wheel steel and the linear hypothesis of damages summation.
6. The contact-fatigue life of the railway wheel is estimated without taking into account the rail joints as well as the decreasing of the fatigue life due to influence of the rail splices on accumulation of damages is calculated.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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CONCEPT OF PORTABLE INFORMATION SYSTEM FOR TRACING TRAIN DRIVE PROFILE

Ranko BABIĆ [1]

Abstract *– In the first part of the paper we shortly considered advantages of electric railways and state of the art strategies for improving energy efficiency of modern electric trains. In this general framework we find a niche to apply some of presented strategies in Serbian Railways, through proposing a data acquisition and information system wich would help keeping engaged power under critical level by coordination of moving trains. Therefore, we propose a concept of data acqusition (DAQ) system which would trace profile of moving train parameters. Since the DAQ system requires sensors we consider voltage and current measuring transformers at high voltage input of electric circuitry in locomotives of various types, and speedometer-tachographs as well. Analysing their specifications we propose modifications to get proper inputs for DAQ modules. Effects of the use of this system include surveying and control of engaged electric power, train actual deviation from the time table, getting a picture of driving style. From the latter one can derive a recommendation or formulate a service protocol for optimal accelerating drive of the train.*

Keywords – Electric railway, High-speed train, Energetic eficacy, Energy recovery, Engaged electric power, Measuring transformer, DAQ system.

1. INTRODUCTION

Electrified railways posses many unquestionable advantages, first of all, energetic efficiency (see [1]) .

Share of electrified railway tracks in leading industrial countries of the world, since 1975, is given on Fig.1 [2]. Share of railways in transport services is 6.3% for passengers (compared to 82.7% of road transport, 10.6% aviation and 0.3% for navigation) and 9% for freight (8.8% road, 0.7% aviation, 81.5% navigation) [2]. The term “navigation” means transport by ships (oceans, seas, and inland waterways).

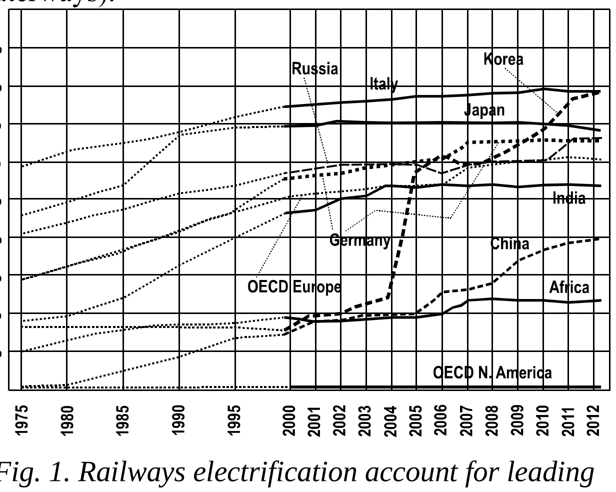

Fig. 1. Railways electrification account for leading industrial countries since 1975 to 2012.

Electric locomotives are very powerful devices and, hence, demanding consumers. Their power ranges up to 13120 kW (4E5K, 1-hour rating, 2014–present), or 10800 kW (IORE 2000–04) [3]. Usual values are about 4000 kW (e.g. classic 1970 series 441 (ASEA), B'o-B'o configuration, 80t weight, permanent/1h power 3860/4080 kW [4]). Electric current supply for one electric traction motor is 1180/1250/1700 A of premanent/1h/3min [5], or for all four electric motors 4720/5000/6800 A.

Despite these facts, electric railway system, as a whole, has low share of 2.1% in total energy consumption [2].

Energetic effectivnes of rail transport is far better if compared to other means of transport [6].

Further improvements are attained in high-speed trains despite the fact the higher speed increases energy consumption by 63 %. For modern passenger train (put in operation on years 2002-2005) the energy consumption is reduced by typically 25–30 % per seat-km or per passenger-km if compared with the older loco-hauled trains of 1994. It is fulfiled through energy consumption decrease strategies [7]:

Vehicles

More efficient traction concepts
Increased electrification
Mass reduction (Lower train mass per seat)
Aerodynamics improvement

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and friction reduction (reduced air drag)
Reduction of conversion losses
Regenerative braking and energy storage
Reduction of "hotel" loads

Technical operations
Reduction of empty trips
Flexible train compositions
Energy efficient driving
Energy efficient timetabling
Better awareness of energy efficiency in personel

Customer demand for rail services
Load factor increase
Marketing strategies for demand increase

New types of electric engines rise efficiency (no cooling fans) up to 3%.

The use of Liquid Natural Gas (LNG) instead of diesel may result in significant savings.

New materials and composites reduce the train mass (and traction energy) up to 4%.

Modern trains with wider and longer bodies (3.45 m external width) increase the transport capacity by around 25 %. This means e.g. 3 cars instead of the older 4-car train (plus a separate locomotive), less train mass, lower aerodynamic drag, and reduced energy consumption by 26 % (per passenger/ton).

Better aerodynamic performance of rail vehicles (smoother roof and walls, and particularly underneath the main floor) can reduce energy consumption up to 8% in regional trains and up to 15% in high-speed trains. Longer and more streamlined noses in the front and rear ends reduce consumption by further 22 %.

Recovered electric energy from braking can be used both internally (e.g. to power lights, air conditioning, door opening and closing, or to charge a battery for later usage when possible) and externally - sent back to power other trains in the same section of catenary. Energy recovery is 17 % of the input to the pantograph.

Modern trains produce less energy loss on the overhead catenary cable and in the stationary supply stations. Advanced semiconductor converters allow the current to be fully in-phase with the line voltage.

Energy consumption variates by season. Low temperatures increase the need for heating in the trains (at low temperatures doors are opened frequently, in particular on regional and local trains). Air density is higher at low temperatures producing higher air drag. At the same air pressure the air density is about 10 % higher at −7 ºC than at +20 ºC, thus producing 10 % increased air drag. The latter is particularly important for high-speed trains running at speeds around 200 km/h or more; as these trains have normally more than 50 % of the energy consumption due to air drag [7].

Load factor (ratio between the actual number of passengers and the number of offered seat, expressed per ton-km, train-km, car-km, seat-km or per passenger-km) is very importanta parameter when energy consumption is considered.

The actual load factor varies largely on different trains (traffic day, week or season, different sections along the line; more or less populated areas), 20–40 % on the average, or 50–75 % for high-speed trains, with competitive travel time and ticket pricing.

The energy consumption is almost independent (less than 3 %) of increased train mass for additional passengers (320 passengers is around 26 tonnes), i.e. independent of the load factor. But if measured per passenger or passenger-km the energy consumption is very dependent of the actual load factor, approximately inversely proportional to its value.

For long-distance trains load factors are typically 55–60 %, and in this market segment energy consumption is around 0.08 kWh per pass-km. For fast regional trains, load factors vary from 20 to about 40 %, while the energy consumption varies from 0.07 kWh per pass-km (for the highest load factor) to 0.18 kWh/pass-km [7].

There are also so called "hotel loads" or HVAC (heating, ventilation and air conditioning, lighting, power plugs, information screens, opening/closing of doors) which range from 10–15% (in some cases up to 50%).

2. RAILWAY REGION SUITABLE FOR PROPOSED DAQ SYSTEM

Electified railways is supplied with electric power from national electroenergetic system (EES). Along with total consumed electric energy the rate of consumption, or the engaged electric power, is a very important parameter since it reflects unacceptable transients of total power delivered by EES. So the Administration of EES encourages or, to say it more directly, forces the big consumers through the pricing policy to decrease the level of engaged power.

Among all these surveyed strategies for decreasing energy consumption which are intensively in progress in leading industrial counties we perceive a niche regarding Serbian Railways in decreasing engaged power and to improve (optimize) train driving profile, particularly at beginning portions of rail sections, when train accelerates.

To achieve this aim one needs to continuously measure the value of engaged power from electric grid, taken at the catenary.

The main idea of proposed DAQ/information system is to trace engaged power in order to decrease its peak values. Such intention is reasonable only in cases when many trains circulate or are moving in certain traffic area. In Serbia, such an area is the city Belgrade with surrounding towns, counting nearly three million people. The most characteristic trafic system within it is Beovoz, having acceptable trafic density to open the issue of engaged power. According to [8], routes of Beovoz are the folowing: Batajnica-Pančevački most with 7 stops, Beograd GŽS-Novi Sad (14 stops), Beograd GŽS-Šid (14), Beograd Dunav-Zrenjanin (15), Beograd Dunav-Vršac 13, Beograd GŽS-Valjevo (17), Beograd GŽS-Mladenovac (11), Beograd GŽS-Požarevac (18). Activity of these routes and trafic intensity can be studied from time table [9].

3. TRAIN AVAILABLE DAQ RESOURCES

Therefore, the supply line voltage and the supply current are to be continually measured, and train velocity as well, with proposed DAQ system. Classical electric locomotives have pretty similar high-voltage electric circuitry. Proposing the DAQ system we intend it to be universal, i.e. adaptable to most of locomotive types currently in use on Serbian Railways. For the sake of this paper we studied Russian commuter 412, Sweden locomotive 441, and Russian loco VL series, all of the system 25kV/50Hz. For that reason description of the DAQ system will be given in general terms.

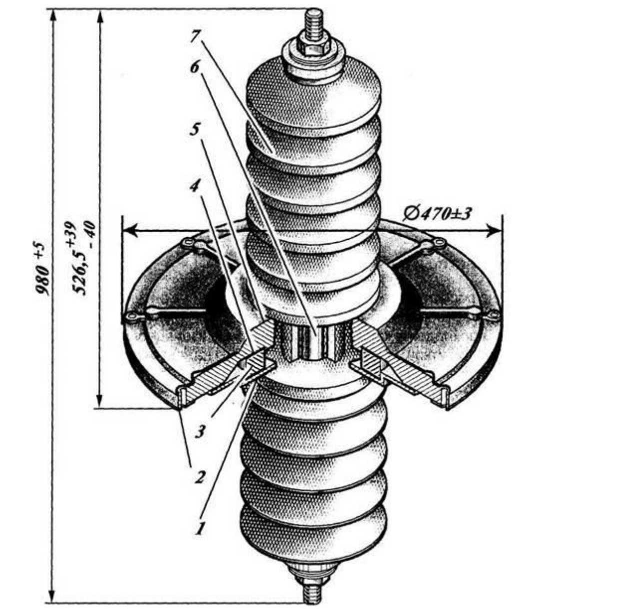

Fig. 2. TPOF-25 current measurng transformer. (6) is the main supply conductor and transformer primary “winding”, (3) is 16-coil secondary winding.

There are already instruments for such purpose available in locomotive driver compartment. These are typical instruments, found in most locomotives of that class. For example, in el-loco 441 at command table in driver cabine, there is block F2 comprising 6 ampermeters (4 for currents of traction electromotors, 1 for braking current, 1 for heating current), 2 voltmeters (V1 for catenary voltage, V2 for traction motors voltage) [5]. V1 actually measures voltage on secondary coil of voltage measuring transformer, positioned on the roof of vehicle, with conversion ratio 25000/403=62, producing secondary voltage 403 V.

There is also current measuring transformer with very similar design in locomotives of series 441 [5] and VL [10], shown on Fig. 2 for VL locomotive. Main supply conductor 25kV/400A serves also as primary input of current measuring transformer at which 16-coil secondary winding one gets 25A output nominal current.

Speedometer/tachograph used in series 441 is well known Hasler-Bern RT-13. Main specifications are: speed range: 0-180 km/h; tape width/length: 102 mm/20 m; tape feed: 5 mm/km, 5 mm/h; recording path length: 3500 km; permissible speed error: ± 3 % ; permissible time error: ± 3 min [11].

On Fig. 3 it is shown detailed electrical circuitry of Hasler speedometer-tachograph [12]. Functioning of transmitter, as a core device of this speedometer, is expained in the caption of Fig. 3. Printing is done on paper 40 g/m^2, covered with 7 g/m^2 layer of wax. Wax is a mixture of organic matters, so the engraved record stay hard for temperatures up to 70°C [13].

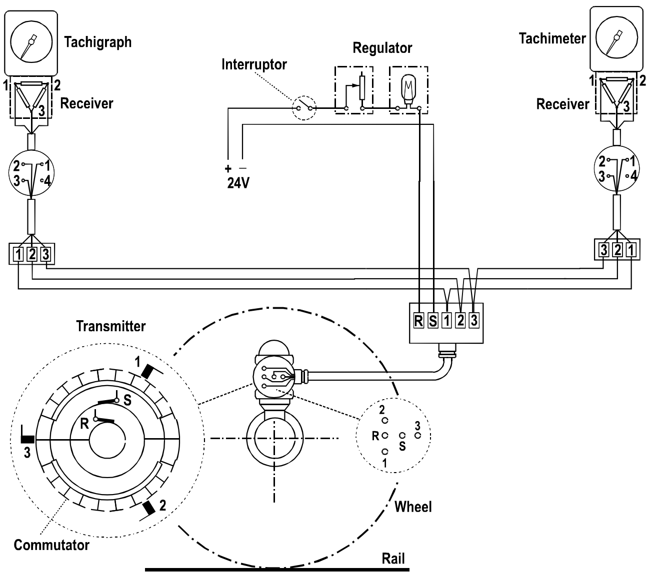

Fig. 3. The rotor of tachimeter transmiter by its commutator converts DC into AC which frequency depends on commutator (or wheel) speed. This AC acts on synchro motors in tachimeter/tachograph which display this frequency as speed.

Speedometer SL-2M on series VL is pure mechanical, with flexible steel wire, making 30 turns per 1 km [10].

4. DAQ SYSTEM DESCRIPTION

The purpose of proposed information system is to collect and store data for their afterward processing and analysis. Hence, the core of the system will be a computer (universal laptop or single-board computer, e.g. Raspberry [14]). To measure values of supply voltage and current a DAQ card is to be used. As an illustration, we consider D8000 series data acquisition modules, with USB interface to host computer. Module D8100 has 7 (channels) voltage inputs with ranges ±0.025V, ±0.05V, ±0.1V, ±1V, ±5V, ±10V, resolution of 16-bit ADC, 25/20 conversions per second, and accuracy ±0.05% of FS max, input burnout protection up to 250 Vac, and input impedance 20 MΩ min. Module D8200 with 7 current inputs has the range ±20 mA and input impedance <100 Ω (70 typical) [15].

To measure secondary voltage 25000/62=403 V from voltage transformer one needs to further decrease voltage level to fall into the module measuring range, recomendably by additional transformer.

To measure output of 25 A from current transformer a shunt could be included. All auxiliary resistors and shunts should be with low tolerance, preferably ±1%, to keep precission in desired range. Of course, any current input can be easily converted into voltage one, and vice versa. Generally speaking, all devices between catenary and input to DAQ module represent a 25 kV voltage sensor wich should be calibrated. The same holds for nominal current of 400 A.

The D8000 series modules communicates with host computer via USB inteface and Modbus RTU protocol, through the virtual serial port. The Modbus RTU binary protocol uses a master-slave technique, in which only the master device can initiate transactions. The slave devices respond by supplying the requested data to the master or by performing the requested action in the query. The master can address any slave device. The returned messages are considered response messages.

In order to measure the real power it will be interesting to measure the power factor cosφ. Our further research of this system is devoted to develope a method to measure power factor cosφ not separetely but from already measured values of voltage and current.

As far as train velocity measuring is concerned, existing speedometer (Hasler) is useless because of its intolerably measuring error of ± 3 %. Therefore, we propose the use of GPS receiver. The accuracy of a moderate model (e.g. Garmin GPS 60 S [16]) is for position < 15 m, 95% typical, for velocity 0.05 m/s steady state, while differential GPS (DGPS (WAAS)) accuracy is for position < 3 m, 95% typical and velocity 0.05 m/s steady state. Update rate is 1/second, continuous. Interfaces with the host computeris via USB, RS232 with NMEA 0183.

5. CONCLUSION

Presentation of energetic effectivnes of electric railways and startegies for its further improvement could serve as recomendations or suggestions how to act in domestic domain. For the present situation, we have found a niche for these general tendencies in an attempt to optimize energy concumption through better control of engaged electric power. This issue is reasonable to cope with only in traffic areas with heavy transport intensity, both passenger and freight. The best match for this is Belgrade railway region, with Beovoz system in it.

Tracing train movements with an acquisition-information system, which we proposed in this paper, we could gather the data to synchronize acceleration of trains when they have peak consumption. IN addition, from this data we get the drive profile of train along the section between two stops from which we may formulate advices for the drive style.

The data which the system collects include values of catenary voltage and current, and train speed as well. Further research will also include possibility to measure the power factor cosφ, not separately but while measuring voltage and current.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '16

ANALYSIS OF THE REASONS FOR EMERGENCY FAILURES IN THE BOGIES AND TRANSMISSION OF THE TRAMS IN SOFIA

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Dobrinka ATMADZHOVA [2]

***Abstract** – This article examines the cases of emergency failures in the bogies and transmission of the trams in Sofia. Based on data from the emergency service for the period from 2009 to 2015 an analysis has been conducted and the leading causes of failures during operation have been determined. As a result of the analysis also have been identified the leading causes of accidental failures in the different types of bogies. The main reasons for the failures of bogie T81 have been defined.*

Keywords – tram, emergency fault, bogie, transmission

1. INTRODUCTION

The analysis made in the article are based on official data for the period 2009 - 2015 [1] of the department "Emergency service", a unit for emergency technical assistance for "Sofia Public Electrical Transport" EAD – Sofia's electric transport operator.

In Sofia are in operation around 20 types of trams. In the period examined in the article, this number is retained, although some types of railcars came out of operation, and others were brought in. However, the total number of tram rolling stock decreases.

In 2013, for the first time since 1999, in Sofia are delivered 20 new trams. This affects the total number of failures on the chassis and powertrain.

2. GENERAL DATA ABOUT EMERGENCY FAILURES

For the period 2009 - 2015 the team emergency services have responded to 3862 calls for emergency failures on the tram system in Sofia. The cases related to the chassis and powertrain were 415. This includes 111 cases of derailment or entry of the tram into two tracks. The summarized data for the intervention of the emergency teams is presented in Table 1.

From the data in Table 2. follows that most failures on the chassis and powertrain are observed in trams which are equipped with bogies type T81.

3. DATA FOR EMERGENCY FAILURES SORTED BY TYPES OF DAMAGE

Faults which caused emergency failures, sorted by nodes and by year are shown in Table 3.

In the "Others" in Table 3 are shown cases of derailment and entry of the tram in two tracks and also other minor damage caused to stop the rail cars.

As 'Other' are listed failures of bogies T65 and Duewag. In the bogies Duewag reason for this is their small quantity and the fact that the exact defect was detected after removing the bogie for repairs in the depot. In bogies T65 the reason for their separation in "Other" is their complete removal from exploitation in 2014.

Tab. 1 Emergency interventions

№	Emergency faults	Year							Σ
		2009	2010	2011	2012	2013	2014	2015	
1.	Total Emergency failures in Sofia's tram system:	594	506	461	639	535	567	560	3862
2.	Emergency failures related to bogies and transmission:	104	68	61	64	40	44	34	415
3.	Emergency failures on only bogies and transmission:	88	50	46	46	25	26	23	304
4.	Emergency failures on the bogies and transmission of bogie T81:	62	31	35	33	18	17	14	210

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Tab. 2 Faults which caused emergency failures

Types of trams	Year							Σ	Types bogies	Year						
	2009	2010	2011	2012	2013	2014	2015			2009	2010	2011	2012	2013	2014	2015
T8M 300	4	6	2	3	0	0	-	15	T 65	14	15	8	5	3	1	-
T6M 400	10	9	6	2	3	1	-	31								
T6M 700	38	14	24	20	6	9	8	119	T 81	68	35	42	36	23	20	16
T8M 700M	27	21	17	15	15	9	8	112								
T8M 500	3	0	1	1	2	2	0	9								
T8M 700 IT	-	2	0	3	2	2	5	14	GT 03	-	2	0	3	2	2	5
T6A2-BG	5	5	4	7	2	4	3	30	Tatra 1009	14	8	6	9	6	10	4
T6A2-Sf	3	3	2	2	4	4	0	18								
T4D	6	-	-	-	-	-	-	6								
PESA 122NaSF	-	-	-	-	-	1	1	2	03 PND	-	-	-	-	-	1	1
T4D-C B4D-C	-	-	-	-	-	2	1	3	Tatra 1435	2	1	0	1	0	5	4
T6B5	2	1	0	1	0	1	2	7								
T4D-M B4D-M	-	-	-	-	-	4	2	6								
Т6МД-1000	1	0	0	0	0	0	0	1	T 86	1	0	0	0	0	0	0
Duewag T4/B4	4	4	2	2	2	4	2	20	Duewag	5	7	5	10	6	5	4
Duewag GT6	1	0	2	4	3	1	0	11								
Duewag GT8	0	3	1	4	1	0	2	11								
Total:	104	68	61	64	40	44	34	415								

Tab. 3 Cases of derailment and entry of the tram in two tracks

№	Faults responsible for emergency failures	Year							Σ
		2009	2010	2011	2012	2013	2014	2015	
Wheelset	Broken wheelset	2	1	1	0	1	0	0	5
	Torn wrapper strap	1	2	0	0	0	1	2	6
	Stuck box bearing	0	2	1	1	0	0	0	4
Wheelset reducer	Stuck wheelset reducer	23	12	13	16	7	7	6	84
	Noise in the wheelset reducer and rising temp.	5	2	1	0	0	0	0	8
	Broken input shaft of the wheelset’s reducer	4	4	3	1	1	3	0	16
	Stuck bearing input shaft of the wheelset’s reducer	1	0	2	0	0	0	0	3
	Broken support bar of the wheelsets reducer	4	6	2	1	0	0	2	15
	Broken hull of the wheelset reducer	6	0	2	1	0	0	1	10
Cardan shafts	Broken long Cardan shaft	15	1	8	9	10	8	3	54
	Broken welds on the Cardan shaft	1	0	0	0	1	0	0	2
	Broken short Cardan shaft	3	1	2	1	1	0	0	8
	Broken shaft flange on the short Cardan/input shaft	4	2	1	1	1	3	2	14
	Disassembled pivot on the long Cardan shaft	0	2	0	4	0	0	0	6
	Disassembled pivot on the short Cardan shaft	2	1	0	1	0	0	0	4
Motors	Broken shaft on the rotor of the motor	5	2	3	2	1	1	1	15
	Broken bolts of the motor	3	0	0	0	0	1	1	5
	Stuck motor	0	2	1	1	0	0	4	8
Other	Derailment, tram in two tracks	16	18	15	18	15	18	11	111
	Other failures to the chassis and powertrain	2	0	1	2	0	1	0	6
	Stuck wheelset T65 (axle box, reducer, engine)	7	8	5	3	1	1	0	25
	Duewag - Stuck wheelset (axle box, reducer, engine)	0	2	0	2	1	0	1	6
	Total:	104	68	61	64	40	44	34	415

Tab. 4 Failures on bogies T81 and power transmission for assemblies

№	Failures on bogies T81 and power transmission for assemblies	Year							Σ
		2009	2010	2011	2012	2013	2014	2015	
Wheelset	Broken wheelset	0	1	1	0	0	0	0	2
	Torn wrapper strap	0	0	0	0	0	0	0	0
	Stuck box bearing	0	2	1	0	0	0	0	3
Wheelset reducer	Stuck wheelset reducer	16	9	11	14	3	5	2	60
	Noise in the wheelset reducer and rising temp.	4	0	0	0	0	0	0	4
	Broken input shaft of the wheelset's reducer	4	4	3	1	1	2	0	15
	Stuck bearing input shaft of the wheelset's reducer	1	0	2	0	0	0	0	3
	Broken support bar of the wheelsets reducer	3	5	2	0	0	0	1	11
	Broken hull of the wheelset reducer	6	0	2	1	0	0	1	10
Cardan shafts	Broken long Cardan shaft	15	1	8	9	10	6	3	52
	Broken welds on the Cardan shaft	1	0	0	0	1	0	0	2
	Broken short Cardan shaft	3	1	2	1	1	0	0	8
	Broken shaft flange on the short Cardan shaft or the input shaft	4	2	1	1	1	3	2	14
	Disassembled pivot on the long Cardan shaft	0	2	0	4	0	0	0	6
	Disassembled pivot on the short Cardan shaft	2	1	0	1	0	0	0	4
Motor	Broken shaft on the rotor of the motor	3	1	1	0	1	1	1	8
	Stuck motor	0	2	1	1	0	0	4	8
	Total:	62	31	35	33	18	17	14	210

Tab. 5 Failures on the bogies T81 and powertrain are grouped by units and their kinematic ties

№	Failures on the bogies T81 and powertrain are grouped by units and their kinematic ties	Year							Σ
		2009	2010	2011	2012	2013	2014	2015	
1.	Wheelset reducer: stuck, noise, raise in temperature, supports.	29	14	15	15	3	5	4	85
2.	Group "Motor – long Cardan shaft".	19	4	9	13	12	7	4	68
3.	Group "input shaft - short cardan shaft - input shaft ".	14	8	8	4	3	5	2	44
4.	Stuck motor	0	2	1	1	0	0	4	8
5.	Wheelsets, axle box, wheel tyre.	0	3	2	0	0	0	0	5
	Total:	62	31	35	33	18	17	14	210

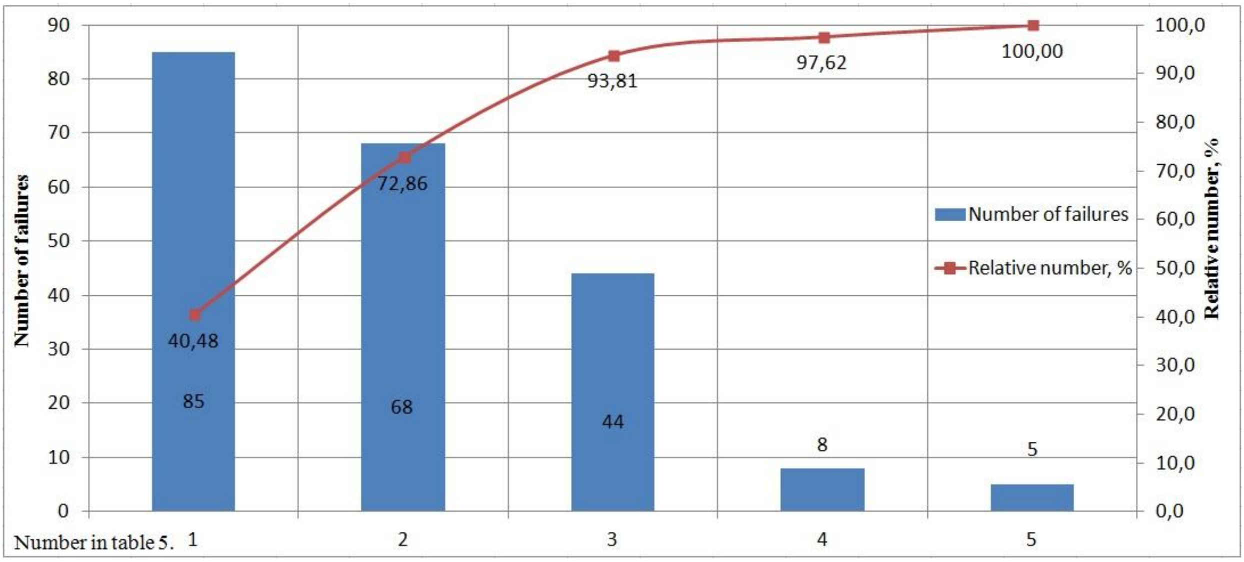

Fig.1. Pareto diagram about the emergency failures in bogies type T81

4. DATA FOR EMERGENCY FAILURES ON BOGIES TYPE T81

The tram bogie is designed for trams type T6M 700 and T8M 700M, and later for T8M 500. The bogie is biaxial with a group propel of the axles. Two-stage leaf springs and overhanging guiding of the axle box. There are two modifications - motive and supporting.

So far the analyzed data shows that the highest accident record is observed in trams equipped with bogies T81. Although the number of trams which are in exploitation has decreased, a high volume of failures on the bogies and powertrain still remains. All causes for emergency failures of the bogies T81 are shown in Table 4.

The sharp reduction of failures on the wheelset reducers in 2013 is due to a correction in their construction. The number of supporting bearings has been increased and also their lubrication has been improved. Meanwhile the high levels of failures in Cardan shafts remains the same. This conclusion has been made after examination of the delivery and repair data, which were provided by "Banishora" depot.

Failures on the bogies T81 and powertrain are grouped by units and their kinematic ties and are sorted by number in descending order in Table 5.

Based on data for emergency failures of the bogies T81 by their nodes and their kinematic connections shown in Table 5. received the following Pareto diagram (Fig. 1).

According to the Pareto-diagram for Table 5. failures on the wheelset reducers and the long cardan shafts have the greatest impact on the overall accident record in trams equipped with bogies T81.

5. CONCLUSION

The analysis of emergency failures of the chassis and powertrain in trams in Sofia shows that the largest share of the total number have the bogies T81. Despite the declining share of railcars equipped with the bogies the number of failures is relatively stable.

It is clear that the future use of the bogies T81 when refurbishing railcars T6M 700 and T8M 700M or newly constructed trams those bogies have to undergo major structural changes.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '16

APPLICATION OF FMEA FOR ESTIMATION OF RISK IN FREIGHT WAGONS MAINTENANCE

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Abstract *– Basic work task is to estimate risks in maintenance of freight wagons in order to provide continuous use of vehicles without defects. Keeping the vehicles functional, which secures safe traffic with as little emergency repairs, is generally based on the system of preventive maintenance. Such system allows scheduled time for dispatching the wagons on all types of inspections, repairs and overhauls, after the wagon has ridden a certain number of kilometers or after a certain period of exploitation. More detailed explanation of using FMEA (Failure Modes and Effects Analysis) in the process of regular repair of freight wagons shall be discussed further, as one of the most used methods for qualitative analysis of reliability. The end goal of this examination is a suggestion how to compile measurement sheets, which are related to all the critical spots acquired using FME analysis, as a solution how to stop the further faults and maintaining or improving the level of safety of freight wagons transportation.*

Keywords – Risk, FMEA, Maintenance, Repair, Measurement Sheets

1. INTRODUCTION

Maintenance of freight wagons includes:
- Constant monitoring,
- Controlling inspections,
- Regular repairs,
- Regular maintenance,
- Unscheduled maintenance.

Constant monitoring of the freight wagons is performed during regular wagon operation and it includes the checkup of car's driving and usable capability and determining and remedy of malfunction according to the confirmed international contract.

Controlling inspection of freight wagons is done for the purpose of periodical functionality checkup of freight wagons' subsystems, systems and devices.

Regular repair of freight wagons is done as a medium overhaul, and medium overhaul is done for the purpose of bringing the technical level of a car to the level which can provide safe use of the wagon until the next regular repair. Medium overhaul of freight wagons includes detailed inspection and repair of all systems and safety devices, especially: running gear, brakes, drawing and buffing devices and mechanisms on wagons.

Regular maintenance is a set of planned works on railway vehicle which, following the determined description of works and corresponding technology procedure, determine vehicle's general condition, inspects subsystems, parts, systems, and remedy faults found on the railway vehicle, after which the vehicle's functionality is being checked upon. Regular maintenance of railway vehicles includes:
- constant monitoring,
- service inspections,
- controlling inspection,
- regular repair.

Unscheduled maintenance of freight wagons is the maintenance of wagons within trains on which are designated for that kind of repair, or wagon repair after it was put out of traffic because malfunction or faults were detected.

Unscheduled maintenance of rolling stock also includes:
- inspection of connection between the wheel hoop and wheel body
- replacement of the broken or worn-out brake pads and installation of the missing ones
- inspection of buffers' fastening bolts, inspection of rivets or bolts on buffers' heads
- inspection of contact surfaces of buffer heads, greasing where necessary [1].

2. FME ANALYSIS

FME analysis is one of the methods for preventive

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quality management. With its help it is possible to analyze the probability of fault occurrence and their impact, even on early phases of production process development, which enables an earlier improvement of quality level. FMEA can be defined as a systematic group of activities focused on:

- identification and evaluation of potential faults on a product/process, and faults' consequences
- identification of actions which can eliminate or reduce events which have caused these faults
- harmonization of the planned and the executed
- reducing costs arising from faults optimization of production strategies [2].

FME analysis is used in developing new processes, new products, adapted processes, deviations from the demanded quality, constant improvement of quality, change of environment, etc.

3. PROCEDURE OF FMEA METHOD EXECUTION

3.1. Preparation

On the beginning of FME analysis, it needs to be determined what will be the subject of the analysis, and then to prepare all the materials necessary for the analysis execution.

3.2. System structure analysis

When the preparation is done, and all the necessary data is collected, a system structure analysis starts. In this steps system is being broken down to subsystems and parts, joined by their functions. Breakdown should be started at the highest level possible, then go to lower levels. The reach of system structure analysis depends from FME analysis goals. The point of system structure analysis is to determine process elements, define responsibility, create team to execute FME analyses and define deadlines.

FMEA team basically consists of a designated leader (team manager) and a number of experts capable to make the analysis of product functioning, possible faults, faults' impact on users, as well as to determine their causes and remedies. With a corresponding instruction within a company, FME analysis is organized and the person responsible for creation of FMEA team is designated. It is most convenient that the manager of the corresponding project to be designated for this.

Further activity flow in analysis execution can be divided into following steps:

- Preparation for the analysis,
- Project, process or construction analysis,
- Evaluation of current state,
- Corrective actions,
- Evaluation of corrective actions effects,
- Documenting the analysis.

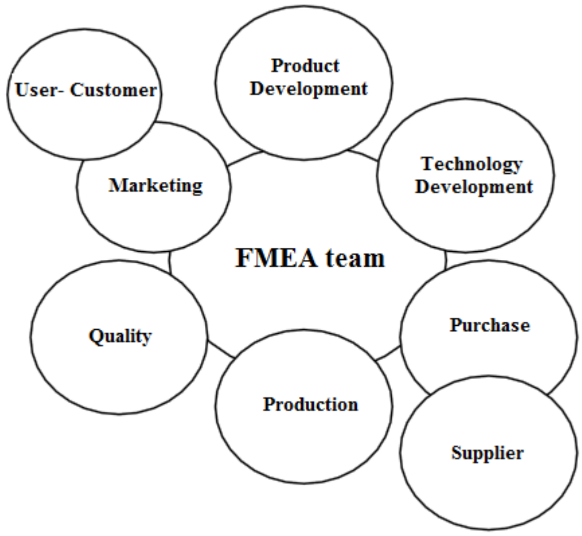

Fig. 1. Basic composition of FMEA teams

3.3. Creation of FMEA table

When the system is broken down into parts, each element can be analyzed in terms of fault occurrence. For the purpose of systematization, this procedure is done using the appropriate table. Table is not standardized and it can vary depending on analysis goals. In order to identify risk positions in freight wagons maintenance process, table states operations in freight wagons overhaul, and quantifies all operations using the methodology of FME analysis, which clearly defines the criteria of elevated risk in all these operations execution.

Tab. 1. Criteria for risk evaluation

D - Detection	Value 1÷10
S - Severity	Value 1÷10
O - Occurrence	Value 1÷10

Tab. 2. The acceptability criterion in the range of I to III

Σ = (**O** x **S** x **D**)	**Criterion**
1÷300	**I**
301÷600	**II**
601÷1000	**III**

Using the sum of results O x S x D, the acceptability criterion is determined, in the range of I to III :

I – means a lower possibility of a fault, and represents lower level of production process control

II – means a higher possibility of a fault, and represents medium or product control

III – represents the highest level of danger of fault and plans elevated level of control with use of special control procedures, including specialized institutions.

In previous steps Detection, Occurrence and Severity of faults were given in numeric scales from 1

Tab. 3. Table view of main operations with freight wagons regular overhaul

OPERATION			D	O	S	Σ
Construction unit	**No.**	**Process description**	Detection	Occurrence	Severity	Product **Σ =(OxSxD)**
1	**2**	**3**	**4**	**5**	**6**	**7**
Underframe and bogie	1.	Detaching of the bogies, disconnection of the bogie and the underframe	2	3	5	30
	2.	Cleaning of all elements, inspection and measuring with records to measuring sheet, repair and painting	8	6	8	384
Wheel set	3.	Axle cleaning and ultrasound inspection for cracks in the axle body	9	8	10	720
	4.	Inspection of axle measurements	7	5	10	350
	5.	Electric resistance measuring	10	8	8	640
Axle bearings	6.	Axle bearings detaching, cleaning from old grease, inspection of functionality of the bearings, fitting rings and labyrinth rings, proper greasing and installation	9	4	9	324
Wagon body suspension	7.	Inspection of spring dimensions	5	4	8	160
	8.	Replacement of the defective springs with new ones	3	8	8	192
Brake devices	9.	Brake devices detaching	3	5	6	90
	10.	Inspection of functionality and measurements of the brake leverage	5	4	8	160
	11.	Air brake – brake test	9	4	10	360
Draw gear	12.	Disassembly of all draw gear and coupling parts and their thorough cleaning	3	3	8	72
	13.	Inspection of measurements and functionality of the draw hook	8	9	9	648
	14.	Inspection of spring properties, device assembling and testing in a specialized workshop	10	9	10	900
Buffering device	15.	Buffer detaching, disassembling and thorough cleaning of all parts	3	3	8	72
	16.	Inspection of spring properties, device assembling and testing in a specialized workshop	10	9	10	900
Bogie, floor, panels, gear	17.	Thorough cleaning of dirt and corrosion from the underframe	3	3	6	54
	18.	Bogie inspection and bringing it to functionality in compliance with measurement sheet	8	8	8	512
	19.	Inspection of bolster bowl and central pivot functionality, their repair or replacement if necessary	4	3	8	96
	20.	Painting of the bogie and its parts	8	6	7	336
Wagon body	21.	Inspection and bringing to functionality of side entrance and gauge doors frames, side panels, locking mechanisms…	7	3	8	168
	22.	Thorough cleaning of dirt and corrosion	3	3	6	54
	23.	Repair or replacement of side panels where damaged	3	3	6	54
	24.	Inspection of wagon body geometry	7	5	9	315
Anti-corrosion coating	25.	Partial repair of the coating with final coating throughout entire surface of the car	7	6	7	294
	26.	Preparation of the surface, thorough protection and painting of the car (by the request of the customer)	7	6	8	336

to 10, where a higher value always represents the worst possible case, resp. we give the value 10 to faults which occur most often, have the worst consequences and they are the hardest to be detected before the system was started. From these numerical values it is possible to calculate the value of risk priority - Risk Priority Number (RNP). This value is calculated using the following formula:

$$RPN = OxSxD \quad (1)$$

Where O is Occurrence, S is Severity and D is Detection. Each element can have RPN value from minimum of 1 through maximum of 1000 points. The higher the value of RPN is, the element is more critical and it should be given higher priority in corrective actions and remedies execution.

The good side to this method is a wide range of values, which makes the ranking easier, resp. there is a small probability that a higher number of elements would have the same RPN value. The problem with this method is evaluating the elements in terms of three above mentioned fault properties. Values given to the elements are more subjective by nature, and they depend on the person who is doing the evaluation.

Detection – This column defines a possible way for fault detection, if a visual inspection is sufficient, or there is a need for certain measuring devices, sampling and so on. This value is numerical and it is marked with D.

Occurrence – Repeatability of element malfunction is a very important data in terms of criteria for elements selection that shall be subjects for improvement. Frequency of malfunctions is a data coming from the nature of malfunction cause.

Severity – Severity of malfunction, depending on the system inspected, can be observed from many views.

4. CONCLUSION

Based on Table 3 which displays sums of product results which have the value ≥ 301 according to criteria II and III, we come to conclusion that output documents of the operations mentioned should be Measuring sheets and Reports (both internal and external). This analysis implies that there are potential "critical" spots which require higher level of control in order to evade the possibility of elevated risk during freight wagons maintenance.

All projects include risks, as well as all processes and decisions throughout product's life cycle. We could say that a risk is a combination of frequency and probability of occurrence and consequences of a certain "dangerous" event. This paper shows the possibilities of use of a classical method of malfunction analysis – FME analysis, by including FMEA process analysis. In practice, it takes a lot of energy, time and money to perform an FME analysis of a complex system. Because of that, modified techniques are needed in order to use this method.

One of the important aspects that lead to fault occurrence in manufacturing processes is a human factor. Therefore we define corrective measures that are related to the participants in manufacturing processes. Connection between analysis of human faults and FME analysis of processes is one of possible ways for displaying more comprehensive analysis for defining measures in order to improve the quality of manufacturing processes performance. [3]

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '16

MONITORING SYSTEMS FOR ROLLING STOCK MAINTENANCE

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***Abstract** – Exploitation of rolling stock as part of the railway traffic, causes continuous improvement and has a constant need for complying with the new requirements; higher speeds, more powerful locomotives need to increase wagon capacity etc. Increasing of complexity of railway vehicles, requires increase of their reliability and durability. On the other hand, in this region, maintenance becomes a problem when a fault occurs to bring the system back to the projected state. The concept of maintenance, should include the principles by which defined plan and maintenance program are realized. The speed of development of technology brings changes in the approach and tends that it is carried out before failure occurrence and aims to prevent or to postpone the occurrence of failure. This type of maintenance represents preventive maintenance, which occurs in the form of preventive planning and prevention according to the state. Preventive maintenance according to the state, is based on the diagnosed condition of the system. With the help of diagnostic system enables the monitoring of vehicle status and superstructure load parameters, is enabled, ensuring constant quality level and providing secure legal evidence of measured values.*

Keywords – Rolling stock, wheel, maintenance, diagnostics.

1. INTRODUCTION

Vehicle maintenance and infrastructure has been significantly changed by requirements of availability and reliability of technical systems and is based on the development of preventive maintenance.

Wagon failure analysis (rail vehicles in general), the study of modern technologies of monitoring and diagnostic methods define a proposal of diagnostic systems on the lines for control of freight wagon during the operation. Therefore, it is expedient to carry out the monitoring of the state, of the individual parts and assemblies in the stage of driving.

2. SOME MODERN TECHNOLOGIES FOR FREIGHT WAGON MONITORING

Systems installed along the railway are generally aimed at the following:

- detection of overheating bearings and wheels,
- detection of wagon parts outside of load profile,
- checking pantograph erectness,
- acoustic detection of defective bearings,
- monitoring the wear of brake pads,
- monitoring the state of profile and diameter of wheels,
- monitoring of bogies geometry and others.

Thermal radiation from objects can be detected by infrared cameras. This technology makes it possible to mark those areas with high or low temperatures. The system uses a "thermal imager" technology and digital image processing. FUS II - Detection of overheated wheels, bearings and blocked brakes have a linear infrared detector with four pixels (Fig. 1).

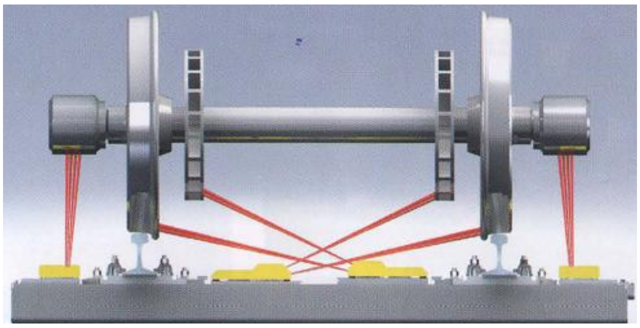

Fig.1. Good FUS II system for the detection of overheated wheels, bearings and blocked discs

With the appearance of a number of different infrastructure owners and operators, there was a problem how to integrate all systems. Association of American Railways (AA), started development of an integrated information system rail (Fig. 2).

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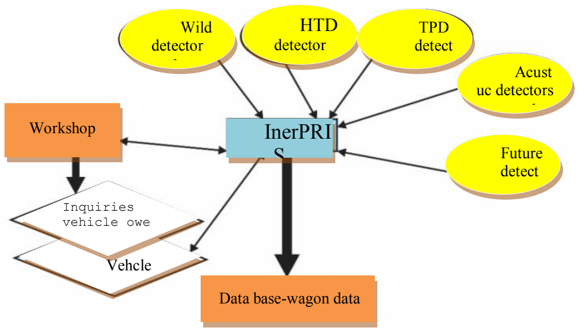


Fig.2. Information System (InterRRIC™)

System for the detection of overheated axle bearings, wheels and discs used in Austria and Serbia is presented on Fig. 3 [3].

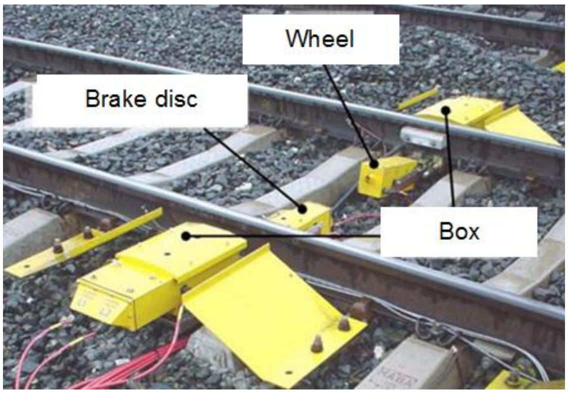


Fig.3. Device for measuring wheel (axel) temperature axel bearings and brake discs

3. SELECTION OF MONITORING SYSTEM

For new types of railway vehicles, which are equipped with diagnostic systems, maintenance interventions are planned based on the processing of sensor signals and stored vehicle parameters.

In support of the new concept of maintenance, it is necessary to design a database for the results of dynamic values measurement of the respective parameters of railway vehicles, at the level of the railway network [1].

Which monitoring system will be applied, in what capacity and where it will be located, depends primarily on:

- analysis of the exclusion of rolling stock (wagons in particular), with special emphasis on the reasons and frequency thereof,
- features of railway line (mountains, plains, specific conditions of use of the brake system - braking on long downs)
- climatic conditions (extreme high temperatures, layers of sand or extreme cold and snow layers
- analysis of the exclusion of rolling stock (wagons in particular), with special emphasis on the reasons and frequency thereof, features stripes (mountains, plains, specific conditions of use of the brake system - braking on long downs) climatic conditions (extreme high temperatures, layers of sand or extreme cold and snow layers etc.
- characteristics of the type of goods transported (ores, construction materials, RID materials, various structures, etc.)
- characteristics of the wagons that operate along these sections, maintenance methods (whether the rolling stock are in the ECM system or not?) and
- transport route of transport of the most common types of goods transported.

4. DATABASE FOR MEASURING DATA STORAGE

The database, which will be described below would enable the acceptance and processing of data from other measuring stations, which would be set up in the future (this paper partly uses data from the former measuring station Batajnica).

The basic idea was to design a database that will on the one hand consistently model the measuring station and the physical sizes which station measure, and on the other hand to enable the generation of new requests if necessary [4]. Based on the data displayed by the existing applications, relational data model was developed, and then according to this model a relational database DIAGNOSTICS OF ROLLING STOCK OF SR has been formed. The database was created in a relational system for database management Microsoft Access 2013. Newly formed structure of database is shown in Fig. 4. Basic relational data model entities are: lines, conditioning, measuring equipment, train and alarm.

Entity LINE modeling the same concept from the real system of SR railway network. It aims to provide an analysis of registered irregularities of technical condition of the rolling stock in terms of tracks on which the irregularity was discovered.

Entity DEVICE modeling different types of devices that are on the track.

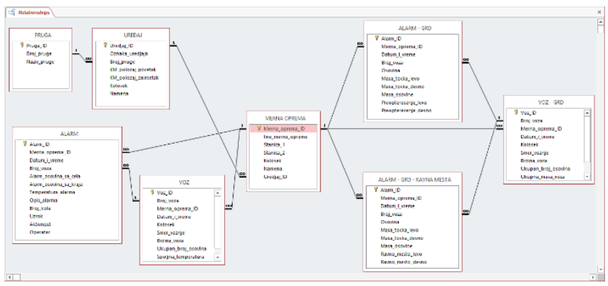


Fig.4. Database Scheme DIAGNOSTICS ROLLING STOCK SR

Entity MEASURING EQUIPMENT modeling different types of measuring equipment, such as:

- Equipment for detecting overheated bearings, axle assemblies (HOA), which measures the temperature of the bearing axle assembly;

- Detection equipment for blocking the axle assembly during the braking (FOA), which measures wheel body temperature 2 cm above the GIS (upper rail edge);
- Detection equipment for overheated brake disc (SOA), which measures the temperature of the brake disk.

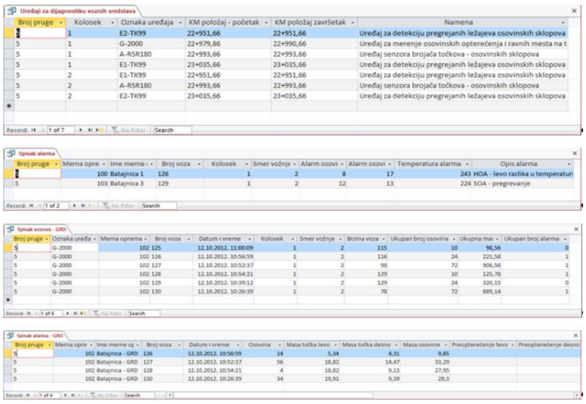
Equipment for measuring the mass of the wagon and axle (GRD), which measures the force with which the wheel runs on the rail at contact point and detects a flat point on the wheel if there are any.

TRAIN entity modeled trains that pass through the measuring equipment for the detection of overheating (HOA, FOA, SOA). Important attributes of this entity are: train number, date, time, track, driving directions, train speed and outside temperature.

ALARM entity modeling alarms - warning that generate measurements of measurement equipment: HOA, FOA and SOA. Important attributes of this entity are: date and time, alarm axle on forehead train, alarm axle from the end of the train, temperature alarms and alarm description. Alarm temperature is measured temperature of: bearing axle assembly, wheel or disc brakes, at which the alarm went on. The attribute of alarm description shows what type of measurement is in question: HOA, FOA or SOA and what kind of overheating is concerned: warm or hot..

Entity ALARM - GRD modeling alarms - warning, which generates measuring of the axle loads. Important attributes of this entity are: date and time, axles, left mass of wheel, right axle wheel mass, left and right overload. Each entities instance of ALARM – GRD is linked to the one instance of TRAIN – GRD entity and to the one instance of MEASURING EQUIPMENT. ALARM – GRD – FLAT SPOTS entity modeling alarms - warnings, generated by detection of flat spots on wheels. Important attributes of this entity are: date and time, axle, flat spot left, flat spot right. Each entities instance of ALARM – GRD - FLAT SPOT is linked to the one instance of TRAIN – GRD entity and to the one instance of MEASURING EQUIPMENT.

Database Diagnostics ROLLING STOCK SR has been created in the way that data from the measuring stations become available for further use and processing. What is the use value of this database becomes clear only when queries over it is created. Fig. 5. shows the results of the execution of four selected queries from the database. The first query generates a list of all the measuring devices, grouped by the railway lines and tracks. The second query creates a list of all alarms caused by various types of vehicles axle assemblies overheating. The third request form the list of all trains detected by the device for measuring the axial load. The fourth request generates a list of all alarms caused by axel overloads or flat spots on wheels. The total number of queries that created the database is much larger than presented, but more importantly, it is unlimited. Requests constantly be added, modified or deleted, according to the needs.



Uređaji za dijagnostiku voznih sredstava

Broj pruge	Kolosek	Oznaka uređaja	KM položaj - početak	KM položaj završetak	Namena
[illegible]	1	E2-TK99	22+951,66	22+951,66	Uređaj za detekciju pregrejanih ležajeva osovinskih sklopova
5	1	G-2000	22+979,86	22+990,66	Uređaj za merenje osovinskih opterećenja i ravnih mesta na t
5	1	A-RSR180	22+993,66	22+993,66	Uređaj senzora brojača točkova - osovinskih sklopova
5	1	E1-TK99	23+035,66	23+035,66	Uređaj za detekciju pregrejanih ležajeva osovinskih sklopova
5	2	E1-TK99	22+951,66	22+951,66	Uređaj za detekciju pregrejanih ležajeva osovinskih sklopova
5	2	A-RSR180	22+993,66	22+993,66	Uređaj senzora brojača točkova - osovinskih sklopova
5	2	E2-TK99	23+035,66	23+035,66	Uređaj za detekciju pregrejanih ležajeva osovinskih sklopova

Record: 1 of 7 No Filter Search

Spisak alarma

Broj pruge	Merna opre	Ime merne	Broj voza	Kolosek	Smer vožnje	Alarm osovi	Alarm osovi	Temperatura alarma	Opis alarma
[illegible]	100	Batajnica 1	126	1	2	8	17	243	HOA - levo razlika u temperaturi
5	103	Batajnica 3	129	1	2	12	13	224	SOA - pregrevanje

Record: 1 of 2 No Filter Search

Spisak vozova - GRD

Broj pruge	Oznaka uređa	Merna oprema	Broj voza	Datum i vreme	Kolosek	Smer vožnje	Brzina voza	Ukupan broj osovina	Ukupna ma:	Ukupan broj alarma
5	G-2000	102	125	12.10.2012. 11:00:09	1	2	115	10	98,56	0
5	G-2000	102	126	12.10.2012. 10:56:59	1	2	116	24	221,58	1
5	G-2000	102	127	12.10.2012. 10:52:37	1	2	98	72	906,56	1
5	G-2000	102	128	12.10.2012. 10:54:21	1	2	129	10	125,78	1
5	G-2000	102	129	12.10.2012. 10:39:12	1	2	129	24	320,15	0
5	G-2000	102	130	12.10.2012. 10:26:39	1	2	78	72	889,14	1

Record: 1 of 6 No Filter Search

Spisak alarma - GRD

Broj pruge	Merna opre	Ime merne op	Broj voza	Datum i vreme	Osovina	Masa točka levo	Masa točka desno	Masa osovine	Preopterećenje levo	Preopterećenje desno
5	102	Batajnica - GRD	126	12.10.2012. 10:56:59	14	5,34	4,31	9,65		
5	102	Batajnica - GRD	127	12.10.2012. 10:52:37	56	18,82	14,47	33,29		
5	102	Batajnica - GRD	128	12.10.2012. 10:54:21	4	18,82	9,13	27,95		
5	102	Batajnica - GRD	130	12.10.2012. 10:26:39	34	19,91	9,39	29,3		

Record: 1 of 4 No Filter Search

Fig.5. Results of the execution of 4 queries of the database DIAGNOSIS OF SR ROLLING STOCK

From this base many reports are created, new reports can also be formed if necessary and existing ones can be modify.

Corresponding number of measuring devices, networked and organized as an operational center, additionally provides:

- enrichment of measurement data with driving data (origin and destination of train, the composition of the train, train drivers phone number, etc.), so that the optimized interventional process can timely start on time,
- significantly reduced stopping for trains with malfunctioning brakes thanks to the operating center staff support to the train driver,
- early detection of problems on the train, which allows scheduling of stopping the train at suitable locations,
- train and vehicle monitoring on the network,
- ability to set alarms to the vehicle depending on the specifications or its specific load,
- System independence from the manufacturer and model,
- existence of preventive maintenance strategy since the given maintenance activities are based on the state of vehicle and infrastructure.

Maintenance management comes down to making decisions that have a unique objective, e.g. decision whether it is necessary to exclude the wagon from traffic must be preceded by series of directed decision [4]: why to exclude, when to exclude, whether immediately or in the final station, before or after unloading, what to do on wagon, how to enable the wagon, where to perform repair (in the train-without detaching, on repairs track, workshop, etc.), how long the wagon will be out of service, i.e. how long it will take to repair the wagon.

5. CONCLUSION

The paper presented models of concepts development of monitoring and diagnostics of assembles of railway vehicles in the process of defining a more efficient system for maintenance of railway vehicles. In this context designing of operating center with integrated-networked measuring stations are proposed.

Designed database of diagnosed SR rolling stock data, with the help of multi-criteria analysis, enable monitoring the technical condition of Serbian Railway rolling stock, as a basic prerequisite for the transition to a new approach to maintenance based on the condition.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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PROTECTING BRAKE MECHANISM OF EXCESSIVE BRAKE FORCE IN LOCOMOTIVES

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Tasko SMILESKI[2]
Nikola STOJKOV[3]

Abstract *– All of the locomotives equipped with locomotive distributor valve type Lst1 which are left in place, on stations or depots, longer than 10 hours, have great possibility to be affected by increased brake pressure in the brake cylinders, even at a level of 10 bars, caused by leakage problems in the pneumatic brake system portion of the locomotives. Major problem of increased brake cylinder pressure are forces in the brake lever mechanisms and slack adjusters type RKPL causing their deformations. A technical solution to avoid this problem is the implementation of overflow protection valve on a pneumatic brake system loco portion as a separate part outside the distributor valve and this is disscused in this paper.*

Keywords – railway, braking, releasing, distributor valve, locomotive

1. INTRODUCTION

Locomotives type 441, 442, 443, 462 and 642 are equipped with similar brake equipment. This is very good in terms of servicing, handling and maintenance of the same.

In terms of usage as in a train or as a single locomotive with speed of 100-160 km/h (dependent on the type) the brake system functions without any problems or failures. As a main unit of the brake in all of them is the distiributor valve type Lst1. This distributor valve is one of the most noble type of distributor valves made until now and is the most practical for installation on locomotives, since it offers the most desired functions and abilities [3].

During a long-term exploitation of these locomotives an anomaly occurred that led to deviations of the brake rigging system and slack adjusters.

From the analysis of the possible reasons for these deviations of the rigging system of the bogies, it was concluded that these deviations occurred because the rigging system was under much higher force than the normally foreseen one. Much higher force can occur if the brake cylinder pressure is higher than the prescribed and foreseen one for the corresponding series of locomotives.

How and when is it possible such pressure and forces to occur? The answer of this question can be given from a deeper analysis of the pneumatic brake system which causes such increased brake cylinder pressure.

2. REASON FOR EXCESSIVE BRAKE FORCE

While leaving these types of locomotives longer in place (on a station or depot) for a time longer than 10 hours an occurrence of much higher than prescribed pressures in brake cylinders is possible which will result with higher forces in the rigging system of the bogies. The distributor valve as a main unit is responsible for such increased brake cylinder pressure. The functional sheme of distributor valve type Lst1 for locomotive type 443 (Lok. 443) is shown in Fig. 1.

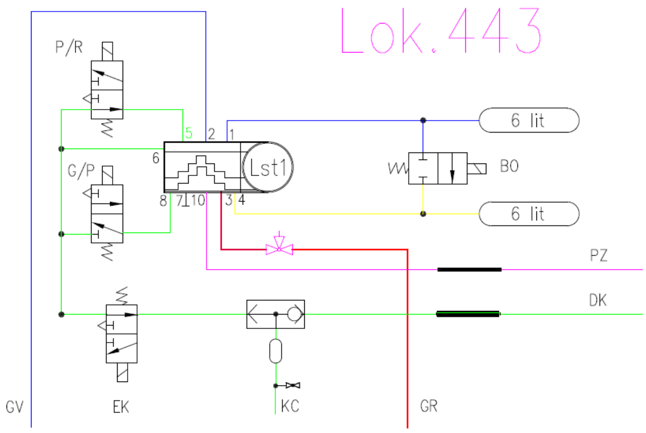

Fig.1. Functional scheme of distributor valve type Lst1 for locomotive type 443

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The amount of pressure in the brake cylinder can reach the value of the existing pressure in the main reservoir of the locomotive. The value of the reached pressure can be 10 bar [4], [6]. This pressure in the brake cylinders represents increased value of approx. 2,5 till 5 times in terms of the prescribed values (2,1 - 3,8 bar), dependent on the series.

There are several reasons that can lead to such anomaly:

Air charge is made by insufficiently purified compressed air;

Dirty pneumatic instalation (pipeline)

Irresponsible servicing of the distributor valve by application of old seals instead of compatible seals;

Ommissions while replacing or intervention on the EP valve for fast release of the locomotive;

Ommissions while testing the brake of the loco.

This anomaly can be foreseen and recognized during tightness test of the brake at an introduced fast brake application.

With such anomaly of the distributor valve type Lst1, the locomotive can safely bring the train to the final destinations without any consequences on the train or the locomotive. Only after reaching the destination it is necessary to leave the locomotive (garage it) by placing the Driver's brake valve FV4a in position PK (Full brake application) and activate the parking (hand) brake. This anomaly on the locomotives is annuled very promptly and is recommended to be done by placing the Driver's brake valve in PR (Position RUNNING), not by activating the valve for fast release. Locomotives without a fitted SPB (Spring Parking Brake) can happen to get activated on their own if are left on a spot with inclination. Higher pressure in brake cylinders causes deformations on brake cylinders, on rigging system and slack adjusters RKPL.

In comparison are presented the possible forces with which can be loaded the brake levers and slack adjusters of locomotives with installed distributor valve type Lst1.

For instance:

a). On Loco. 441 normal force is approx. 36642 N [1],

As possible force occurs approx. 114064 N;

b). On Loco. 462 normal force is approx. 33184N [1],

As possible force occurs approx. 164690 N;

c). On loco. 642 normal force is approx. 36000 N [1],

As possible force occurs approx. 94700 N.

3. SOLUTION TO THE PROBLEM BY INSTALLING A PROTECTION VALVE

For overcoming this occurrence it is necessary to supplement the distributor valve type Lst1 with a valve, protection valve (ZK), which shall be placed (fitted) outside of the distributor valve, while shall function as an integral part of it (Fig. 2). The newly fitted valve should perform the following two functions:

Not to permit occurrence of higher (than the prescribed) pressure in brake cylinders, which is why it is necessary to be fitted.

To correct the function of the max. pressure limiter in cases of large deviations than prescribed values.

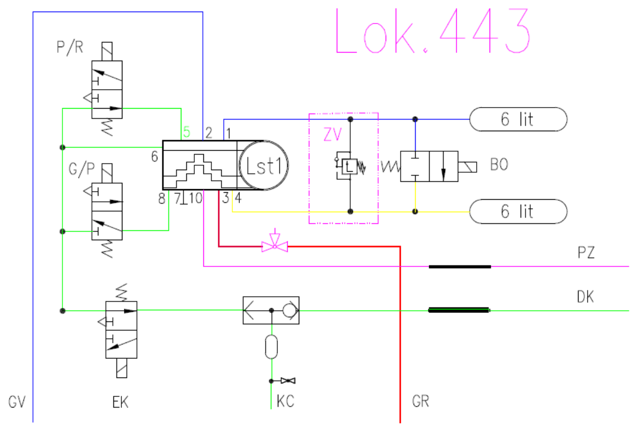

Fig.2. New functional scheme of distiributor valve type Lst1 for locomotive type 443

3.1. Model of action of integrated protection valve

Pressure in brake cylinder (KC) in the locomotives (with distributor valve type Lst1) depends on the the pressure difference in the working chamber (RK) and the expansion reservoir (EKS-R). If that difference is within the prescribed values than the pressure in the brake cylinder (KC) shall be within the frames of the prescribed values. The system contains also a main pipe (GV), reservoir main pipe (GR), direct brake (DK), protection against slippage (PZ).

Supplemented protection valve has the function that in case of pressure difference increase in working chamber and expansion reservoir to normalize i.e. bring it within the prescribed values, therewith also the pressure of the brake cylinders shall automatically normalize without any delays [2].

The protection valve is desirable to start functioning when the difference in pressures of the working chamber and expansion reservoir is within the limits of (1,5 -1,6) bars [4]. This function of the protection valve develops until the pressure in the expansion reservoir drops till 0 bar. The further destiny of the brake cylinder pressure shall depend on the tightness of the working chamber i.e. can only be reduced. The fitting of this protection valve on the distributor valve type Lst1 is not problematic and is performed outside of the distributor valve, as a parallel connection with the EP valve for fast release, between the working chamber and the expansion reservoir.

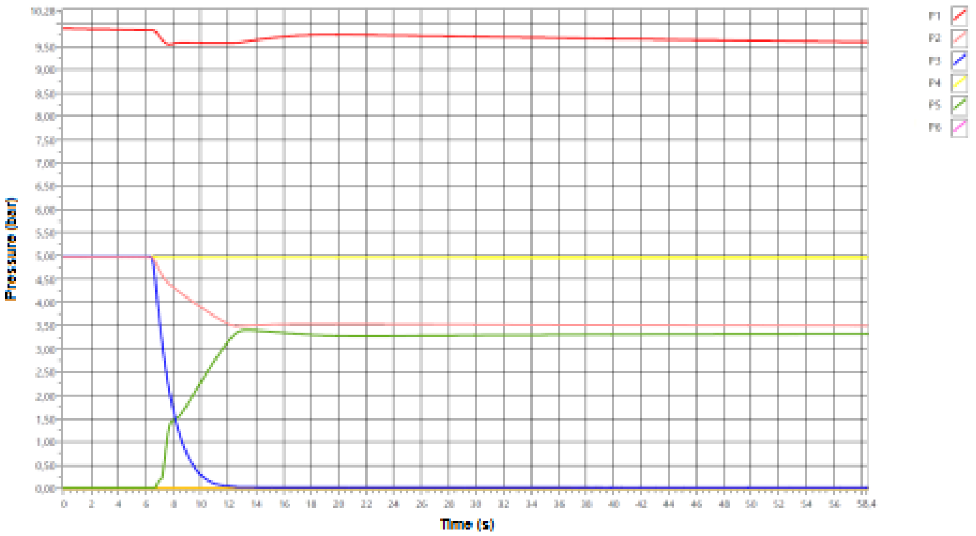

Fig.3. Diagram of the function of the distributor valve without pressure anomaly

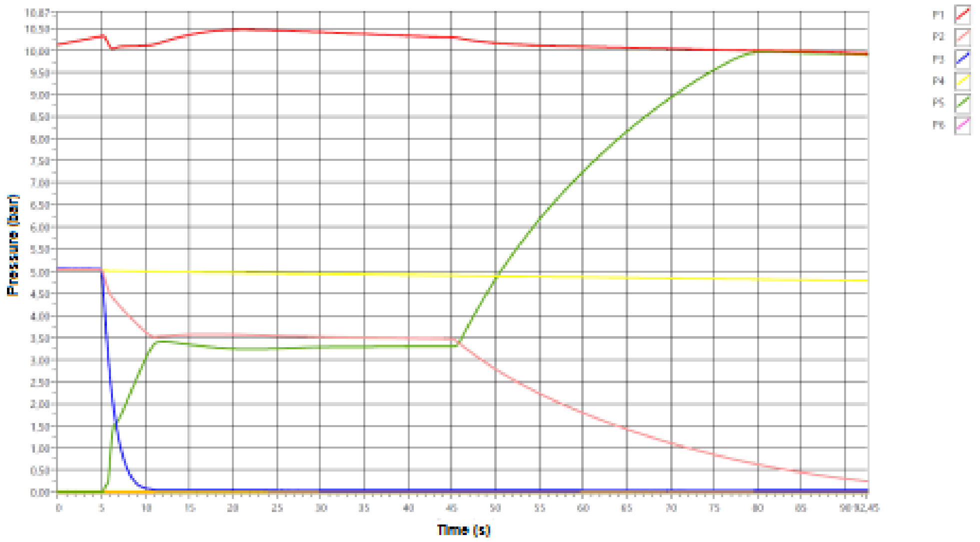

Fig.4. Diagram of the function of the distributor valve with pressure anomaly

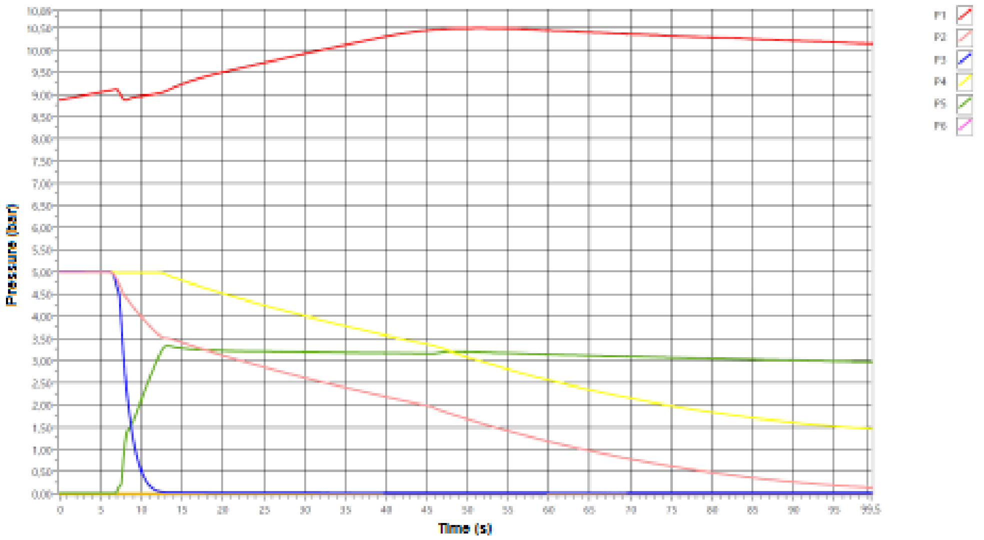

Fig.5. Diagram of the function of the distributor valve with extreme pressure anomaly

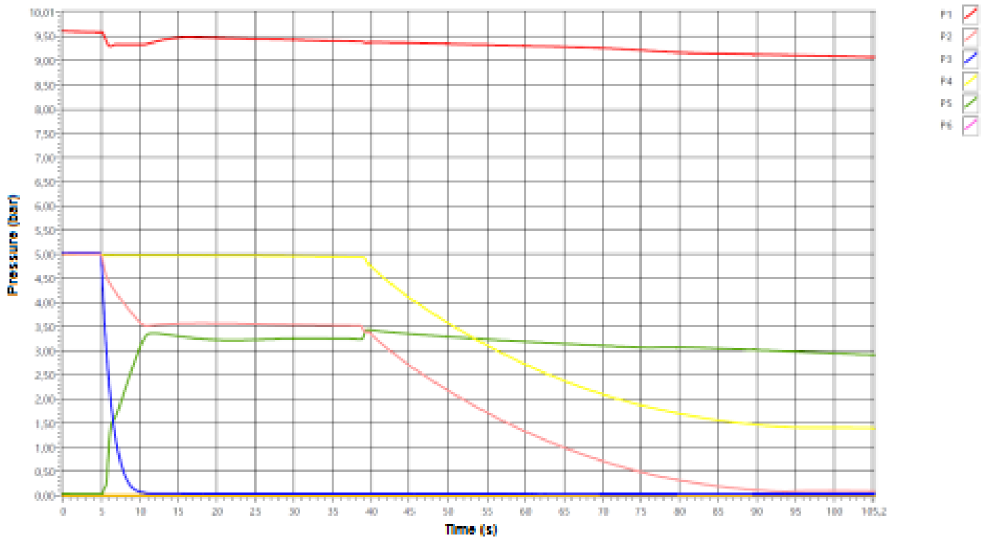

Fig.6. Diagram of the function of the distributor valve with pressure anomaly for the case with installed protection valve in Lst1

In Fig. 3 to Fig. 5 are shown the diagrams of pressure change over time in different cases of the distributor valve without installed protection valve for the case without pressure anomaly (Fig. 3), with pressure anomaly (Fig. 4), with extreme pressure anomaly (Fig. 5) and the same but for the case with pressure anomaly for the case with installed protection valve in Lst1 (Fig. 6) where its function can be seen and behavior of the compressed air in the brake cylinders for avoiding fractures of slack adjusters RKPL and brake linkages [5]. On the presented diagrams the following pressures are shown: P1 - feeding pipe pressure; P2 - connection without function; P3 - main pipe pressure; P4 - working chamber pressure; P5 - Brake cylinder pressure; and P6 - expansion reservoir pressure.

4. CONCLUSION

As it can be seen from the diagram that in Fig. 6, curve green color that I displayed the dependence of the pressure in the brake cylinder depending on the time, that ommendations towards installation of protective valve has the function that in case of pressure difference increase in Working chamber and Expansion reservoir to normalize i.e. bring it within the prescribed values, therewith also the pressure of the brake cylinders shall automatically normalize without any delays (Fig.6).

If an anomaly is detected on the Distributor valve type Lst1 then it is necessary the same to be serviced (repaired) in an authorized service shop.

The distributor valve shall be repaired, but the deviations and damages on the rigging system remain permanent. For its bringing in a normal condition new parts are necessary and many other adjustments, if possible, when the locomotives are placed out of function for a long time. In such repairs it is necessary to include many expert people and offices, while as for the expenses from the claims are much higher than the value of the distributor valve type Lst1 and its repair [7]. Because of all of these reasons implementation of a protection valve can increase the relialibility and reduce any claims and adittional expenses.

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ELECTICITY CONSUMPTION MONITORING IN ELECTRIC LOCOMOTIVES CLASS ŽS 441-700

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Abstract *– A measurement-information system for monitoring electricity consumption in electric locomotives class ŽS 441-700 is presented in this paper. The measuring part of the presented system, with the corresponding GSM/GPRS communication modem, was installed in locomotive 441-707, which belongs to the "Srbija Voz" JSC enterprise, in May of 2016. After additional requests by the Commission (established by the Directorate of "Serbian Railways" JSC), the system was upgraded by adding the corresponding table board and GPS modem, and new test series were conducted. One of the basic advantages of the presented system is the simplicity of installation and variety of information that can be obtained.*

Keywords – Electric locomotives, Electricity Consumption monitoring, Measuring system.

1. INTRODUCTION

Electricity consumption of electric locomotives in Serbia is becoming important after the transformation of the national railway company "Serbian Railways" JSC, which is now divided into several independent legal entities. Namely, electricity consumed by individual electric locomotives and trains had not been measured while the company was one legal entity. All electricity meters for consumed electricity billing were located in substations that supply the contact lines, which meant that total electricity consumption was measured. In this case, where all substations, as well as all locomotives belong to the same legal entity, it is not a problem at all. The company treated the received electricity bills as an expense of the accounting entity.

Division of the company into several legal entities ("Infrastruktura železnica Srbije" JSC, "Srbija Voz" JSC, "Srbija Kargo" JSC) brought many changes. One of them was that electric locomotives were split between companies "Srbija Voz" and "Srbija Kargo", while all substations became property of "Infrastruktura železnica Srbije". The public Enterprise "Electric Power Industry of Serbia", as a legal supplier of electricity in the Serbian market, recognizes the enterprise "Infrastruktura železnica Srbije" as the only legal electricity consumer. However, the other two legal entities are recognized as the owners of electric locomotives are end users of electricity. In order to monitor their business activities, for each of the abovementioned companies, pertaining to their spending, a realistic share of the total electricity bill had to be determined and split between them each month. To do this in a proper way, these companies would have to have information about electricity consumption of every single locomotive.

One of the technical solutions for monitoring electric locomotives' electricity consumption will be presented in this paper. It is being tested on one of the locomotives that belongs to the enterprise "Srbija Voz" (locomotive 441-707) JSC over the period of the past several months.

2. THE SYSTEM DESCRIPTION

Measuring Information Systems (MIS-1U) are multifunctional devices designed for measuring and monitoring electricity consumption parameters in low and medium voltage networks.

A variant of this series of devices marked with MIS-1U_v2.0 was developed so that its characteristics fully meet the needs for monitoring single-phase

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electrical quantities in electric locomotives. This system is installed in locomotive 441-707.

The most relevant electrical parameters that this device can measure and record are:

- RMS value of the voltage and current;
- Active, reactive and apparent power;
- Frequency;
- Active and reactive energy;
- Maximum demand (average from the instantaneous power, in kW or kVA, during a defined time interval – 15 minutes in Serbia).

The basic variant of the device, which was tested in the initial period, was equipped with an ETHERNET communication interface and a GSM/GPRS modem with the appropriate antenna. Also, the device had a global positioning system (GPS), which enabled recording of the current coordinates of locomotives or train.

The device was designed so that the measured electrical parameters, GPS coordinates and identification data (train number, train driver ID number and station number) were recorded on a memory microSD card that could be easily accessed via aforementioned communication interfaces. Figure 1 shows how the device is connected in the electric locomotives ZS series 441-700.

2.1. Basic characteristics

Basic features of the device include:

- Input for measuring effective value of the single-phase AC voltage (250 V to 450 V);
- Input for measuring effective value of the single-phase alternating current (5 A);
- Power supply input (67 V to 143 V DC);
- The device measures locomotive supply voltage effective value, main current effective value, active power, reactive power, apparent power, frequency, active energy and locomotive maximum demand;
- GPS module allows locomotive coordinates recording;
- All data (measurement data, location data and identification data) are stored on a memory microSD card in a time interval that is adjustable in the range from 1s to 15s;
- Data are saved in text files in .csv format, which allows very easy analysis of recorded data in different software packages (e.g. Microsoft Office Excel). One text file contains information on a daily basis stored in a monthly folders;
- The device has an Ethernet communication interface and GPRS communication;

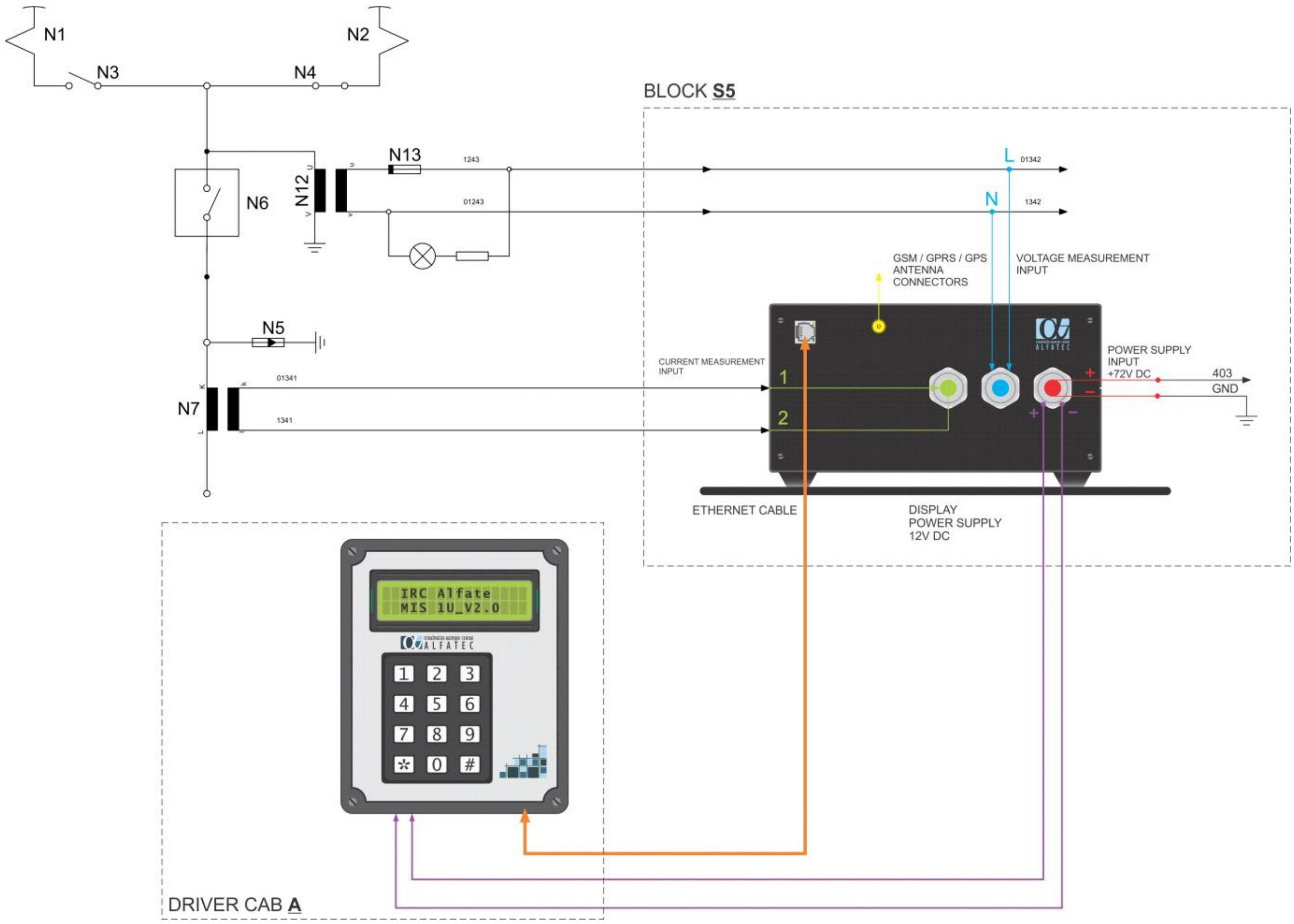

Fig.1. The MIS-1.U v2.0 connecting diagram in locomotive

- The Ethernet interface is electrically isolated and enables communication with MIS-1U v2.0 devices over a LAN computer network. Using this communication interface, it is possible to adjust the parameters of the device and collect data recorded on the memory card;
- Access to the recorded data and/or adjustment of device parameters is done via FTP protocol using any FTP client software like FileZilla or Total Commander;
- Aside from the FTP protocol, the device has implemented DDNS client service that allows access to the machine via the Internet using a unique URL address, which connects it to a computer network via the Ethernet interface. The external IP address type of the computer network can be static or dynamic;
- GPRS communication is used to collect data from the memory card as well as for setting the parameters of the device via specialized software.

2.2. The system upgrade

After additional requests from the Commission established by the Directorate of Serbian Railways, the system was upgraded by adding the corresponding table board and GPS modem.

The table board is located in the locomotive control room. Using this module, the locomotive driver should enter the following data:

a) **The driver's license number** (5-digit number from the driver's license).

b) **The number of the train** (the number 10000 should be entered for maneuvers).

c) **The station number (the number from the station Code).**

If the previous data are correctly entered, the following text appears on the module display: **„Pocetak voznje …" („Start driving…")**

After the driving tour, the driver is obligated to check out entering the license number again.

3. TYPICAL REPORTS

The information that is recorded by the system, along with the data entered by the train driver, is used to create standard reports in graphical, tabelar, or textual form. Remote servers that collect data automatically form typical reports and send them to pre-selected e-mail addresses. Some types of the reports are shown in Figures 2-4.

3.1. Graph reports

The daily changes in contact line voltage, as well as in the locomotive's active power consumption, are presented in the figures 2 and 3, respectively.

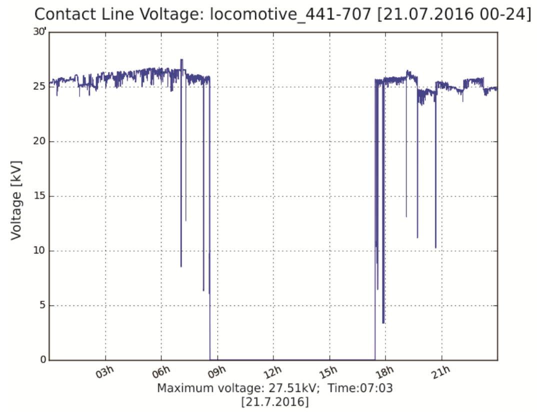

Fig.2. The daily changes in contact line voltage

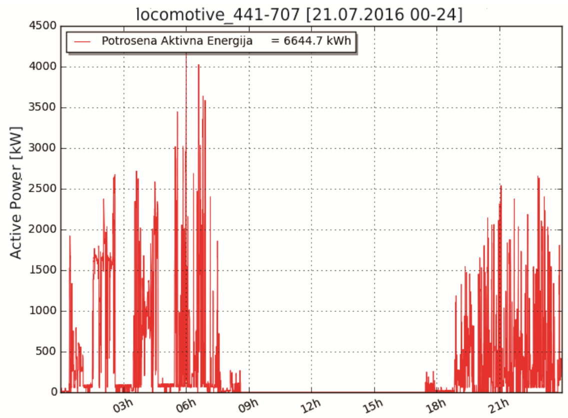

Fig.3. The daily changes in the locomotive's active power consumption

Locomotive: Locomotive_441-707 [04.08.2016.]

The train number	The driver's license number	Date/ departure time	Departure place	Date/ arrival time	Arrival place	Consumed active electrical energy [kWh]	Consumed reactive electrical energy [kVArh]
292	01810	3.08.2016. 23:34:43	Niš	4.08.2016. 06:34:01	Beograd	1585.0	1244.0
17720	01315	4.08.2016. 08:08:30	Beograd	4.08.2016. 12:03:41	Beograd	1035.0	791.0
335	01810	4.08.2016. 17:56:14	Beograd	4.08.2016. 21:33:34	Lapovo	871.0	657.0

Fig.4. The locomotive's daily tours and corresponding information about consumed electricity

3.2. Table report

Table reports showing the locomotives daily tours and corresponding information about consumed electricity is presented in the Figure 4.

The example presented in the Figure 4 shows that one locomotive driver did not respect the procedure and did not enter the information about the station numbers. For this reason, the train number 17720 row has the same name put into the cells for departure and arrival location (Beograd). In such a situation, one can check the complete locomotive's route based on GPS coordinates. The example is shown in Figure 5.

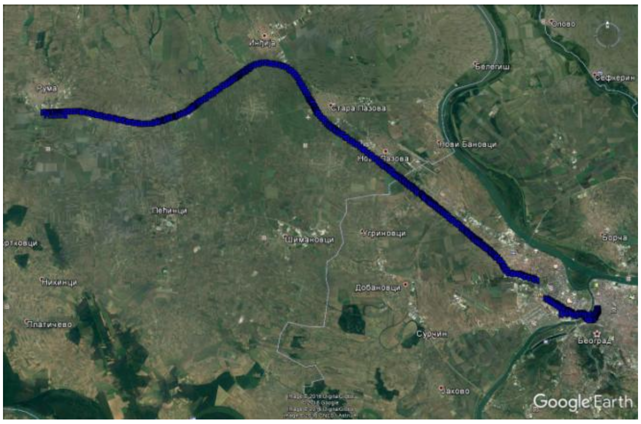

Fig.3. The locomotive's route

4. CONCLUSION

This paper presents a system for measuring electricity consumption on electrical locomotives, which was tested on one of the locomotives that belong to the enterprise "Srbija Voz" JSC, in the past 3-4 months.

The basic advantages of the presented system are:

- Installation of the device did not require additional space on the locomotive, because the system connects to the existing voltage and current measuring transformers.
- Installation of the device is performed by a maximum of a few hours and does not require the special overhaul workshop (installation can be carried out while the locomotive is standing on a sidetrack).
- Minimal changes in the locomotives' connection diagrams are required.
- The system begins with storing data and sending the data to a predetermined data server, just after installing it and performing basic setup.
- Besides data collection, the server runs background software that can automatically generate reports in a graphical or tabular form and send them to a predefined e-mail address.
- All collected data is available to users in text format or in a standard XML format.
- The measurement part of the system is a device that the Power Company, but also a large number of electricity consumers, uses to control electricity consumption, and have the corresponding declaration of conformity to standards.
- The system producer has extensive experience as an independent party that often appears in the role of an expert in disputes between Electrical Utilities and electricity customers.

ACKNOWLEDGEMENT

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STATIC ANALYSIS OF BEHAVIOUR OF AXLE ASSEMBLY OF FREIGHT WAGONS

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Abstract – *In this paper the deformation of an axle assembly of freight wagons was determined using the finite element method, on a case of the ambient temperature of 20 °C and the maximum permitted load per axle of 22.5 tonnes. This was done considering bearing deformations, because they have the dominant influence on the exploitation life, and the contact of a wheel with a rail. The analysis was done for two characteristic cases loads: the radial load for the straight line moving and the radial and axial load while moving in a curve. The static behavior in the case of the load during curve moving was considered for different speeds and at different heights of the cant of rails.*

Keywords – Railway, Axle assembly of freight wagons, Static behavior, Finite element method.

1. INTRODUCTION

Railroad transportation represents one of the oldest forms of transport. In modern times, it is in second place after sea transport in terms of the amount of cargo carried, and second after road transport when it comes to passengers. It's most important function is the long-distance transport of industrial and agricultural materials, wooden construction material, ores, and semi-products of the chemical industry.

Even if in comparison with other forms of transport, the railroad has a range of advantages related to its economic benefits (lower energy use, and especially, ecological sustainability; the ability to transport various types of goods), the inefficiencies that are created by railway regulations have placed limits on the industry which have prevented effective competition within the sector. The standstill in the innovation of railroad technology and the inadequate response to the significant increase in smaller packages of goods, alongside the reduction in goods that are suitable for railway transport (such as ores, coal…), are the primary explanations for the decrease in railway transport. These days, the European Union treats the railway as the transportation provider of the future and seeks to reaffirm railway transport throughout Europe, while seeking competitive, secure and quality transportation of all types of goods. The realization of these goals, among other elements, requires the construction of modern wagons that are adjusted to marketplace challenges, specific technological requirements, and systems that allow for loading/unloading operations to be carried out quickly [1].

Mohan [8], upon applying finite element methods, conducted a prediction of the thermal and static behavior of the towed railway vehicle wheels. The temperature value for the wheel flange amounted to 70 [°C]. By static analysis, Von Mises strain values were determined depending on the deformations caused by static load. The maximum deformation occurred on the wheel flange and amounted to 0,2196 [mm], while the maximum strain on the wheel was 46,34 [N/mm^2]. In this research, the analysis of the static behavior of the wheel was conducted only for the wheel itself without the other vital parts of this assembly (bearins and axle). By the integration of the heat and static behavior on one model, the amounts of displacement and strain on the wheel were determined. The maximum displacement on the wheel flange amounted to 1,084 [mm] and the maximum strain on the wheel amounted to 148,98 [N/mm^2].

2. AXLE ASSEMBLY OF FREIGHT WAGON

The axle assembly of freight vagons can be placed in different types of bearings (cylindrical roller, spherical, and conical-roller). The placement of the axle assembly of freight vagons in the wheelset is

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conducted with cylindrical rolling bearings (bearing code NJ 324 EC.M1C4 VA301) [2]. In Fig. 1, the axle assembly is shown as well as details of the bearings.

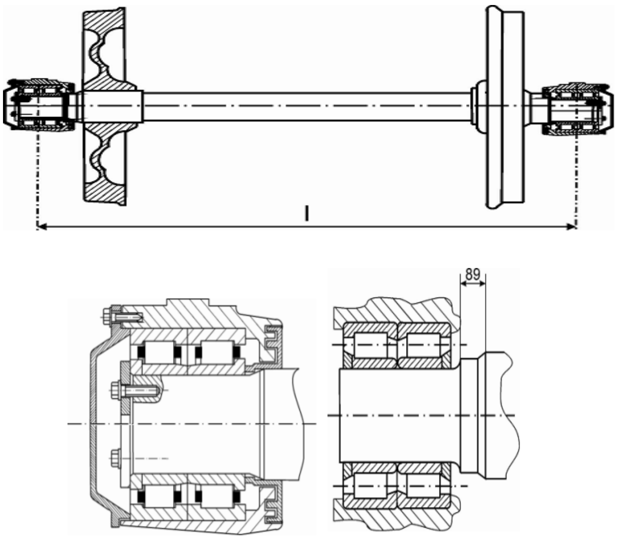


Fig.1. Appearance of axle assembly of freight vagons with bearings details

3. MODELING OF STATIC BEHAVIOR

In Fig. 2, the model of the axle assembly of freight vagons is shown, modeled by the application of the PTC Creo Parametric system.

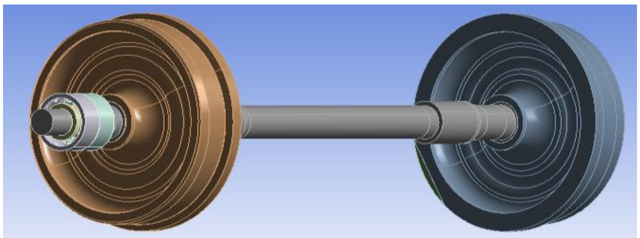


Fig.2. Appearance of the axle assembly of freight vagons

The configuration of the coordinating system, choice of contact pairs (CONTA 174, 64 contact pairs), load definition, choice of finite element type (SOLID 87, mesh of 33754 elements and 59726 nodes) was conducted within the framework of pre-processing.

Definition of the wheelset stiffnes was conducted by the application of spring-type contact pairs. The radial stiffnes of the bearings was specified on places where the rolling parts are found, and it is noted that the radial stiffnes of the bearings is linear. The total value of the radial stiffnes amounts to 4000 [N/μm] and it is taken from the catalog. The axial stiffnes of the bearings was also specified by a spring-type contact pair and amounts to 25% of the radial stiffnes.

The axle load per single axle amounts to 22,5 [t], which is proportional to the load of 220725 [N] in the radial direction and this load also appears upon movement in a straight line and the movement of the train across a curve. Upon the movement of the train through a curve, axial and radial load is also in effect. The load in the axial direction is calculated on the basis of the equation:

$$F_C' = F_c - G_C \tag{1}$$

In the previous equation:

F_C'- is the axial load,
F_c- is the centrifugal force,
G_C- is the normal load on the railway tilt plane.

Centrifugal force is calculated on the basis of the equation:

$$F_c = m \times v^2/R \tag{2}$$

where:
m- is the mass of the load (*m*=22500 [kg]),
v- is the speed of the train's movement across a curve (*v*=20÷40 [km/h]),
R- is the curve radius (*R*=500 [m]).

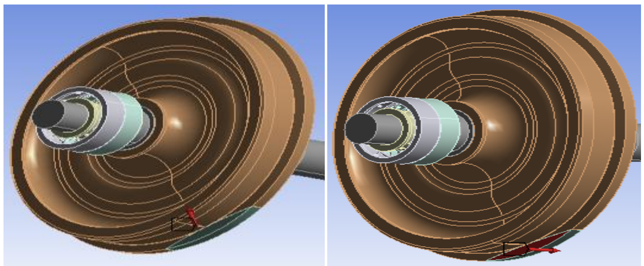
The horizontal component of the vehicle's weight is calculated on the basis of the equation:

$$G_C = m \times g \times \frac{h}{s} \tag{3}$$

where:
g- is the acceleration due to gravity (*g*=9,81 [m/s^2]),
h- is the camber height (*h*=110÷180 [*mm*]),
s- is the width of the track (*s*=1435 [*mm*]).

After defining the load, it is necessary to define the load in a mathematical model (in the radial and axial directions), as well as the displacement.

The load is defined on the wheel flange, and on figure 3 you can see the surface which it affects, as well as the direction of the influence.



radial *axial*

Fig.3. Load on the wheel flange

In this research, the influence of the Hertz contact theory, on which the contact surface between the wheel flange and head rail, as well as between the wheel flange and side edge of the rail, are dependent, was not considered.

Displacement are defined on the outer ring of the bearins and side edge of the inner ring (limited movement in the direction of all three axis points X=0, Y=0 i Z=0) which are shown in Fig. 4.

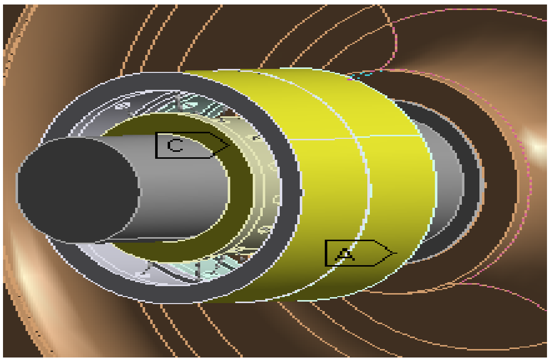


Fig.4. Displacement movement

Following the calculation and after post-processing, a graphic model of the distribution of displacement on the axle assembly was obtained. On Fig. 5, a graphic model of displacement in the radial direction (axis direction Z) and the maximum load of 220725 [N] per axle.

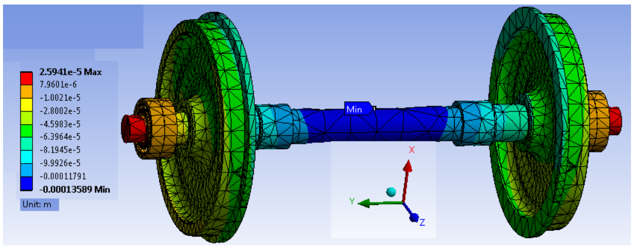


Fig.5. Displacement in the radial direction

4. RESULTS AND ANALYSIS

In this research, the effect of radial load which occurs upon the straight-line movement of the train for instances of maximum load transportation (220725 [N] per axle) was considered, as well as the axial load upon different speeds of train movement across curves (v=20÷40 [km/h]). The deformation value upon radial load depends on the mass of the load that is transported in the wagon, and with an increase in mass, the deformations (displacement) in the axle assembly are increased. Characteristic points S_1, S_2 i S_3 for which displacement are considered are defined on the axle assembly shown in Fig. 6. Displacement in axial directions X i Y will not be considered for radial loads.

For the maximum allowable load to the axle assembly, the displacement values in characteristic points of the axle assembly in the Z axis direction are shown in Tab. 1. It should be kept in mind that the symbols related to the movements shown are consequences of the defined limitations and loads. On the basis of the previous, we are led to the fact that the S_1 and S_2 displacement directions are suitable, while the direction in point S_3 is opposite from the real behavior of the axle assembly.

Maximum strain occurs at the point of contact between the wheels and the head rail (at the place affected by the load) and amounts to 42 [N/mm^2]. During the train travel across a curve, radial and axial loads also affect the axle assembly.

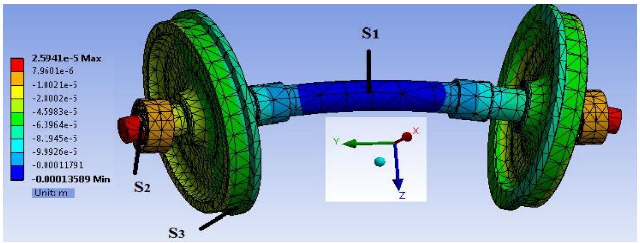


Fig.6. Characteristic points on axle assembly

Tab.1. Displacement in characteristic points

Charact. points	S_1	S_2	S_3
Displacement [μm]	-1352	108	-523

Displacement upon train travel across a curve in speeds of *v*=20÷40 [km/h] are also considered for three camber heights *h*=110, 140 i 180 [mm] in the axial (Y axis direction).

Displacement values in the direction of the Y axis are shown in Tab. 2, 3 and 4. In Fig. 7, a graphic model of displacement are shown for a a *v*=20 [km/h] travel speed and camber height of *h*=140 [mm] in the Y axis direction.

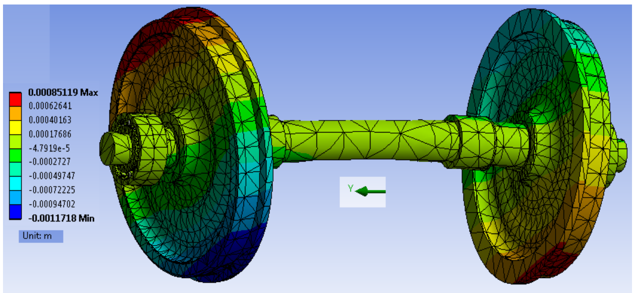


Fig.7. Displacement in the Y axis direction for the camber height of h=140 mm

Tab. 2. Displacement in the Y axis direction in characteristic points for a camber height of h=110 mm

Speed at which the train movements v=20 [km/h]			
Charact. points	S_1	S_2	S_3
Displacement [μm]	-4	-64	-1500
Speed at which the train movements v=30 [km/h]			
Charact. points	S_1	S_2	S_3
Displacement [μm]	-3	-60	-1470
Speed at which the train movements v=40 [km/h]			
Charact. points	S_1	S_2	S_3
Displacement [μm]	-2	-53	-1400

Tab. 3. Displacement in the Y axis direction in characteristic points for a camber height of h=140 mm

***Speed at which the train movements v*=20 [km/h]**			
Charact. points	S_1	S_2	S_3
Displacement [μm]	-4	-85	-1750
***Speed at which the train movements v*=30 [km/h]**			
Charact. points	S_1	S_2	S_3
Displacement [μm]	-3	-74	-1680
***Speed at which the train movements v*=40 [km/h]**			
Charact. points	S_1	S_2	S_3
Displacement [μm]	-2	-67	-1586

Tab. 4. Displacemet in the Y axis direction in characteristic points a camber height of h=180 mm

***Speed at which the train movements v*=20 [km/h**			
Charact. points	S_1	S_2	S_3
Displacement [μm]	-4	-125	-1987
***Speed at which the train movements v*=30 [km/h]**			
Charact. points	S_1	S_2	S_3
Displacement [μm]	-3	-110	-1925
***Speed at which the train movements v*=40 [km/h]**			
Charact. points	S_1	S_2	S_3
Displacement [μm]	-2	-95	-1826

On the basis of numerical results shown in Tab. 2, 3, and 4, it is evident that by increasing the height of the camber h, the displacement of characteristic point S_3 are increased in the direction of the Y axis, and the maximum displacement amounts to -1987 [μm] for the camber height of h=180 [mm] and movement speed of v=20 [km/h]. The displacement of characteristic point S_1 amounts to a maximum of -4 [μm], while that of the characteristic point S_2, amounts to a maximum -125 [μm].

5. CONCLUSION

In this research, the results of the static behavior of the axle assembly of freight wagons that is placed in cylindrical-roller bearings are shown. The paper also is an attempt to make computer modeling of static behavior using finite element method. Mathematical calculating determined displacements of the characteristic points of the axle assembly. Displacement values upon radial and combined load are concurrent with the results of other authors [8].

ACKNOWLEDGEMENT

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Strategy and Policy

COMPARATIVE ASSESSMENT OF EUROPEAN RAILWAYS BASED ON EU TRANSPORT SCOREBOARD DATA

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***Abstract** – Modelling transport policy inevitably entails establishing proper monitoring and reporting scheme. During 2015, European Union launched new Transport Scoreboard - an interactive web database that compares Member State performance in the number of transport-related categories. The aim is to provide a decision making support for achieving high standard Single European Transport Area and sustainability. This paper explores the possibilities of exploiting transport scoreboard data in comparative assessment framework. Using data for railway sector relationships between countries and indicators are analysed simultaneously with analytical tool Co-plot.*

Keywords –Transport Scoreboard, European Union, railways, comparative assessment, Co-Plot.

1. INTRODUCTION

Monitoring is one of the key parts of the policy process. It can be defined as an 'ongoing process by which stakeholders obtain regular feedback on the progress being made towards achieving their goals and objectives' [1, p.8]. It is commonly related to evaluation with the distinction that evaluation generally involves more extensive analysis (procedures, design and methodology) and it can be done independently to provide an objective assessment of whether or not something is on a track [1]. Generally each policy is accompanied with proper monitoring mechanism in order to enable evaluation of policy - rigorous and independent assessment contributing to decision making.

Establishing proper monitoring and reporting scheme is common for policy of European Union (EU). It is an ever-challenging task for both policy makers and practitioners. Probably one of the biggest achievements is 'TERM - Transport and Environment Reporting Mechanism,' established jointly by European commission, Eurostat, DG MOVE[1], DG ENV[2] and DG CLIMA.[3] TERM reports use available data on 'Core Set of Indicators' to assess trends and overall progress towards policy targets.

In the field of the railway policy basic monitoring mechanism are RMMS Questionnaires. RMMS stands for Rail Market Monitoring Scheme and refers to the collecting data on rail market developments in EU member states. RMMS was established in 2007 in order to monitor technical and economic conditions and market developments of EU railways. Reports are published every two years. The RMMS questionnaire is standardized and a part of specific Regulation (the latest is Regulation 2015/1100) implemented to ensure consistency in the Member States' reporting obligations.

Recent advances in the field of transport policy have been made in establishing interactive on line data-base covering four transport-related categories and 29 indicators. It allows comparison of EU member states and highlights top and bottom performs in each category [2]. It is called EU Transport Scoreboard - EUTS and the newest version is published in 2015.

The Scoreboard for transport can serve as good baseline but some additional analytical tools are needed to move from framework to assessment. In this paper we propose to rely on multivariate graphical technique, called *Co-plot*, introduced by Lipshitz and Raveh [3]. Besides useful visual outcome the strength of *Co-plot* is in ability to analyse variables and

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observations (here countries and indicators) simultaneously.

We applied *Co-plot* to perform comparative assesment of raliways in EU countries. We decided on Transport scoreboard data because RMMS reports suffer from gaps in data availability as well as methodological discrepancies.

The paper is organized as follows. First EU transport Scoreboard is introduced with special attention to themes and indicators for railway sector. In the section three *Co-plot* is briefly introduced and followed by cross-national evaluation of EU railways. The paper ends with concluding remarks and future research directions.

2. EU TRANSPORT SCOREBOARD

The scoreboard is a collection of few key performance metrics that best indicate a progress towards defined strategic goals. It is mostly used to support business strategies and originate from the balance scorecards that were first introduced by Kaplan and Norton, in 1992 at Harward Buisines School [4].

As designed to link strategy with action scoreboards have easily found their way to support policy agendas. The usual components of a policy scoreboard are: indicators with all the metadata (sources, definitions, coverage, etc.); search engines with different filters, visualisation tools, links to external sources and related documents, communication modules (query blocks, FAQs, blogs, comments, etc.) as well as links with various explanatory notes.

EU Transport Scoreboard is in fact an online, open source, interactive data base. It is designed to support monitoring and evaluation of EU transport policy achievements. It is a common reporting approach in EU, devised for several policy fields (transport, research and innovation, information society, consumer satisfaction). Probably the most comprehensive one is Digital Agenda Scoreboard-DAS.

EUTS can be accessed either by country or by one of the four categories relating to the Commission's priorities. Each of the categories contains a group of indicators as shown in Table 1.

For example perceived quality of transport infrastructure and progress towards completion of the TEN-T core network are used to reflect Member State performance and potential to increase growth and employment. Also, research and innovation are seen as a key factor for reducing emissions and energy use, keeping with the fact that transport accounts for 24% of all greenhouse gas emissions and for 32% of all energy used in Europe [2].

Interestengily, data sources, although in majority, are not entirely based on Eurostat and/or DG MOVE records. Various world data bases are included such as: Global Competitiveness Report publish by WEF[4] (for indicators reflecting infrstructure quality) or Doing Business reports of World Bank (for average time to export/import by sea).

Tab. 1. Indicators included in EU transport Scoreboard

Theme/Category	Indicators
INTERNAL MARKET	**Market share of all but the principal freight rail undertakings** **Market share of all but the principal passenger rail undertakings** Pending infringements - Road **Pending infringements - Rail** Pending infringements - Maritime and inland waterways Pending infringements - Aviation Pending infringements not related to a specific mode of transport Transposition of EU transport directives Employment share in high growth transport enterprises
INVESTMENT AND INFRASTRUCTURE	**Quality of railroad infrastructure** Quality of port infrastructure Quality of air transport infrastructure Quality of roads Average time to import/export by sea Completion of TEN-T Road Core Network **Completion of TEN-T Conventional Rail Core Network** **Completion of TEN-T High Speed Rail Core Network** Completion of TEN-T Inland Waterways Core Network
ENERGY UNION AND INOVATION	Private expenditure in R&D in transport **Electrified railway lines** Share of renewable energy in transport fuel consumption New passenger vehicles using alternative fuels Hours spent in road congestion annually
PEOPLE	Road fatalities per million inhabitants **Rail fatalities per million train-km** Women employed in the transport sector Consumer satisfaction with urban transport **Consumer satisfaction with rail transport** Consumer satisfaction with air transport

3. EXPLOITING EUTS FOR COMPARATIVE ASSESSMENT OF EUROPEAN RAILWAYS

There are nine rail transport indicators in the EUTS (bolded in Table 1).

To compare member states performance, EUTS

[4] *World Economic Forum*

offers several visualisation tools (not nearly comprehensive as those in DAS): a bar chart arranged in descending order with a highlight for the top five performers (green colour) and the last five laggards (red colour) and a corresponding coloured map of the Europe. Also in a 'country view' output – a country rank is indicated for the each indicator.

To move forward and offer more informative visualisation of EUTS data we propose to rely on multivariate graphical technique *Co-plot*. By the means of two dimensional graphical display this method allows to observe similarities between the observations according to the composite of all variables; relationship between variables and relation between observations and variables [5]. It has been applied in various fields but also criticized (see [6]). An example of the application in the field of transport is the study on urban density and energy consumption [7].

To demonstrate the usability of *Co-plot* in cross-country evaluation we will first briefly formally present the *Co-plot* and then apply it in the field of EU railways using EUTS data.

3.1. *Co-plot* in brief

Co-plot produces graphical display of *n* observations and *k* variables (from X_{nxk} matrix). The display is formed from two superimposed graphs – one with points that represent observations and other containing arrows that symbolise variables. There are four steps in *Co-plot* application.

First, matrix X_{nxk} is transformed in matrix Z_{nxk} using eq.1:

$$Z_{ij} = (x_{ij} - \bar{x}_j)/S_j \quad (1)$$

where $\bar{x}_j$ are means and S_j are standard deviations.

In the second step simetric *nxn* matrix S_{il} is formed containing measures of disimilarity for the each different pairs of observations. The disimilarity is evaluted using city-block distance (sum of the absolute deviations, eq.2):

$$S_{il} = \sum_{j=1}^{k} \left| Z_{ij} - Z_{lj} \right| \geq 0, \; (1 \leq i, l \leq n) \quad (2)$$

Steps three and four are used to form two above mentioned superimposed graphs. In the stage three multi-dimensional scaling (Guttman's Smallest Space Analysis) is applied to map the matrix S_{il} (i.e. *n* observations) in the Euclidian space. In the fourth step variables are outlined as arrows in this space. Each arrow (variable) starts from the centre of gravity of *n* points and is placed so that correlation between the actual values of variables and their projections on the arrow is maximal. Arrows representing highly correlated variables point to the same direction.

Two measures of the goodness-of-fit are used: coefficient of alienation Θ for the observations and the correlation coefficients for the variables. They both are used to decide whether to eliminate some variable and/or observation.

3.2. Cross/country comparison of EU railways using *Co-plot* and EUTS

The initial data sample for cross-country comparison contained 25 EU countries and eight indicators. Because of the lack of the data three countries (Cyprus, Luxemburg and Malta) and one indicator (Completion of TEN-T High Speed Rail Core Network) had to be removed from the sample. Some missing data were obtained from additional sources (mostly RMMS reports). Following the procedure described in the previous section *Co-plot* is applied. Due to low value of the correlation coefficient one more indicator was excluded from the analysis (Pending infringements for Rail) and matrix X_{25x7} was resubmitted to the *Co-plot*. The coefficient of alienation was 0.147[5] and average correlation was 0.786, both indicating acceptable goodness-of-fit.

The graphical display is presented in Figure 1. First we can observe two clusters of countries one occupying the left part of the graph and the other positioned on the right side. The first group of the countries (UK, SE, IT, PT, BE, NL, FI, AT, CZ, DK, IE, DE, ES, FR) are in the part of the space where the most of the arrows point to. These countries can be considered as better performing. The other group (BG, HU, EL, SK, LV, LT, SL, EE, HR, RO, and PL) is in the part of the graph without the arrows, indicating that these countries can be considered as less successful.

Considering the variables (indicators) *Co-plot* results imply that there are two variables with extremely positive correlation (variable 1 and variable 2 associated with market share of all but principal freight and passenger rail undertakings). This means that opening of the market is to some extent taking place simultaneously in passenger and freight traffic. As seen from the *Co-plot* Sweden and United Kingdom are the most prominent examples. This is in line with RMMS report [9] from 2014 where these two countries are highlighted as the only that have fully opened their commercial services and services under public service obligation.

Using *Co-plot* we can also see that these two variables concerning market openness are conflicting with variable 8 on consumer satisfaction with rail transport. Customer satisfaction with rail transport is found to be poor across EU [10]. However, the conclusions about the relationship between variables cannot be drawn mechanically especially in the case

[5] *Values below 0.15 are considered good. For more information about θ see [8]*

of activities that require time to experience benefits.

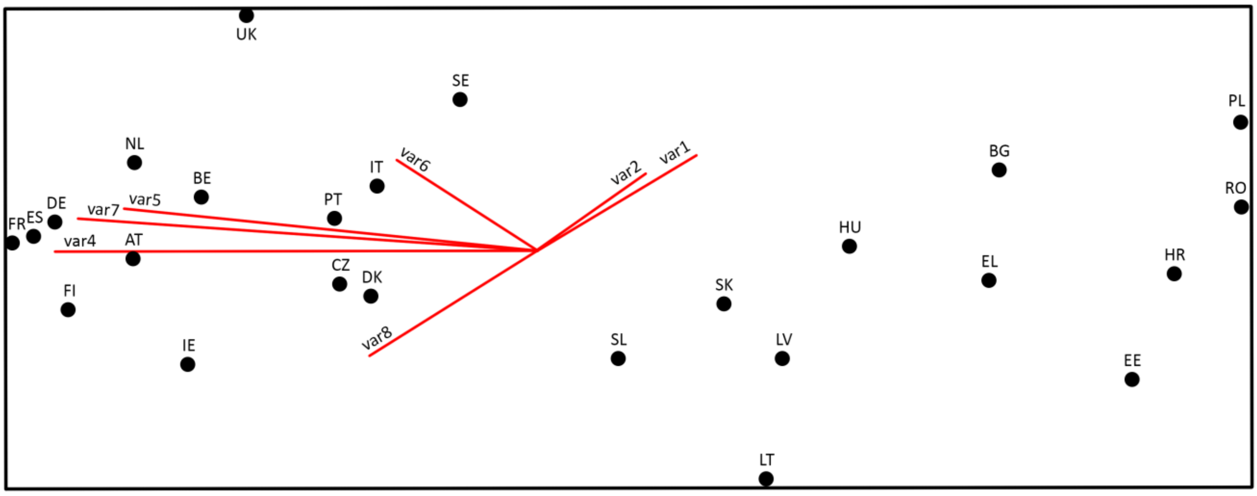

Fig.1. Co-plot output for EU railways

As highlighted in the DG MOVE report (published in April 2016) on the Market Opening and Railway Restructuring [10] there is much to be done until the liberalizations shows its effects through better customers' experience. The report also indicates that rail services are ranked 27th of 30 service industries mainly because infrastructure managers (even the new entrants) lack incentives to improve services and lower the costs [10, p. 5, 47].

Arrows located in the same direction and thus positively correlated are those associated with quality of rail infrastructure, completion of TEN-T conventional rail network, level of electrification and rail fatalities (variables 4, 5, 6 and 7). There are seven EU countries showing relatively good performance regarding these aspects (IT, PT, DK, NL, DE, ES, FR). Sweden and UK although successful in terms of the market liberalization are underperforming in the level of electrification and that is why they are positioned outside the cluster of above-mentioned seven countries. The advantage of the *Co-plot* is in the ability to observe this kind of relationships that are often camouflaged when aggregated measures are used (e.g. composite indices).

4. CONCLUSION

In this paper we discuss about EU Transport Scoreboard and how it can be exploited for comparative assessment in the field of railways. We propose to rely on the graphical multivariate technique called *Co-plot*. Results revealed two groups of countries similar in their performance. Also the results implied that conclusions must be drawn carefully due to the nature of the method and indicators themselves.

ACKNOWLEDGEMENT

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WHERE DOES COSTS COVERAGE AND TRACK ACCESS CHARGES STRUCTURE GO AFTER ADOPTION OF REGULATION 2015/909/EU?

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Abstract *– The previous EU Directives have recommend that the charges for the minimum access package and track access to service facilities shall be set at the cost that is directly incurred as a result of operating the train service. However, at the same time, no provision indicated the identification of costs that should or should not be considered by this term. In the access charges models are even more used average costs measured per train kilometers and gross tonne kilometers, allocated by category of railway lines and type of trains. Only with the adoption of Regulation 2015/909/EU, the term and coverage of direct infrastructure costs incurred as train operation is more precisely defined. Additionally, the true novelty is the introduction of a vehicles impact to wear and tear the infrastructure, which will cause further controversy. In this paper are presented and discussed key solutions of the Regulation, especially the complexity of the introduction of the direct costs based on the wagon-vehicle-lines relationship in the access charges modeling.*

Key words – Railway infrastructure, direkt costs, cost modeling, access charges.

1. BACKGROUND

In May 2013, the European Commission filed a lawsuit to the European Court against the Polish Railways (C-512/10) who, among other things, failed to fulfill the obligations required under Article 7(3) of Directive 2001/14/EC[1] concerning the principle of charging. The Polish railways, within the framework of the direct costs, also included depreciation costs, a part of indirect costs and some of the financial costs for the development and modernization of infrastructure. The Commission is of the opinion that the phrase in Article 7(3) of the Directive[2] "... based on the costs that are a directly incurred as a result of operating the train services" refers to marginal costs. Also, it considers that the marginal costs are the costs created by the actual run of trains, and fixed costs such as, for example, overhead costs related to the infrastructure operation and even in the absence of train movements, do not belong there.

The Commission statement that the term "cost that is directly incured as a result of operating the train services" refers that the marginal cost was unfounded by Polish railways. The Directive 2001/14/EC does not define precisely the term, but EU countries enjoy a certain degree of freedom in defining the costs constituent elements and cost modeling.

The Court noted that Directive 2001/14/EU does not indeed contain any definition of the term "cost that is a directly incurred as a result of operating the train service" and that no provision of the EU legislation identifies the costs covered by, or not covered by, this term. Thus, the interpretation of the term of direct costs, as well as defining the coverage of these costs, has significant practical difficulties.

Moreover, the European Court declared that the depreciation could not be considered as a direct cost because it is not determined on the basis of the real wear and tear of infrastructure due to the train service operation, but on the basis of accounting rules. The judgment states that indirect maintenance costs, rail

[1] Directive 2001/14/EC of 26 February 2001on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification.

[2]Directive is an act of secondary EU legislation which describes the objective, which is mandatory for Member States and the deadline for its achievement, but is the responsibility of the State to choose the form (model) and the means of achieving that goal. Directives come as a compromise between the need for uniform legislation within the EU and the need to maintain as much diversity of legal systems of the Member States. While Regulations equate EU legislation, Directives harmonize the EU legislation.

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traffic management costs and financial costs, according to economic theory and terminology, have no direct link with the operation of train services and can not be viewed as direct costs.

Even the next Directive 2012/34/EU has not clarified the term of direct costs incurred by the movement of trains. Therefore, the appearance of significant differences in the implementation is not surprising, and in particular in: (1) the interpretation of the term of direct costs, (2) the coverage of certain categories of these costs, and (3) the portion of marginal and direct costs in total costs.

According to all above mentioned, the Commission has proposed a new Regulation[3] (not a directive), adopted by the EU Parliament in June 2015, entitled the Regulation 2015/909/EU on the modalities for the calculation of the cost that is directly incurred as a result of operating the train service, which is the subject of this paper.

2. NEWS IN 2015/909/EU – ADDRESSED SOLUTIONS CONCERNING COSTS

2.1. Current interpretation of the term direct cost, access charges structure and modeling costs

There is no explicit definition of direct cost in EU legislation till Regulation 2015/909/EU addoption. In Nash (2009) we find: "It is clear from other documents that DGTREN equates direct cost with short run marginal cost, which is at least a clearer economic concept although "despite much research" there remains debate on how to measure it." Furthermore, research has been carried out in order to find how to measure short run marginal cost. Wheat, Smith, and Nash (2009) define marginal cost as follows: "Marginal cost is (Average cost) multiplied by (Usage elasticity)". This means that marginal cost is estimated based on average cost multiplied with the part that varies with usage. On the other hand, according to economic theory, direct costs are equal to marginal cost. Takinig in to account these two approaches, states have exceeded the problem of calculating the direct costs.

Since the beginning of the European railway market liberalization (1991) until today, the cost allocation in access charges models has been done primarily by category of infrastructure and its maintenance costs, on the one hand, and according to the type of train and infrastructure wear and tear due to it mass, on the other hand. So far, the cost of wear and tear, and maintenance, have been used in models as average costs per train kilometers and/or gross tonne kilometers.

For modeling costs were used econometric and/or engineering models of cost allocation, which are a result of simplified wagon-track relation in the process of wear and tear of the infrastructure.

2.2. Eligible and non-eligible direct costs

The Regulation 2015/909/EU is an expression of the EU's efforts to uniquely define methods (modalities) for the calculation of costs arising directly from the movement of trains. Under this regulation are given (1) the modalities for the calculation of the direct cost and the direct unit cost, (2) the constituent elements of direct costs, (3) non-eligible costs and (4) modeling costs.

Direct costs on a network-wide basis shall be calculated as the difference between, on the one hand, the costs for providing the services of the minimum access package and for the access to the infrastructure connecting service facilities and, on the other hand, the non-eligible costs referred to in Article 4.

The Infrastructure Manager (IM) may include in the calculation of its direct costs on a network-wide basis in particular the following costs: (1) the part of the costs of points infrastructure, including switches and crossings; (2) the part of the costs of renewing and maintaining the overhead wire, the electrified third rail or both, and the supporting overhead line equipment; (3) the costs of staff needed for preparing the allocation of train paths and the timetable; (4) costs of staff needed for keeping open a particular stretch of line scheduled outside the regular opening hours of this line (Article 3, paragraph 4).

The Regulation clearly declares non-eligible costs, ie. costs that do not belong to the direct costs for the whole network. These are: (1) fixed costs relating to the provision of a stretch of line which the IM must bear even in the absence of train movements; (2) costs that do not relate to payments made by the IM; (3) costs or cost centres that are not directly linked to the provision of the minimum access package; (4) costs of selling, decontamination, recultivation or renting of land or other fixed asset; (5) network-wide overhead costs, including overhead salaries and pensions; (6) financing costs; (7) costs related to technological progress or obsolescence; (8) costs of intangible assets; (9) costs of track-side sensors, track-side communi-cation equipment and signalling equipment if not directly incurred by operation of the train service; (10) costs of information, non-track side located communication or telecommunication equipment; (11) costs related to individual incidences of force majeure, accidents and service disruptions; (12) costs of electric supply equipment for traction current if not directly incurred by train operation; (13) costs related to the provision of information, unless incurred by train operation; (14)

[3] *The characteristic of Regulation is its direct application in Member States. This means that their use does not precede, nor is it necessary, some other type of legal or by-laws of the Member States. They are binding fully and erga omnes, starting from the authorities of the Member States, to natural and legal persons. Regulations equate national legislation of the EU countries.*

administrative costs incurred by schemes of differentiated charges; (15) depreciation which is not determined on the basis of real wear and tear of infrastructure due to the train service operation; (16) the part of the costs of maintenance and renewal of civil infrastructure that is not directly incurred by train service operation (Article 4).

However, in order to all of the above to be feasible, it is necessary to harmonize the costs data accounting with the given modalities for the calculation of the cost directly incurred by operation of the train service. So far, only a few countries have kept such a detailed cost data, and dispose with a quality data over a longer period. Therefore, the infrastructure managers are given a 4 years period for the gradual transition to the established modalities.

The main reasons for such a precise and clear definition of modalities for the calculation of direct costs are: effective management and cost control (understanding of the cost causation and origin), as well as an infrastructure productivity increase. The modalities for the calculation of direct costs should be regularly updated and tested in accordance with best international practice. The constant comparison with other's achievements enables the future unification of costs coverage and access charges structures, but also better network performances indicators. Unification is required in terms defined as productivity, the spread of new technologies (introduction of new technologies usually contributes improving the management and infrastructure quality) and monitoring costs by cause.

Although the Regulation states the direct costs should be calculated on the network-wide basis, it still gives space for different interpretations of these costs because it solely defines non-eligible costs, and not what should be included in the direct costs. This indicates that it is not the final solution, and there will still be dilemmas about its interpretation.

2.3. Calculation of the direct cost and direct unit costs

Calculation of the direct costs may be based on defined distribution, relationship - mathematical formula, resulting from the analysis of historical and current data on costs. Additionally, estimated values or replacement values, forecast costs and forecast performance levels could be used; and which can be duly justified in an objective manner.

Infrastructure Manager may use the average variable costs as a proxy for marginal costs, for the calculation of costs that are a result of direct train movement. There is even a trend of going in the direction of marginal cost generalization.The effect of such calculation are the access charges for the minimum access package and for the access to the infrastructure connecting service facilities based on the marginal cost principle which ensure the optimum effictive use of available infrastructure capacity.

When it comes to calculation of the average direct unit costs for the entire network, the Regulation allows the IM to determine the average direct unit cost by dividing the direct costs on a network-wide basis by the total number of vehicle kilometres, train kilometres or gross tonne kilometres forecasted for or actually operated. Only one of three measures, or any combination of these, can be used for the calculation.

The Regulation states that Member States may allow the infrastructure manager to modulate the average direct unit costs to take into account the different levels of wear and tear depending on several parameters, such as: train speed, type of traction, axles, different parameters stripes, etc. Therefore, the costs of infrastructure wear and tear are thoroughly monitored and counted according to the causation; hence, in addition to the characteristics of the trains and infrastructure, the characteristic of vehicles or railway lines with certain design features are taken into account.

2.4. Cost modeling

Regulation allows the IM to calculate the direct costs by applying econometric[4] or engineering[5] cost modeling. Any way of cost modeling applied must be supported by reliable evidence for approach and the taken level of costs coverage. However, it is stressed that the EU continues, due to the different stage of infrastructure in the states, will continue to follow international practice in analysis and research of infrastructure costs and their calculation, suggesting that they still can expect some changes and that the matter is at the beginning.

Costs modelling can include characteristics of trains, infrastructure and vehicles, so that we can now expect a combination of measuring units (train kilometers, gross tonne kilometers and vehicle kilometers). Such direct unit cost calculation reflects a causal consequential relationship between costs and train service.

Also, if there are differences in the cost per network segments, cost modeling may be done by these segments and, thus, these included in the overall cost model.

As in the case of calculation of the direct costs, the Regulation leaves room for the application of more ways of modeling. We should continue to check, or even further develop, cost models published so far; so that on the one hand, they comply with the specificities and characteristics of infrastructure and costs monitoring in a given country, and on the other hand, reflect the services based on the direct costs of train movement.

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[4] *Econometric cost modeling is modeling based on quantitative analysis of the costs, using data obtained by economic statistics.*

[5] *The engineering cost modeling is modeling based on a qualitative analysis of the costs by using data obtained by analytical approach - based on the knowledge of experts in terms of allocation and cost estimates.*

3. SUMERY AND OUTLOOK

Integrated railway companies, the exclusive model of organization until 1991 and the emergence of Directive 91/440/EEC, have not kept in their costs accounting by services, as required by the market and the market model of the railway sector organization. However, after more than two decades long experience of applying the models of railway vertical separation, a way of keeping costs slowly evolved in terms of their accounting treatment required by market relations (RGL, 2009). There are various and numerous reasons for this, but this process will certainly speed up with the adoption of Regulation 2015/909/EU.

The adoption of this Regulation reduces the freedom in defining direct, marginal costs. It most certanly will contribute to shorten the difference in the coverage of costs for benefits in EU countries, and their networks, and enable comparison of costs of different IM. Since the adoption of the Regulation has only been a year, so we can not discuss experiences in the implementation. Therefore, here is provided the brief example of Swess which has gone furthest in the structuring of direct costs and the maintenance of accounting records.

According to published Network statement 2016/2017, Swess applies the new access charges system. Now the access charges for basic service package makes basic price, contribution margin and electricity price. Cost modelling and its allocation is carried out according to the causes and follows the requirements of various market segments, the operator of the vehicle and the network. Unit costs are, in addition to train and gross-tonne-kilometers, and in the relationship with vehicle kilometers. The combined (bottom up) econometric/engineering method is used for cost modeling. This allows a much more realistic cost allocation by cost causation. Therefore, the new access charges structure is much more complex than the existing one in EU countries.

Until today, most of the IM has not been able to monitor costs at the level of detail that is possible. Therefore, one may quite reasonably ask why the new Regulation suggests detailed structure and coverage of costs when it comes to infrastructure wear and tear, without pre-set categories of management costs[6] being trully implemented? Does the introduction of parameters, related to the vehicle impact on the infrastucture wear and tear in the cost modeling, actually put national railway industry in favor and indirectly imposed the introduction of modern vehicles? At the same time, does that put a pressure on small operators, who are the competition to the national, to further invest in more modern vehicle fleet? On the other hand, when we do the cost modeling, if vehicle parameters, such as given in Regulation, are taken in consideration, in addition to the network parameters and trains, the model accurately describes the costs by causation and origin. A gross tonne kilometers based access charges, do not transfer cost savings signal on the infrastructure side to the business case of the operator or vehicle user. Accordingly, cost modeling should be based on the vehicle-railway relationship. Such approach encourages the infrastructure costs management and development of railway vehicles which are better adapted to the characteristics of the line (track-friendly vehicles).

The facts show that the European IM are still looking for the modalities of how to cover the direct costs, as well as the structure and amount of access charges reflect the costs of services providing. The key reason for this situation is the lack of quality data on costs, or in carrying costs and clear signals to be sent to operators through access charges structures. Harmonized access charges modeling under the syncronized direct, and marginal costs, while keeping the specificity of local networks, requires a detailed knowledge and definition of costs by the IM; which starts with this Directive. Apart from that, when prices are consistent and clear, operators react swiftly and intelligently to pricing signals, as long as they are consistent; and objective of the European charging legislation of the optimum effective use of the available infrastructure is reachable.

At the end, of all discussion, in fact, comes down to the question whether now is the right moment for the levy of such a structure of acces charges and costs. This is perfectly legal question to which the answer will be able to give only the actors in the transport and railway market in the time ahead of us.

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KEY PERFORMANCE INDICATORS FOR FUTURE SUSTAINABLE BUSINESS DEVELOPMENT OF INFRASTRUCTURE MANAGERS

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Abstract *– Since traditional, pre-reform, railway companies were neither ready nor capable of adapting to conditions of liberalized market, many of them fell into a situation that change of ways would be imminent. With dividing once integrated companies on now more focused business divisions, company goals have altered. The former ''engineer's'' way of operations is abandoned and substituted with a more ''commercial'' one. What, next to change of business approach, also changed is the relationship between the state and railways. The state is no longer willing to invest substantial financial means without knowing where and how these are spent, and also what the state is gaining in return. Up until now, in order to fulfil own business goals and interests, infrastructure managers were assessing results of their operations based only on qualitative and quantitative operating indicators. Nowadays, business is assessed based on performance indicators which have the purpose of helping company's commercially based operations. Also, they have a very important function of tracking the effects of financial means invested by the state – value for money. Systematization of newly formed and hereditory performance indicators of only one of now divided and operationaly independent company, namely the infrastructure manager, poses a considerable challenge. In this paper, it is illustrated from two aspects. One aspect illustrates the relation with the state, which is the owner of infrastructure and the principal financier – performance indicators that follow infrastructure utilization and endorse future investment and subsidies. The other illustrates success of operations by assessing effectiveness, efficiency and productivity of the company. Thus, performance indicators are being tracked for the sake of transparent relationship with the state and for assessing improving own market position.*

Keywords – performance indicators, systematization, infrastructure manager

1. INTRODUCTION

Significant traffic and revenue decline in the early 90's induced most of the European major railways to embark upon a process of restructuring. As a result, the infrastructure manager (IM), freight and passenger operators are now operating as separate and independent companies. Through the process of restructuring, EU wishes to cut substantial financial losses railways are causing, without even knowing where exactly do these losses come from.

Newly formed and functionally and operationally separate companies are let free to do business in market conditions. They now have their own, new, goals which are focused on achieving better financial results and also on competitiveness. Along with the change of predefined goals, the way of doing business also changed, which in other words means that a so called commercial approach is introduced instead of an outdated engineer's approach which was more focused on formal fulfillment of a "predefined timetable". Good planning and capacity utilization are now at the centre of attention in order to achieve as big revenue as possible, thus justifying the financial means obtained from the state, which is still the main source of funding.

Hence, generating revenue does not necessarily mean generating profit. Of the newly formed companies, only freight operators are capable to generate profit while passenger operators and infrastructure managers still generate losses. These losses are still covered by subsidies, but with a big difference of knowing where exactly are losses being generated, through annual business and operation reports. Having in mind that IM manages and maintains the infrastructural capacities owned by the state, his businesses and performance indicators, which are the subject of this paper, are of special interest for the state. It is clear that IM can never

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be a profitable company, but it is at least possible to decrease his subsidy, which is foremost secured through a contract between the state and the IM, but also through changing the way of business, which is now based more on efficiency, effectiveness and productivity.

As a measure of contract abiding, and also of business achievements, IM measures various performance indicators. As oppose to the period before the restructuring, key ones today are those which are more correlated to the achievement of satisfactory financial results, and only after them come those indicators which are more correlated with technical, and especially technological quality of operations.

On the one hand, based on key performance indicators (KPI), the IM assesses his own business performance and adjusts his market position. On the other hand, through key performance indicators, he shows, in a transparent way, his business performance to the state, and also measures the fulfilment of his contract obligation.

2. NEW GOALS AND CONTRACT OBLIGATIONS

In times before the restructuring, when in most of countries only incumbent railways were operating, the way of doing business was significantly different. There wasn't too much attention on performing well financially, and vast majority of substantial losses were covered by the state through subsidies, practically with no questions asked. According to that situation, goals of incumbent railway were oriented almost exclusively on performing well in technical, and especially in technological sense. For the purpose of performance assessment, only qualitative and quantitative indicators were measured, and they were more focused on operations.

After the restructuring and vertical separation, the way of business of separated companies has changed and is now based more on commercial principles and to achieve good financial results as primary goal. This primary goal, IM fulfils through market oriented service and by cutting the subsidies. His grim reality is generating losses, but a way to decrease subsidies is to generate as big as possible revenue with the smallest possible expenses. Thus, one might say that the goals of IM are: best possible infrastructure capacity utilization; to sell as many as possible paths; efficient track maintenance; and planned investment in existing and new infrastructure.

What has also changed after the restructuring, and besides to the way of doing business, is state's attitude towards railway companies, and especially towards the IM. The state is no longer willing to exert substantial funds without knowing where these investments are going and what the gains are. The state also requires more efficient and transparent spending of funds, and as a proof of such behaviour, the IM has an obligation of submitting annual, quarterly or monthly business and operations reports. Finally, in order to assure the fulfilment of requirements, the state introduced the contractual obligation, which determines how and under what terms the IM obtains state funding, the amount of funding, and also the KPI which are being measured as a way of ensuring that the contract is fulfilled. KPI depict performance of IM and effect of subsidies on quality of infrastructure maintenance and also of IM's service.

3. KEY PERFORMANCE INDICATORS (KPI)

Under the new circumstances (opened railway market, change of way of business, contractual obligations), rating and measuring operational performance with qualitative and quantitative indicators cannot be satisfactory. A new approach was necessary, foremost because the goals have changed. Reaching these goals implies producing adequate outputs, so a new expression is now being used: *performance indicators*, which are much more focused on company's outputs. IM's outputs are many, but those which are marked as most noteworthy are: number of sold paths, length of sold paths, revenues, number of trains and train kilometres. Each of these outputs can be marked as a performance indicator by itself.

As with outputs, the number of performance indicators that could be monitored is numerious , but the key ones are those which are correlated with accomplishing good financial results. This does not mean that non financialy correlated performance indicators cannot be marked as key ones. A good example confirming this statement is that some of the former qualitative and quantitative indicators are marked as KPI.

Nowadays, performance indicators are being monitored for two reasons. First one is related to company's own objectives, and the second one is related to objectives of stakeholders. For own needs, KPI are being monitored for purposes of evaluating and upgrading own business performance. For the needs of stakeholders, namely the state and regulatory bodies, performance indicators are being monitored and separated for transparency reasons, evaluation and fulfillment of contractual obligation and out of statistical reasons. Therefore, it is common that many KPI are essential parts of annual business reports.

4. SYSTEMATIZATION OF KPI FOR IM

Systematization means recognition and separation of KPI and either their clustering or dissipating accirding to selected criteria, and finally presenting them alltogether. Due to a great number of performance indicators themselves and the fact that many of them can be marked as key ones and also measured from many different aspects, systematization is quite a challenging task. There is no absolute recommendation to determine which indicators shall be marked as key ones or even their numbers [1], [2].

The basic criterion to determine performance indicators which are in this paper marked as key ones, and therefore went through process of systematization, is that they represent indicators of company's financial performance or at least those indicators which company's financial performance is dependant from. Thus many of the indicators which were monitored prior to restructuring, primarily quantitative operations (performance) indicators which were formerly marked as key ones, are found on the list. This is mostly because indicators of financial performance very much depend on asset utilization depicted by indicators such as e.g. train kilometers and number of trains.

As a criterion for clustering, or better said dissipation, it has been constituted that an indicator should represent either effectiveness[1], efficiency[2] or productivity[3] of operations [3]. Effectiveness, efficiency and productivity are measures that are not primarily monitored in monopoly market or by companies more oriented towards quality of technical or technological operations. However, with changing the way of doing business and with greater focus on good financial performance, such expressions usually common in economy, are now being widely used. In this manner, it is much clearer to see how well the company is performing because performance indicators defined in this way touch the the deep core of the problem and show whether the company is acting in right direction and using its resources properly.

Fig. 1 shows KPI for tracking how well the IM is performing by showing effectiveness, efficiency and productivity both from technical and financial aspects.

It is clear that technical and financial indicators are being equally monitored. According to the number of KPI for productivity, it would seem that it is of lesser importance for the IM, because of their relatively small number. Apperantly, the IM is more interested to, financially efficient, reach satisfactory outputs in technical sense whoose creation demands very small number of inputs.

From the perspective of preset goals, technical effectiveness indicators held in greatest regard are number and length of sold paths, because they are IM's source of income. Other indicators of technical effectiveness are more important for maintainance planning (number of trains, passenger km, gross-tonne km). Productivity indicators have for the IM the exact same meaning as for any other market-oriented company which is adequate asset utilization which minimizes the expenses.

The largest number of finacial performance indicators is related to efficiency, because the IM must efficiently dispose his resources in order to decrease the subsidies. The most important of these indicators is percentage of income from subsidies, but the rest of the indicators are also significant. Indicators of financial productivity are related only to revenue from IM's assets usage, thus confirming the statement that it is essential for the IM to generate revenue by using his resources in appropriate manner in order to deminish the expenses.

As for the KPI being monitored for the reason of transparency towards the state, which is the owner of infrastructure and also the principle financier, those indicators indicate the effects to safety, infrastructure quality, utilization and productivity of state funding (Fig. 2) [1], [2], [5]. In other words, they are the measure of *value for money*. Based on them, what is also being monitored, is the fulfillment of contractual obligation essential to approve future subsidies and investments. They usually belong to a group of newly formed, post restructuring, indicators, especially by the IM.

Each of these indicators has a different meaning for the state. The relative importance of these KPIs is set according to principle idea of introducing contractual obligation between the IM and the state. One of these ideas is that the state's financial aid will enable the IM to operate without losses and to maintain the infrastructure.

5. SUMMERY AND OUTLOOK

Railway companies today operate in market conditions and accordingly they need to introduce new KPI instead of old ones which were being monitored in times of monopoly and closed-up market. The main difference of railway companies, especially the IM, from companies operating in other markets is significant state ownership. Because of that, and also because of the subsidies, there is a strong need to innovate KPI for purposes of monitoring operation and its effects, and also for the reports which are required to be published.

In network systems such as railway infrastructure, a great number of KPI appears. Thus it is crucial to carry out their systematization, which is suggested by

[1] *Effectiveness means whether a company produces desired set of outputs accorting to its objectives.*

[2] *Efficiency measures how well a company uses its own resources by determining the amount of inputs needed to produce certain amount of outputs.*

[3] *Productivity is a rather specific measure of efficeincy, because in a certain way it also tells how well are resources being used. It is a ratio of already produced outputs to already invested inputs.*

	(green)		(brown)
Train-km per employee	▲	Revenue per employee	▲
Train-km per network km	▲	Revenue per sold train-path km	▲
No. of trains per network km	▲	Revenue per network km	▲
Average train/load weight	●	Ratio of revenue to expenses	●
Gross-tonne-km per network km	●	Ratio of revenue to subsidies	●
Passenger-km per network km	●	Expenses per employee	●
Pct. of passenger and freight trains	●	Maintenance cost per track-km	●
Average length of carriage	■	Cost per sold train-path km	●
Punctuality (pct. of late trains)	■	Ratio of operating revenues and expenses	●
Length of sold paths	■	Operating revenue	●
No. of trains	■	Operating expenses	●
Gross-tonne-km	■	Total revenue	■
Passenger km	■	Total expenses	■
Train km	■	Track access charges	■
No. of sold paths	■		

Legend
■ / ■ *Technical (technological) / Financial effectiveness*
▲ / ▲ *Technical (technological) / Financial productivity*
● / ● *Technical (technological) / Financial efficiency*

Fig.1. Performance indicators for IM business monitoring

No. of collisions	▲
No. of derailments	▲
No. of accidents on railway crossings	▲
No. of speed restriction	●
Average length of speed restrictions	●
No. of failures of signaling-systems	●
Train km according to track category	■
No. of sold paths	■
Average length of carriage per train	■
Train km/no. of employees	⬢
Revenue of access charges/operational expenses	⬢
Operational expenses/train km	⬢

Legend
■ *Utilization*
▲ *Safety*
● *Quality of infrastructure*
⬢ *Productivity*

Fig.2. Performance indicators for contracting obligation between IM and State

this paper. Further, arise problems related to availability and reliability of data, as well as record keeping and estimation of indicators. Sometimes the indicators are hardly measurable and comparable. Also, the same KPI do not have the same meaning for different actors (IMs), especially if they are not the same size.

It should be observed that through the process of systematization, many of the indicators from earlier period are still being monitored, which proves that it is still crucial for the IM to achieve a considerable quantity of outputs and proper asset utilization. Considering that railway is still a huge system with a great tempo of investments, such approach is quite reasonable and expected.

However, compared to the period before the restructuring, the main difference is that the goal of achieving good technical results is not purely asset engagement, but relies more on achieving good financial results with quality asset utilization – good assets management.

Another, very important, aspect for innovating the KPI comes out of the fact that the state approves funds based on the contract, and thus needs to have the insight how is the taxpayers money being spent.

Practice shows that there is a big difference in number of indicators appearing in annual reports. It can be noted, that with the passing of time, number of indicators grows, which indicates that both parties (the state and the IM) need time to adapt to new circumstances. The level of market development also effects the number of KPI being monitored. For example, Swiss railways are extracting a far greater number of indicators than Hungarian railways because the level of market development is more advanced.

Also, new circumstances (market conditions and market operating), all effect on increase of importance and numbers of financial indicators.

At last, it should be mentioned that for infrastructure managers at the EU level, managing and tracking of KPI are still in early phases.

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COTIF INTERNATIONAL RAILWAY LAW TO CONNECT DIFFERENT NETWORKS

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Abstract – *More than a century ago several European countries established agreements between their governments that would facilitate international cross-border traffic for goods and then for passengers. In addition, in order to facilitate cross-border operations from the technical point of view, European countries also established harmonised conditions for the usage of vehicles in different railway systems.*

Since then, the development of railway technology and railway networks has followed the political context in which they found themselves, resulting in the fact that there has been little technical harmonisation between the national networks.

Even today, this technical fragmentation still significantly affects the railway´s competitiveness in Europe. Nevertheless, OTIF, inspired by the European Union's vision of a fully interoperable railway system, is now looking forward and is seeking modern solutions in the original spirit of the Bernese Convention.

The future of efficient international railway traffic relies on finding the optimum level of technical and legal harmonisation. This paper, from the OTIF Secretariat summarises the current scope of COTIF and explores a possible next step towards achieving not only legal, but also operational and technical interoperability between its Member States by creating a network of connected railway systems. In this network, not only passengers, goods, and vehicles, but also complete trains are exchanged and operated across borders between the national systems under a single legal regime.

Keywords – COTIF, legal regimes, CIM, international cross-border traffic, interoperability.

1. INTRODUCTION

The international cooperation in railways started in the second half of the 19th century, when bilateral or multilateral agreements among railway administrations or treaties between governments were concluded. With the adoption of the 1435mm gauge of many European countries, through a creation of rules governing the carriage of goods and passengers by rail (CIM[1] and CIV[2] conventions) the international cross-border traffic was made possible.

Beside CIM and CIV conventions (which later become appendices A and B to COTIF), COTIF also covers regulations for the transport of dangerous goods, contractual conditions of use of vehicles and infrastructure, and requirements for the international admission and use of vehicles. In other words, COTIF [1], fully provides for the exchange of freight or passenger vehicles across borders.

COTIF does however not cover all legal requirements needed for the operation of complete trains across borders. This particular type of international railway traffic, where a railway undertaking runs its train on a foreign State's rail infrastructure, is further referred to as 'interoperability'. Interoperability is one of the principles on which the EU bases its common railway policy, with view of making the railways more efficient and customer focussed. Also for states outside the EU interoperability could be a concept that may help to increase the added value of their rail system.

[1] *"Règles uniformes concernant le Contrat de transport International ferroviaire des Marchandises" (CIM)*
[2] *"Règles uniformes concernant le Contrat de transport International ferroviaire des Voyageurs" (CIV)*

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2. THE MODEL OF INTEROPERABILITY AT EU LEVEL

At present, the EU is a prime example of a regional area that has defined legal provisions to transform a patchwork of largely incompatible railway systems into a consistent and modern model. The model is consistent because it enables the railway system to become genuinely interoperable, and it is also modern as it promotes innovation. On the one hand, technical developments are encouraged as the regulations rely mainly on functional requirements and go into prescriptive detail only when necessary for technical compatibility or safety. On the other hand, safety management through common safety methods allows members of the sector to define transparent and non-discriminatory voluntary harmonisation. These underpinning principles make the EU provisions interesting for consideration in a wider geographical context.

3. ASSUMPTIONS FOR DEFINING A TARGET SYSTEM

In order to extend the scope of common technical regulations outside the EU for mutually agreed international traffic, it will be necessary to adapt and simplify the EU's fully developed regulations.

First of all, EU rail legislation covers the entire rail system, including main lines as well as branch lines. In the framework of developing interoperability within COTIF, provisions will only cover international traffic. This may allow for more harmonised access rules.

Furthermore, from a practical point of view many non-EU OTIF Member States are in the process of developing their railway systems and thus have a better chance of harmonised development.

Finally, the concept of interoperability in the EU is linked to the opening of the markets within a competitive model. However, within their own borders, or in regional areas such as the GCC project in the Gulf[3], States can also organise their railway system around an organisational model that aims at cooperation and reciprocity rather than competition. COTIF is and should remain compatible with any organisational model of railways.

The desire to make railways more efficient and business-oriented is not exclusive to Member States of the EU. In order to use railways to their full potential for international traffic, it would be advisable to allow international train access to be coordinated and agreed upon with neighbouring States without imposing a common market model for train operation.

[3] *Gulf Cooperation Council, political and economic alliance of six Middle Eastern countries—Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain, and Oman.*

4. THE NEED FOR A MULTILATERAL LEGAL BASIS

Some countries or groups of countries already use the interoperability concept as defined in the EU, and in particular the Technical Specification of Interoperability (TSI) as a basis for the development of new networks. This is to a certain extent the case in China, with the local version of European Rail Traffic Management System (ERTMS), and this is also the intention of the GCC for the future Gulf network.

In the view of the OTIF Secretariat, the best way forward is to use a multilateral instrument, since:

- The interoperability provisions in the EU take far reaching legal integration, such as a single European market between EU Member States, as a basis. Even if a neighbouring State of the EU wished to have international rail traffic with the EU, it would not only have to make its own legal provisions compatible with the EU railway regulations, it would also need a bilateral agreement with the EU for it to interact correctly (examples are Switzerland and Norway);
- Every State outside the EU that wished to establish rail interoperability with its neighbouring States would have to conclude bilateral or multilateral agreements. In order to avoid multiple and potentially incompatible agreements, international harmonisation of rules in the scope of COTIF seems more efficient.
- The regulations will be managed at intergovernmental level in order to ensure that all Member States and their respective stakeholders can participate in defining the regulations.

5. FOUR LEVELS MODEL OF INTERNATIONAL RAILWAY HARMONISATION

The railway systems that rely on COTIF for their international relations could be seen as a network of connected but separate systems model, where passengers, goods, vehicles, and/or trains are exchanged between the national systems. The network could be modelled on the basis of virtual levels, where harmonising to a higher level will allow smoother and more harmonised international traffic, but also require more complex and harmonised regulations.

From a conceptual point of view, four layers or levels can be distinguished in the process of achieving international railway harmonisation of rules, starting from the international contractual regulation of the transport of goods and passengers (level 1) to a unified railway market (level 4), as illustrated in Figure 1.

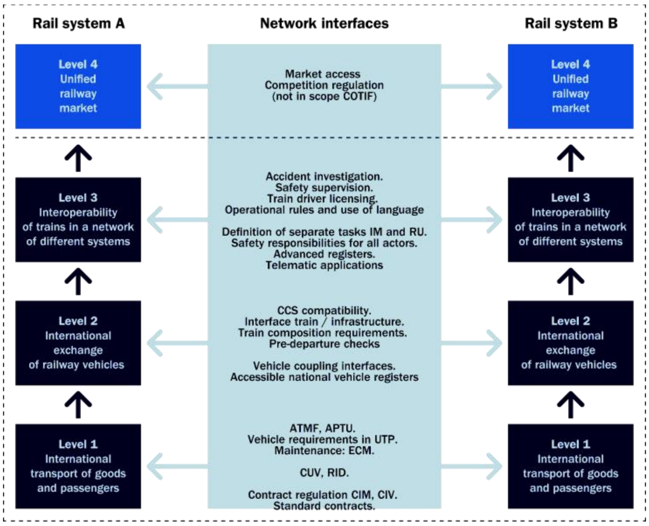

Fig.1. The four levels model of international railway harmonisation

It is important to note that for each level, several types of legislation are required, such as contractual liability, technical regulations, safety responsibilities and operational provisions.

5.1. Level 1: railways and their customers

At the first level of this network model is COTIF contract law as set out in CIM and CIV, facilitating the transport of goods and passengers across borders by means of harmonised contractual provisions. These are business-driven provisions, in order to establish enough legal certainty for consignors and passengers to use the railways as a mode of international transport. These provisions have been developed under COTIF since the first Convention at the end of the 19th century. These provisions do not regulate the railway system itself but provide an interface between the railways and its customers. They are considered private or contractual law, defining the relations between the contracting parties. These provisions are also used for international traffic within the EU.

RID is applied across the different levels of this model as it applies whenever dangerous goods are concerned.

5.2. Level 2: exchanging vehicles across borders and between railway companies

A second level of this model sets out requirements to be applied in the railway system itself by facilitating the use of freight wagons or passenger coaches in international traffic. In order for vehicles to be used in different railway systems, harmonised technical provisions need to be applied for the interfaces between the vehicle and the infrastructure and also between the vehicles themselves. These provisions were previously set out by the Technical Unity[4], and the RIC and RIV agreements. RIC and RIV were agreed, updated and applied by railway companies, whereas COTIF provisions are agreed between States. Technical Unity, RIV and the technical parts of RIC are no longer in use.

Today, superseding provisions have been set out in the UTPs and the approval processes are set out in ATMF [2]. In addition ATMF makes reference to the EU provisions in its Article 3a, which sets out the conditions under which vehicles authorised in the EU can be used in non-EU OTIF Contracting States and vice versa. By means of transposing all vehicle related TSIs into UTPs under COTIF, all vehicle rules (also those necessary for interoperability and safe design) are fully covered in level 2.

Railway undertakings that operate foreign vehicles in their trains should be in a position to trust that the vehicle is well maintained. For this purpose, the entity in charge of maintenance (ECM) has been defined, which must ensure that each vehicle is in a good state of maintenance. All these provisions are considered public law, describing obligations for any person or entity.

In order to establish sufficient legal certainty for vehicle keepers to have them used abroad, the CUV [3] sets out provisions that regulate the contractual liability between the keeper and the railway undertakings using the vehicles. The CUV is considered private or contractual law, defining the relations between the contracting parties. The CUV provisions are also used for contracts between keepers and carriers within the EU. To implement the provisions of CUV, but also elements from public law, such as the ECM regulation [4], the railway sector has developed standard multilateral contracts in the form of the General Contract of Use for wagons (GCU) which set out the detailed contractual provisions between the signatories.

5.3. Level 3: interoperability; running complete trains across state borders

A third level of the network model is referred to as interoperability. Interoperability means that a train coming from one country will operate on the network of the neighbouring country. This means that a complete train will cross the state border to continue

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[4] Technical Unity was an intergovernmental agreement that came into force on 1 April 1887. These rules were prepared at two international conferences on the Technical Unity of Railways in October 1882 and July 1886. The participating countries explored and found solutions to facilitate cross-border operations from the technical point of view. Technical Unity was applied from the beginning in Austro-Hungary, France, Germany, Italy and Switzerland and later, other countries also joined: Belgium, Bulgaria, Denmark, Greece, Luxembourg, Turkey and Yugoslavia. Article 10 of APTU regulates the abrogation of Technical Unity by the entry into force of the UTP.

its operation on the infrastructure of the neighbouring state. Such type of operation requires the infrastructure manager of the host state to be able to cooperate with more than one railway undertaking. It is therefore necessary that the mutual responsibilities between railway undertakings and infrastructure managers are clear and that they have the procedures and communication tools in place to take on these responsibilities.

5.4. Level 4: market regulation – not in the scope of COTIF

In addition to the levels 1,2 and 3 States may agree on market regulations, which e.g. set out access rules and rules for competition. This market harmonisation is referred to as level 4.

The EU, for example, adopted a single system vision, by harmonising the tasks and responsibilities of all railway actors active in the EU. The provisions applied in the EU in the framework of the Interoperability, Safety and Access Directives (in addition to the provisions of COTIF for contract law and the dangerous goods regulation) describe a unified railway market. These provisions allow, conditionally, new railway undertakings to be established, to get access to the national networks, to run national and international trains and to compete with other railway undertakings.

The EU provisions take far-reaching legal integration as a basis and as such are not suitable for use outside the EU. Even if a neighbouring state of the EU wished to adopt (part of) the EU railway regulations, it would still need a bilateral agreement with the EU for it to interact correctly with EU law.

COTIF is a convention between sovereign states and not an instrument for economic integration. For these reasons it is not feasible to consider developments in COTIF leading to the systematic integration of national railway systems or to the introduction of a unified railway market. Therefore, the further development of COTIF should focus on level 3 of the described model. It should however be ensured that any provision under COTIF does not conflict with EU law as all EU Member States with a rail network are also Members of OTIF.

6. CONCLUSION

COTIF does not comprehensively cover interoperability; however, it does provide elements relating to interoperability, such as technical provisions for locomotives and passenger rolling stock and, with the new Article 15a ATMF, some elementary provisions for train composition and operation. Also the CUI [5], which sets out the contractual relations between railway undertakings and infrastructure managers, is applied in an interoperable model.

Possible future COTIF requirements should e.g. cover the operational interfaces between railway undertakings and infrastructure managers as they are, in addition to technical compatibility, at the core of interoperability. Specifications could be developed at a conceptual level first, focussing on the principal safety responsibilities of the actors and between the actors, by setting them out in a new Appendix to COTIF. As a second step, more detailed provisions could be set out in "secondary" legislation developed under the new Appendix, in a way similar to how UTPs[5] are developed under APTU [6].

Not all Member States of OTIF may be interested in or ready for interoperability, which implies having foreign trains operated on their territory. A new Appendix to COTIF would allow each Member State to choose whether or not to apply the new Appendix.

At the same time, States that choose to apply the provisions on interoperability are presumed to actually want to promote and facilitate the international operation of trains on their territory; said States should therefore put in place (national) provisions that promote the operation of international trains on their networks, including access to all facilities and services required for such operation.Promoting the interoperability concept, so that the States will apply it, will require also a common vision that is shared by EU/OTIF, but equally by the European Union Agency for Railways and UIC (non-governmental union of railway companies). It will thus be crucial to develop a common understanding between the said organisations to allow efficient access to the sector and to States outside the EU.

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[3] **CUV** – Appendix D to COTIF 1999, in the revised version that entered into force on 1 July 2015. (Appendix D to COTIF 1999)

[4] **ATMF Annex A,** Certification and Auditing of Entities in charge of Maintenance (ECM), in the version that entered into force on 1 December 2015 (ATMF-Annex A)

[5] **CUI** – Appendix E to COTIF 1999, in the revised version that entered into force on 1 July 2015. (Appendix E to COTIF 1999)

APTU – Appendix F to COTIF 1999, in the revised version that entered into force on 1 July 2015. (Appendix F to COTIF 1999)

[5] Uniform Technical Prescription

TRAIN PATH ALLOCATION ON CONGESTED RAILWAY INFRASTRUCTURE – IS A SERVICE PRIORITY CRITERIA LIMITING DEVELOPMENT OF COMPETITION?

Nikola STOJADINOVIĆ [1]
Branislav BOŠKOVIĆ [2]

***Abstract** – Despite the new entrants on the railway market in many European countries, the capacity allocation mechanism still relies on the same service priority criteria as before adopting 91/440/EEC directive. Implementation of these criteria on a competitive market generates problems in cases when railway operators request the same infrastructure capacity at the same time, and the infrastructure manager is often not able to meet all requests. This article tries to answer on question: which criterion has been used for train-path allocation on the section of infrastructure where the infrastructure manager declared congestion, and differences between European countries. Moreover, do those service priority criteria preserve status quo on the market protecting railway incumbents from competition and therefore limiting development of competition? The paper discuss about criteria and their effects to competition development in railway market.*

Keywords – Train-path allocation, Priority criteria, Infrastructure congestion, Railway market.

1. INTRODUCTION

Despite many changes in railway sector in the last two decades in EU, there is no clear evidence of improvements in efficiency and competitiveness. In railway market, there is a sharp distinction between new entrants and incumbent[1] railway operators, because they still have unequal treatment. Moreover, railway sector is still maintaining privileged position for incumbents by using different procedures and mechanisms. The outcome is dominant share and position of railway incumbents in national railway markets across the EU. Many mechanisms provide a favorable position for incumbents. They can be recognized as inherited (unchanged) procedures or mechanisms that are not yet adapted to the liberalized market conditions. Therefore, unchanged procedures from a period of monopoly might produce an unequal treatment for operators and discourage further market development.

[1] *Incumbent railway operator is a legal successor of a vertically integrated railway company. Those companies were founded after vertical separation of a state railway company – the monopolist. The majority of these operators are mostly in public ownership.*

One of the inherited mechanisms in railway sector is a mechanism for infrastructure capacity allocation. It has significant importance for capacity allocation of congested parts of infrastructure. This paper considers current mechanisms for high demand regulation on congested parts of a railway network, applied in EU member-states. In addition, this paper estimates their effect on railway market development.

2. THE INFRASTRUCTURE CONGESTION PROBLEM AND ITS IMPORTANCE

The congestion of railway infrastructure can be defined as higher demand for train path from the available capacity. Higher demand on an infrastructure section usually appears in certain periods of day. Congestion is usually appearing through conflict demand for train paths, where fulfilling one request usually causes exclusion or displacement of other train path request. Therefore, the infrastructure manager has to decide to which train will assign a priority. The question is which decision-criteria infrastructure manager will use for capacity allocation of the congested infrastructure. Figure 1 shows inputs and outputs of the capacity allocation procedure. The first possible outcome of the procedure is drafting conflict-

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free timetable. In other case, the infrastructure manager declares congestion on a network section.

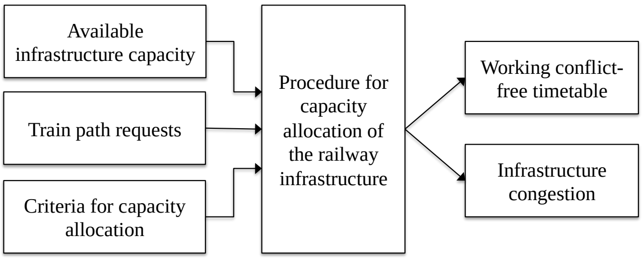

Fig.1. Input and output of the capacity allocation procedure

Infrastructure capacity management in past was based on train-timetable drafting procedure. Vertically integrated railway companies solved train-timetabling problem using priority of train service. Moreover, the order of drawing train paths in timetable depends on established ranking, usually based on service hierarchy [1]. Train requests are divided into certain categories according to their type of service and quality. Each category of train is given a priority order, where highest-priority trains have right to first pick attractive train-paths. Higher ranked train has priority in capacity allocation over a train with lower ranking. The highest-priority trains are safe during capacity allocation procedure, while other trains need to adjust to the higher ranked trains. The last step in train-timetable drafting is resolving potential conflicts. If conflict appears, vertically integrated railway company management is appointing internal committee to resolve remaining conflicts between train paths. In order to resolve conflict demand, intern authorities mainly used their experience and an intuition. Therefore, the literature considers this methodology as an administrated mechanism of railway capacity allocation [1][2].

We can conclude that vertically integrated railway company threated allocation of scarce capacity as an internal problem. After deregulation of the railway sector, the capacity allocation problem has become more complex. By adoption and implementation of the Directive 91/440/EEC and the first railway package[2], the member-states shell allow different companies, new entrants and incumbents, to have access to capacity on the same basis. Above all, the member-states (infrastructure managers) are obliged to prevent any kind of discrimination of new entrants on behalf. of incumbents. Those decisions are adopted in order to foster competition in the liberalized railway market.

The railway market in EU is officially and actually liberalized[3]. Although, there are many new raiway operators competing for the market with incumbents, the framework for capacity allocation procedure remains unchanged as before 91/440/EEC Directive adoption. This means that inherited procedure is securing grandfather rights to incumbents for the majority of train paths. Following this procedure, incumbents always have a "pole position" among participants for capacity. Besides, the administrative mechanism largely relies on preceding train timetable with considerably high share of train-paths designed by infrastructure manager. Obviously, such situation is preventing railway operators to act quickly according to customer requests, especially in terms of congestion. Uncoordinated demand is challenging the administrative mechanism. Actually, many independent railway operators trigger this kind of demand. In addition, higher demand is likely to generate conflicts between many train path requests. The current mechanism for capacity allocation and its preserving is limiting competitiveness growth of the railway service in the transport market.

3. MECHANISMS FOR CONGESTION RESOLVING IN LIBERALISATED RAILWAY MARKET

In case of higher and uncoordinated demand for train paths, the infrastructure managers are using mechanisms for regulating congestion in railway network. In Directive 2012/34/EU, the European Commission has defined frameworks for regulating higher demand and for resolving conflict between train path requests. Levying additional infrastructure charges that reflects the scarcity of capacity of the particular section of the infrastructure regulates higher demand during periods of congestion. On the other hand, if conflicts between different requests appears, the infrastructure managers initiates procedure for resolving conflict.

3.1. Peak demand management by levying access charge on scarce capacity

Infrastructure charges are introduced to provide incentive for efficient allocation of scarce network capacity [2]. If increased saturation emerges, the infrastructure managers could impose additional charges that reflects scarcity cost [3]. The scarcity costs arise in cases where presence of one train prevents another train from operating, or requires it to take an inferior path [4]. Unlike congestion cost, scarcity cost happens in service planning or train-

[2] *The first railway package adopted in 2001 enabled rail operators to have access to the trans-European network on a non-discriminatory basis. On 26 February 2001, the Council adopted the three Directives known as the "rail infrastructure package": 2001/12/EC, 2001/13/EC and 2001/14/EC.*

[3] *Rail freight transport has been completely liberalised in the EU since the start of 2007, for both national and international services. The market for international rail passenger services has been liberalised in the EU since 1 January 2010.*

timetable designing [5]. The higher charges tend to reduce peak demand from operators for congested parts of a network. Train path with higher charge is ready to purchase only operator with highest private value. Infrastructure managers in France and Germany represent two different approaches for determining charges for scarce capacity. The French infrastructure manager is imposing higher charges for train paths during peak hours. On the other hand, in Germany the infrastructure manager calculates higher access charge for train paths on lines with high utilization.

3.2. Procedure for resolving conflict demand on scarce capacity infrastructure

During train-timetable drafting procedure, the infrastructure manager could face with conflict demand for infrastructure capacity. In cases when the infrastructure manager is not able to meet the requirements of all interested railway operators, he will initiate coordination procedure and dispute resolution system. If it is not possible to satisfy requests for track capacity adequately, the infrastructure manager immediately declares congested on that infrastructure section [3]. The algorithm for capacity allocation from train path application to final working train-timetable is given in Fig. 2.

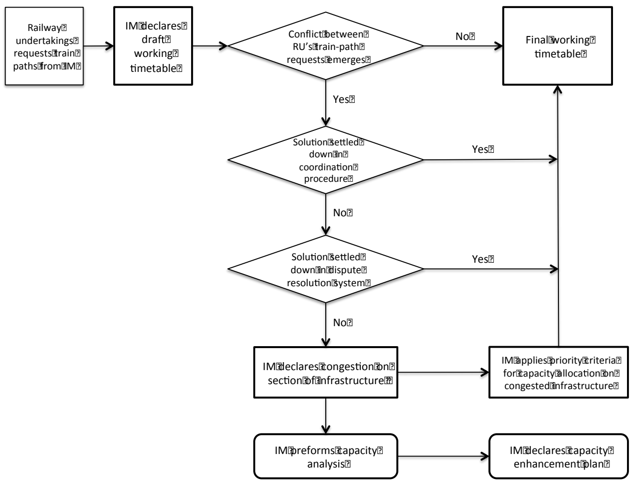

Fig.2. Algorithm for capacity allocation with procedures for solving conflict demand according to Directive 2012/34/EU

If scarcity charges are not imposed or not achieved a satisfactory result and the infrastructure is declared congested, the infrastructure manager uses priority criteria to allocate infrastructure capacity. The infrastructure manager could give a priority to particular services. For example, the importance of a service to society could get priority over the other services. This means that other competing services will be consequently excluded[4]. By that, the member-states could give priority to services in public service obligation or other domestic and international services that member-states want to promote, under non-discriminatory conditions[5]. The infrastructure managers are obliged to publish applied priorities and decision-criteria for capacity allocation on congested infrastructure in Network Statement.

4. IMPLEMENTED DECISION-CRITERIA FOR SCARCE CAPACITY ALLOCATION

Once the congestion is declared, the infrastructure managers in Europe are using different decision-criteria for capacity allocation. For purpose of this paper, we give a brief review of the decision-criteria implemented in Austria, Belgium, Hungary, Germany, Poland, Switzerland and Czech Republic, from published Network Statements in 2016. The most applied decision-criteria could be systematized into four categories, depending on:

- Level of service quality of train speed,
- Type of service (passenger or freight),
- Service frequency or travel length,
- Date when a train path request is submitted.

For the infrastructure managers, the most important services they award priority are services of public service obligation system and services according framework agreements with operators. In Belgium and Poland, the priority is given in following order: fast Intercity trains; slower passenger trains; faster freight trains and other train services. On the congested part of infrastructure, the German infrastructure manager is giving advantage to cross-border service request, then clock face or integrated network services and finally freight train path requests.

In case when conflict requests between the same priority services could not be resolved, the German infrastructure manager organize first-price sealed bid auction. In this type of auction, bidders (railway operators) have one attempt to submit sealed bids, so that no bidder knows the bid of any other participant. The highest bidder pays the price they submitted and awards a priority for train path. Besides, in Germany this type of auction has been implemented in Switzerland, Poland and Czech Republic. Unlike those countries, the Hungarian infrastructure manager awards priority to services with regular interval timetable; services with traveling time longer than 24 hours; services with longer distance; a regular day-to-day services; train path requests submitted earlier.

Some infrastructure managers are using special decision-criteria for some parts of network. For example, at Rhine-Alpen freight corridor in Germany, the priority is given to request with highest product of train kilometers and days with train operation. At newly line Unterinntal in Austria, all freight trains with

[4] *Directive 2012/34/EU, article 47 paragraph 4.*

[5] *Directive 2012/34/EU, article 47 paragraph 4.*

maximum speed 100 km/h or higher and all passenger trains with maximum speed 160 km/h or higher have priority over other path requests. On the parallel existing route shown above, path requests for local and suburban passenger trains have priority in allocation.

5. IMPLICATIONS OF CURRENT MECHANISMS ON DEVELOPMENT OF THE RAILWAY MARKET

Generally, in allocation process of scarce capacity, the infrastructure managers are following the hierarchical order: cross-border and Intercity passenger trains, local passenger trains, intermodal freight trains, and finally other freight trains. The basic assumption for this priority order is that freight service flexibility is much higher than flexibility of passenger transport service. As incumbents still have a major share in passenger rail services, the applied decision-criterion for capacity allocation is providing "grandfather" rights for train paths to them. Decision-criteria gives priority to services with higher social value, but it sacrifice services with higher market value. Following this procedure, current allocation mechanism does not contribute to efficient utilization of the congested infrastructure. This situation is often discouraging freight operators to submit train path request even if their service have highest market value. Bearing that in mind, the conclusion is that applied decision-criteria at congested parts of network disputes development of freight railway transport, especially at congested corridors and in railway nodes.

On the other hand, the effect of the access charges for scarce capacity is very limited. Higher charge reduces higher demand of inefficient services for scarce capacity and therefore regulates congestion. However, the income of additional charges are often insufficient to cover full cost of critical capacity enhancement [5]. The infrastructure managers still do not have methodology for scarce cost estimation in order to allocate cost to operators on non-discriminatory basis. With higher charges, infrastructure manager could potentially burden railway operators with the aim to cover cost of its own inefficiency. Furthermore, uncontrolled additional charges may decrease railway service competitiveness.

6. CONCLUSION

In terms of competition on the railway market and infrastructure congestion, the current mechanism for capacity allocation does not achieve acceptable level of efficiency, transparency and equal treatment for all railway operators. Besides the railway sector liberalization in EU member-states, the administrative mechanism for capacity allocation with traditional priority criterion remains unchanged. The mechanism does not recognize private values for train-paths, and this criterion is not included during railway capacity allocation.

One alternative approach is implementation of the auction mechanism for capacity allocation. If this mechanism is not suitable to be implemented for whole network, there are many reasons for employment auction for scarce capacity allocation. Auction mechanisms are able to solve two problems in the same time that railways are currently solving separately. The first question is which operator is going to get a train path, while the second is by which price. The question of access charge level is especially sensitive and complex in case of congestion. In auction mechanism, railway operators will have opportunity to participate proactively in determination of access charge level that market are willing to pay. Besides, decision-criterion of service priority will be replaced by private value criterion. Only then, freight operators could apply for train paths under equal condition.

In the near future, the train-path allocation problem in terms of competition could appear in Serbia. After the vertical separation of the Serbian Railways, there are three new companies: "Infrastruktura železnice Srbije", "Srbija Kargo" and "Srbija Voz". This move is one of the very important initial steps towards liberalization of the railway market in Serbia. With recent significant investments in passenger EMU rolling stock, the increasing of volume of passenger transport could be expected. The volume is already increased at some sections of Pan-European railway corridor X, particularly at line Belgrade-Novi Sad and inside Belgrade's railway node. However, there is already a certain volume of freight service so it is reasonable to expect declaration of congestion. Accordingly, there is a cause to consider modification of the administrative mechanism for scarce capacity allocation towards a market-based mechanism.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '16

CHALLENGES OF CABLEWAYS REGULATION PROCESS

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Abstract – *Cableways, as specific type of railways, presents complex transport system that has not been regulated by law in the Republic of Serbia. Cableways should be regulated from safety, technical and legal aspect. The European Union created unique safety cableways system within EU territory by adopting Directive 2000/9/EC. In March, 2016 Regulation on cableways installation 2016/424/EU was adopted with the effect from 2018. After adopting the Law on Cableways Designed to Carry Persons in 2015, the field of cableways in the Republic of Serbia is regulated and harmonized with EU legislation for the first time. Regarding touristic and other potentials of the Republic of Serbia, cableways field regulation brings significant challenges that need to be resolved. The paper shows systematic approach on regulation of legal and institutional framework for cableways in the context of European legislation and standards in the cableways field, as well as problems that should be resolved in Republic of Serbia. The paper suggests and discusses possible scenarios for efficient regulation of institutional framework for cableways.*

Keywords – cableways, regulation, harmonization, institutional system.

1. INTRODUCTION

Cableways, as a special form of railways[1], represent the means of transport, which has a growing economic role and significance, and whose capacities and complexity is in constant growth. As such, especially when it comes to public transport and the transport of persons, it requires institutional arrangement that protects the health and safety of customers in transport. In this sense, cableway field has recently been poorly organized in all continents. It was mostly left to the local authorities and rules that treated cableways exclusively as a structure, not as a transport system.

On the other hand, cableways market is growing rapidly throughout the world, especially in Eastern Europe, Asia and South America. In the EU there are about 17,500 cableways representing 60% of all cableways in the world. Approximately 2,000 operators manages their work. Around 80% of the cableways in the EU are represented in ski centers, and other in the cities; while France, Austria, Italy, Germany and Switzerland are the main market of cableways in the EU with 50% of the total number of cableways. The biggest two cableways manufacturers are from the EU, and traditionally have the strongest position in the cableway market by producing about 80-90% cableways globally.

In the Republic of Serbia, there are about 70 cableways[2] located at ski slopes. This number is steadily increasing due to the tendency of mountain tourism growth. In a country, so far there has not been any institution that would take care of the safety of cableways transport or any record of the cableways. According to the new Law on Cableways, that jurisdiction is given to the Directorate for Railways, whose main role is railway market regulation and safety of railway traffic. Serbian Law on Cableways designed to carry persons is partially harmonized with the Directive 2000/9/EC. Its application is not possible until the adoption of by-laws which are in draft and whose adoption will complete the

[1] *Cableways are so called guided systems for the transport of passengers or goods, where transport is enabled by ropes, set up along the route. Cableways are under Directive 2000/9/EC divided into: funicular, cable car (as hanging cableway with cabins and with seats) and drag lifts.*

[2] *The approximate number of cableways for 2015 according to the List of all cableways in the territory of the Republic of Serbia prepared by the Directorate for Railways*

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conformity with the Directive.

Due to tourist and other potentials of Republic of Serbia, cableway regulation carries significant challenges. This paper presents a systematic approach to the regulation of the legal and institutional framework for the cableways, from different aspects and in the context of European legislation and standards in this field, as well as problems to be solved in the Republic of Serbia. The paper proposed and discussed possible scenarios of effective regulation of the cableways institutional framework.

2. REGULATION OF THE LEGAL AND INSTITUTIONAL FRAMEWORK IN CABLEWAY FIELD IN THE EU

In order to harmonize national regulations in the field of cableways for the transport of persons on its territory, the European Union, adopted the Directive 2000/9/EC; which introduced new concepts and procedures, as well as the new approach in regulation the matter of cableways filed legislation. Directive roughly defines the basic safety requirements with a special emphasis on conformity assessment of products, clear rules for the nomination of Designated Body for conformity assessment and rules for carrying out market surveillance.

Harmonization of national regulations, which regulate the cableway field, with the Directive 2000/9/EC aims to ensure that the basic safety requirements are uniquely applicable on the EU territory. The institutional framework editing is not prescribed by this Directive, except the general provisions on the Notified Body for conformity assessment which was established by the Member States while taking into account local conditions.

However, the Directive allows Member States to freely solve many questions and create their own national models based on a common criteria and requirements. Sixteen years after Directive entered into force, the Regulation on Cableways[3] 2016/424/EU was brought, whose implementation starts in 2018. This regulation repeals Directive 2000/9/EC, sets clearer and more detailed rules on the issue of placing the product on the market, in particular the cableways subsystem, harmonizing with the new horizontal legislative framework. When placing safety components and cableways subsystems on the market, the Regulation aims to exclude different interpretations of conformity assessment procedures, as it has been the case so far, and that the application will be uniform in all EU Member States. At the same time, this protects manufacturers that meet high safety standards.

The Regulation also does not solve issues related to the key points of the institutional framework in the cableways field; therefore, the following national legislation must include provisions with a clear division of responsibilities for:

- approval of operation for cableways,
- conformity assessment of safety components and subsystems,
- performing expert inspection,
- granting concessions for the cableways, and
- indirectly, system of education and / or training in the cableway field.

The specificity of the cableway, as well as other transport infrastructure facilities, is that it represents a facility that must have a building permit and use permit like any other facility. However, on the other hand, when in operation, cableways become a mean of public transportation, which is bound by rules and regulations that observe a cableway as a vehicle. This means that, besides regulations on planning and construction, rules that define the requirements and conditions for the safety of the cableways as a means of transport must be applied, which has not been the case so far.

When observing the cableway as a means of public transport, it is necessary to, in some provisions of national legislation related to this area, clearly define the rules referring to the person responsible for the safety of the cableways (cableway manager) and state instruments that control his operation.

The instruments of control over the work of the cableway manager are:

1) an independent institution or legal entity that has been certified by the State[4], responsible for the performance of professional technical inspection of the cableway; a positive report of the expert inspection is a condition for obtaining approval for the further cableway operation;

2) inspection of the cableway that can be implemented at the local and / or central level;

3) the issuing approval of operation for cableways.

3. INSTITUTIONAL ARRANGEMENTS FOR THE AREA OF CABLEWAYS IN SERBIA

In the Republic of Serbia, there has not been any specific law governing the cableway field so far. The matter in this area has been poor (insufficiently legally regulated) and non-harmonized, until the adoption of the Law on Cableways designed to carry persons ("Official Gazette of RS", no. 38/2015).

There have not been any institutions at the State level, which dealt with the issues regulating this

[3] *The essential difference between directives and regulations is that the directive is transposed into national legislation until regulation is adopted on the EU level without the possibility of intervention in national authorities and it is the same for everyone in the EU*

[4] *In most EU countries this person is accredited*

specific field of transport, particularly, from the most important aspect - safety. Relevant departments of the ministry responsible for construction and local self-government, treating cableways as a structure, only issued the construction and use permit for the cableways. Institutional framework in this field did not exist, except competency of the inspection and market surveillance that is given to the inspectors for railway transport.

The provisions of Directive 2000/9/EC related to the division of cableway, basic requirements, safety of construction and operation of the cableways are fully transferred by Law on Cableways designed to carry persons. Provisions on conformity assessment of safety components and subsystems of the cableway are partially transferred; and will be fully transferred to the provisions of sub-legal act on the conformity assessment of safety components and subsystems of the cableways, which is currently in the adoption process.

Although, in the course of writing the said Law, the justification of establishing and registration of body competent for conformity assessment of safety components and subsystems of cableway installations was considered, in order to harmonize with the Directive, taking into account that in the Republic of Serbia there are currently no manufacturers of cableway parts; however, there is still a possibility of establishing and registration of such body. The body must be in accordance with the law governing technical requirements for products and conformity assessment, and bylaw on the conformity assessment of safety components and subsystems of the cableway, which regulates more closely the requirements that the body should meet.

For the first time, the Law on Cableway designed to carry persons delegates institutional responsibilities and obligations of the parties defined by this Law, which affect the security of the cableway operation, while they will in large part be further elaborated in the bylaws.

In accordance with European legislation, it is provided that:

- For the safe cableway operation the legal entity is responsible - cableway manager, with clearly identified way to conduct its job in a safe manner,
- A person authorized by the competent national authority is responsible for carrying out the compulsory annual expert technical inspection and technical inspection after the cableway overhaul (conditions that this person must fulfill will be determined by the by-law).

It is also prescribed that executive cableway workers (executive staff) must have proper education, complete the vocational training program and pass the certification exam.

The cableway field is not included in any Serbian educational institution[5], although it requires specific knowledge; therefore, the question is how can a person gain qualifications in order to conduct an cableway expert inspection, or become a person who performs a program of vocational training, or a person who may be an examiner for the professional examination. Conditions that such persons must meet shall be determined by by-laws, which will regulate this issue[6].

One solution may be to initiate the introduction of an appropriate educational program for the cableways on some of the Technical Faculties. This would create a targeted educational profile that would adequately deal with cableways, by taking into account the high security requirements that must be fulfilled when it comes to cableways. When speaking of persons performing the expert inspection of cableways, they should possess, in addition to proper education, a license for that work. For now, there is no such license, therefore, options are to recognize some of the existing license types or to introduce a new license for cableways.

As for vocational training and professional development, the most appropriate scenario would be if the vocational training program was prescribed by the national by-law, whereby the level of training should be adequate to jobs that executive staff performs. It should be taken into account that the same level of knowledge is not required for operational manager, who should possess the highest level of knowledge, and, for example, the person that performs less complex tasks at cableway. It should be determined based on the level of training, which training the cableway manager should perform, and which training some other adequate institution, person or legal entity should perform. It should be bearing in mind that a large number of cableway operational persons (executive staff) is seasonal; therefore, it would be good if the cableway managers were qualified to perform certain trainings.

When it comes to the validity period of the professional exam, it needs to answer the dilemma on whether and for which jobs (tasks), the executive staff should retake an exam, performed periodically or on prescribed occasions as well.

For the implementation and supervision of the Serbian Law on Cableways designed to carry persons, the division of responsibilities is defined in the following manner:

- Supervising the implementation of this law and by-laws made thereunder, as well as the inspection has been entrusted to the Ministry of Construction,

[5] *This area is partly studies in most faculties of mechanical engineering and only in part related to the ropes.*

[6] *During the drafting of the law between the actors no consensus was reach on this issue.*

Transport and Infrastructure. The Law prescribes that the inspection is performed through the Republic inspector[7] for railway transport;

- Jurisdiction over the issuance of annual approval for operation of the cableways, as well as cableway records and all entities defined by this Law that affect the safety of the cableway operation was entrusted to the Directorate for Railways.

4. CONCLUSION

European legislation has introduced in the cableways field that the basic safety requirements are uniquely applicable in the EU. Regulation of the legal framework for the institutions in charge of the implementation of the Directive is fairly uniform, although it is not prescribed by the Directive but left to the Member States. State authorities responsible for the cableways are usually within the Ministry for Transportation, as an independent agency (such as STRMTG in France), or are otherwise associated to Ministry’s railway sector.

In the Republic of Serbia, the set up of the institutional framework for the cableways is at the very beginning and there are many aggravating circumstances. In first place, there is the lack of adequate human resources ie. of professionals in this field, particularly those who have previous work experience in the field of cableways. This is the consequence of the situation in the Republic of Serbia, where neither any state institution has dealt with the cableways, nor is the cableways present in the education system. An important aggravating circumstance is the current situation of State authorities in the Republic of Serbia, which is characterized by serious reduction of the administration capacity at national and local level.

In this situation, the administration capacities are only partially able to be established in regards to clearly defined legal requirements which regulating this field. Due to the features of the cableways as technological and transport system, on the one hand, and significant progress in the regulation of railways in terms of EU integration and solutions, on the other hand, institutional capacities should undoubtedly be developed within the institutions of the railway sector. More importantly, there is a great analogy between regulations and activities related to cableways and the railway. Therefore, solutions must be, at this moment, searched in upgrading the knowledge and capacity of existing human resources in the Directorate for Railways – in the part of the arranging safety requirements and the competent Ministry of Transport - when it comes to inspection control and control over the implementation of Law.

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[4] TAIEX Presentation Austrian Legislation on Cableway Installations, Vienna, 2016.

[5] TWINNING Presentation General information about organization and functioning sector in charge with cableways in France, Beograd, 2015.

[7] *Currently, there is no possibility to delegate control even at the local level, which would be much more meaningful because of the territorial distribution of cableways; primarily because of the lack of administrative capacity at the local level. This lack is expressed even at the national level in the work of the inspection.*

NETWORK STATEMENT LEGISLATION AND IMPLEMENTATION

Branka NEDELJKOVIĆ [1]
Zorica RADOVIĆ [2]

Abstract – *The separation of transport services from infrastructure manager has been implemented in Serbia in August 2015, after carrying out the status changing of the "Serbian Railways" JSC by separation of the infrastructure manager „Serbian railway Infrastructure" JSC, and railway undertakings „Serbia Cargo" JSC and „Serbia Train" JSC. In February 2016 for the first time in Serbia infrastructure manager has published Network Statement, on which newly established railway undertakings submitted to Directorate for Railways, as regulatory body, their remarks and comments. Respecting the importance of the Network statement in terms of railway market opening and providing for non-discriminatory access to railway infrastructure, the topic of this paper is to present the legal regulation of the Network Statement in the Republic of Serbia, the problems in applying of these regulations and practice of the Directorate for Railways regarding Network Statement.*

Keywords – Network Statement, market, services, regulatory body, infrastructure access.

1. INTRODUCTION

Since 2005, when rail access legislation was introduced in Serbia, publishing the ***Network Statement*** for 2016 is the most important step towards the establishment of the railway ***market***.

A status change of the "Serbian Railways" JSC by the formation of new companies „Serbian railway Infrastructure" JSC, and railway undertakings „Serbia Cargo" JSC and „Serbia Train" JSC in August 2015, is signifacant in terms of implementation the relevant provisions of the Law on Railways ("Official Gazette of RS", No. 45/2013 and 91/2015) concerning the railway ***infrastructure access.*** However, full separation of the infrastructure management and transport operations is not required by the Law on Railways, so it was not necessary step for opening the railway ***market.***

Easy and fair acces to relevant and updated information on the network and access conditions is required for the establishing and functioning of the railway ***market*** and the implementing legal provisions on railway ***infrastructure access*** and and use for all interested railway undertakings under equal conditions.. Quality of the information on the network is of a particular importance for fair railway infrastructure acces, especially due to information asymmetry between the incumbent railway undertakings and new entrant railway undertakings.

Network statement is the "key to market access", since it summarise all relevant information on the network's rail infrastructure, and on commercial and legal access conditions.

We decided to choose this topic due to the significance of the ***Network Statement*** for the establishment and development of the railway ***market***, particularly in terms of the competence of the Directorate for Railways as a ***regulatory body***.

1.1. Network Statement in the EU Legislation

In order to ensure transparency and non-discriminatory access to railway infrastructure, EU legislation introduced in February 2001 obligation for rail Infrastructure Managers to publish a ***Network Statement,*** by adoption of Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification.

Directive 2001/14/EC was repealed by Directive 2012/34/EU on establishing a single European railway area (Recast). Directive 2012/34/EU brings together in a single new act Directive 2001/14/EC and other two Directives from the First Railway Package and all the amendments made to them.

Directive 2012/34/EU introduced the obligation of the infrastructure managers to publish a ***Network Statement*** on at least two EU official languages and make it available free of charge in electronic format on the web portal of the infrastructure manager. This

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Directive reinforces the obligation of the infrastructure manager to develop and publish a ***Network Statement*** after consultation with the interested parties. The content of the ***Network Statement*** is set out in Annex IV of the Directive.

In the framework of the IV railway package, the European Commission proposed the adoption of the Directive amending Directive 2012/34/EU, which, inter alia, obliges Member States to ensure that infrastructure managers have set up and organised Coordination Committees for each network. According to the proposed text, membership of this committee shall be open at least to the infrastructure manager, known applicants and, upon their request, potential applicants, their representative organisations, representatives of users of the rail freight and passenger transport ***services*** and, where relevant, regional and local authorities. Member State representatives and ***regulatory body*** concerned shall be invited to the meetings of the Coordination Committee as observers. One of the responsibilities of the Coordination Committee is to make proposals concerning or advising the infrastructure manager and, where appropriate, the Member State on the content and implementation of the ***Network Statement.***

2. NETWORK STATEMENT IN THE SERBIAN LEGISLATION

The obligation of the infrastructure manager to adopt and publish the ***Network Statement***, its content and adoption procedure, in Serbia is regulated by:

- Law on Railways ("Official Gazette of RS", No. 45/2013 and 91/2015)
- Rulebook on the content and form of the ***Network statement*** ("Official Gazette of RS", No. 97/2013) and
- Articles of Association of the Joint Stock Company for the management of public railway infrastructure "Infrastructure of Serbian Railways", Belgrade ("Official Gazette of RS", No. 60/2015 and 73/2015).

The content of the ***Network Statement*** is affected by other bylaws, as the Rulebook on the Schedule Allocation of Railway Infrastructure Capacity („Official Gazette of RS", No. 140/14), Regulation on evaluation methodology for the elements for determination of the compensations for usage of the railway infrastructure ("Official Gazette of RS", No 122/14), etc.

However, this paper focuses on the three key legal sorces, as presented below.

2.1. Law on Railways

Network Statement is defined by the Law on Railways as a document determining the criteria and the procedure for infrastructure capacity allocation, charging and service fees, as well as any other information required to be able to submit a request for path allocation.

Article 18 of this Law provides that the ***Network Statement*** shall contain in particular: general provisions; conditions for access to and use of rail infrastructure; overview of traffic and technical characteristics of available rail infrastructure and restrictions pertaining to its use; principles, priorities and criteria for infrastructure capacity allocation; types of ***services***; principles for levying charges and service fees along with the level of charges and their calculation method.

The ***Network Statement*** shall be published for information purposes at the infrastructure manager's web site and may be obtained from the infrastructure manager in a hard copy and electronic copy, upon payment of the amount which may not exceed the cost of its announcement.

The law stipulates the obligation of the infrastructure manager to modify and amend the ***Network Statement*** should there be any changes in the data contained in it.

Article 24 of the Law on Railways stipulates that the principles governing the coordination process shall be defined in the ***Network statement*** and a conflict resolution system must be referred to in the ***Network Statement.***

Article 29 of the Law defines the ***services*** provided to railway undertakings, the minimum package of ***services***, track access to service structures, ie service facilities, use of service structures, i.e. service facilities, additional and ancillary ***services***. The same article stipulates the obligation of the infrastructure manager to provide information on charges and service providers in the ***Network Statement*** for the ***services*** that are not provided by the infrastructure manager, use of service structures, i.e. service facilities, additional and ancillary ***services***.

Article 36 of the Law stipulates that the discounts approved by the infrastructure manager shall be published in the ***Network Statement***.

Article 41 of the Law provides that the procedures and criteria for setting of priorities in the event of infrastructure capacity congestion shall be set forth in the ***Network Statement***.

Article 93 of the Law stipulates that the Directorate for Railways (hereinafter: Directorate), in the field of regulation of the railway ***market***, inter alia, decide upon complaints of applicants for train path allocation, particularly having in mind possible unfair conduct or discrimination by the infrastructure manager or railway undertakings in relation to the ***Network Statement*** and criteria determined in the ***Network Statement***.

The same article stipulates that the Directorate monitor and analyze the conditions of the competiton on the railway ***market*** and review, at its own initiative, ***Network Statement*** in order to prevent discrimination among the applicants for train path allocation. The Directorate shall particularly check whether the ***Network Statement*** contains the clauses or envisages discretionary rights of the infrastructure manager that could be used for discrimination of the applicants for train path allocation.

Article 95 Paragraph 5 of the Law stipulates that if the Directorate determine during the appeal procedure or during the procedure instigated ex officio, that the competition on the railway ***market*** has been violated, it shall enact a decision on measures for the elimination of the determined violation.

The same article stipulates that the Directorate implements administrative enforcement of its decision in accordance with the law governing general administrative procedure.

Article 198 of the new Law on Administrative Procedure ("Official Gazette of RS", No. 18/2016), which will apply from 1 June 2017, stipulates that the authority in charge of enforcement compel the enforcee to fulfill obligations by imposing fines if execution by another person is not possible or not appropriate to achieve the purpose of enforcement. The fine shall be imposed on a legal entity in the range of half of its monthly income, up to ten percent of its annual revenues that are earned in the Republic of Serbia in the previous year and can again be imposed until the enforcee fails to fulfill its obligations imposed by the decision.

2.2. Rules on the content and form of the Network Statement

Rules on the content and form of the ***Network Statement*** is issued by the minister responsible for transport on the basis of Article 18 Paragraph 2 of the Law on Railways.

This regulation provides for detailed contents of each part of the ***Network Statement***, following the ***Network Statement*** Common Structure which was recommended by RailNetEurope (RNE).

2.3. Articles of Association

Article 16 of the Articles of Association of the "Serbian Railways Infrastructure" JSC provides that the General Meeting adopt ***Network Statement*** with the consent of the founder, i.e. Government.

2.4. What is not Network statement

To address identified concerns regarding the legal nature of the ***Network Statement***, we would like to point out that this document does not constitute an offer to conclude a contract for use of the railway infrastructure, nor general conditions of standard clause contracts.

Article 32 of the Law on Contracts and Torts ("Official Journal SFRY", Nos. 29/78, 39/85, 45/89 - decision and USJ 57/89, "Official Journal SRJ", No. 31/93 and "Official Journal SCG", No. 1/2003 - Constitutional Charter) stipulates that an offer shall be a proposal for entering into a contract made to a specific person and containing all essential constitutive elements of the contract, so that its acceptance would amount to the entering into contract.

Article 33 of the same Act regulates general offer and stipulates that a proposal to conclude a contract made to an unspecified number of persons and containing essential constitutive elements of contract envisaged by the proposal, shall be valid as an offer, unless something else follows from circumstances of the case or usage.

The ***Network Statement*** does not contain the essential constitutive elements of the contract on the use of the railway infrastructure, nor they can be specified without specific train path reques, and therefore ***Network Statement*** can not be considered an offer.

Article 142 of the Law on Contracts and Torts provides that general terms and conditions specified by one contracting party, either contained in a standard clause contract or being referred to by the contract, shall supplement particular agreements, as established between contracting parties in the same contract and, as a rule, shall be binding as those.

The ***Network Statement*** is a document containing information which is necessary to be able to apply for the train path allocation and can not be considered as general conditions in terms of the Law on Contracts and Torts.

Elements of the contract on the use of rail infrastructure are prescribed by the Rulebook on the elements of the contract for the use of railway infrastructure (”Official Gazette of RS”, No 5/16).

It is our opinion that infrastructure manager and railway undertaking can agree that particular elements of the ***Network Statement*** are an integral part of the contract on the use of infrastructure, and binding as such.

3. DIRECTORATE FOR RAILWAYS CASE STUDY

On February 2016. "Serbian Railway Infrastructure" JSC has published on its website ***Network Statement*** for 2016.

Soon after, in March 2016 the railway undertakings "Serbia Train" JSC and "Serbia Cargo" JSC submitted to the Directorate complaints and comments regarding deadlines for ***Network Statement*** publishing and its content.

After considering "Serbia Train" JSC and "Serbia Cargo" JSC complaints and comments regarding

Network Statement 2016 and reviewing the available information on the website of "Serbian Railway Infrastructure" JSC, the Directorate has established the possibility of competition violation on the railway ***market*** in terms of the Law on Railways, and initiated ex officio proceedings against the company "Serbian Railway Infrastructure" JSC.

Following the procedure the Directorate issued a decision establishig that non-fulfillment of the obligation to publish the ***Network Statement*** for 2017 constitutes a violation of competition on the railway ***market*** in terms of the Law on Railways. Directorate has concluded that due to this failure the train path alocation is disabled in the procedure of drafting of the timetable for 2017, thereby limiting ***infrastructure access*** rights.

Directorate also established that ***Network Statement*** for 2016 contains deficiencies that may result in restricting access to railway infrastructure to all interested railway undertakings, that could lead to discrimination against applicants, which is a violation of the competition in the railway ***market*** in terms of the Law on Railways.

By the same Decision Directorate has established measures to eliminate the violations in accordance with the Law on Railways.

"Serbian Railway Infrastructure" JSC has implemented within the given deadlines all the measures established by Directorate Decision. ***Network Statement*** for 2017 and Amendments to the ***Network Statement*** for 2016 are adopted and sent to the Government for approval. The process of obtaining approval from the Government to the said documents is still in progress.

Analysis of the ***Network Statement*** for 2016 showed certain ambiguities and inconsistencies in the regulations which regulate the access and use of railway infrastructure, in particular the issue of charges and the time frame for submission of train path applications and decisions upon requests.

Challenging issue was traction current supply, due to lack of harmonization of railway regulations and regulations in the energy sector, where the ***market*** is also opened.

Also, Directorate decision regarding ***Network Statement*** can not be fully implemented due to provisions of the Articles of Association of the "Serbian Railway Infrastructure" JSC which stipulates founder approval of the ***Network Statement*** and its amendments. Founder approval significantly slows down the procedure and, in our opinion, it is not necessary. The ***Network Statement*** is a set of information needed to apply for the train path allocation and it is not a decision act which establish the amount of charges or any other aspect of the company's operations.

4. CONCLUSION

The publishing of the ***Network Statement*** for 2016 is the first step to establishing of the railway ***market*** in Serbia, despite the fact that it was published after the deadline and regardless of the ***market*** violations that Directorate established.

Its contribution consists in the fact that it pointed out the need for improving some of the national legislation, for which the relevant authorities have already started the initiative.

Also, we expect that, after the experience with the published ***Network Statement*** for 2016, infrastructure manager will present ***Network Statement*** timely and with all required updated information stipulated by the relevant legal provisions, in order to achieve the purpose of this document, and allow transparent and equal ***infrastructure access*** to all potential users and thus provide for successful functioning of the railway ***market***.

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SWOT ANALYSIS OF THE MINISTRY OF TRANSPORT AS A COMPETENT AUTHORITY FOR PSO CONTRACTS

Slobodan ROSIĆ [1]

Abstract *– After Regulation No. 1370/2007/EC entered into force, all the non-profit passenger transport railway services of public interest had to be contracted between a railway company and a public transport authority. Public transport authorities now have to possess the capacities for contracting a public service obligation (PSO), its monitoring, and managing the process, which are new competences compared with the previous practice. Since contracting and acquiring the service in question is of public interest, it is necessary to consider which form of competent authority is the most efficient with regard to the demands of the Regulation and the parties involved. This paper is devoted to the general assessment of the suitability of the ministry of transport as the competent authority for PSO contracts, with specifics related to the application to smaller countries and networks, as is the case with Southeastern Europe. SWOT analysis was used as the method of research.*

Keywords – public service obligation, public transport authority, railway, SWOT analysis.

1. INTRODUCTION

The creation of a unified European "railway space", deregulation and liberalization of the railway services market require a different institutional organization both with regard to laws and by-laws and the state institutions themselves. This relates to all levels of state authorities, from the EU over the national and regional levels, all the way to the local level. The implementation of the EU regulations in the area of railway transport demands great changes in the institutional framework of every country. In the period prior to this reformation, the institutional structure of the railway sector in Europe was rather simple. Integrated state companies, with monopoly at the national level, were constantly monitored by a competent ministry of transport, and in some cases were even part of the ministry itself. Almost all of the most important decisions needed to be approved by the government. At the same time, the vast majority of activities related to the development and operation of the entire railway sector in practice took place in the companies themselves. The ministry only conducted legislative and certain control activities.

From the abovestated, it can be concluded that the states, i.e. their governments and competent ministries, were mostly unprepared for the beginning of enormous changes required by the process of market liberalization, since their resources in the railway sector were quite scarce. Apart from human, organizational, financial and other resources demanded by the competent ministry of transport, it was necessary to establish several new regulatory agencies (for market regulation, traffic safety, incident investigation, company licensing, notified and appointed bodies). Apart from these bodies, whose foundation stemmed directly from the introduction of a market, the concept of funding the development of infrastructure and non-profitable services in passenger transport was also altered. With the publication of *Regulation No. 1370/2007/EC on public passenger transport services by rail and by road and repealing Council Regulations EEC No. 1191/69 and 1107/70*, the former concept of subsidies was changed to the concept of state aid which required the conclusion of a contract between the state and the company receiving the aid.

Despite the fact that the restructuring processes of European railways began back in 1991, to date least attention has been paid to the issue of constructing the capacity for contracting obligations and monitoring both public services and the funding of maintenance and construction of railway infrastructure. This statement relates not only to the practice but also to the literature. Thus, it does not come as a surprise that there are numerous different solutions and models in the EU states with obvious disrepancies concerning the institutional level and capacity of the competent contracting bodies. This paper analyzes the compatibility of the ministry of transport as an institution in charge of contracting and monitoring public service obligations, i.e. transport.

2. PROVISIONS OF REGULATION NO. 1370/2007/EC WITH REGARD TO THE TRANSPORT AUTHORITY FOR PSO

During the restructuring process of the transport sector in the EU, a need arose in the area of subsidized

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public transport services to break monopolies, encourage competition and introduce greater control of the budget resources spending, so as to gain a higher quality transport with lower prices. The PSO regulation provides a legal framework for achieving those goals.

In December 2009, Regulation No. 1370/2007/EC on public passenger transport services by rail and by road and repealing Council Regulations No. 1191/69 and 1107/70 entered into force. The fundamental requirements/rules promoted by this regulation are as follows:

1. The competent authority is obligated to ensure that the public transport services are performed, with an adequate compensation to the performer of these services.
2. The no-obligations subsidies will no longer be awarded. The allocated resources will now be defined as state aid which needs to be in the form of a contract between the competent transport authority and a railway company.
3. The regulation prescribes the content of the contract, which has to include the following items: an accurately defined transport obligation which needs to be fulfilled by an operator; parameters which determine the compensation and/or the type and framework of the exclusive right, with the aim of preventing overcompensation, regardless of the manner in which the contract is concluded (directly or through a tender); arrangements for cost and income distribution; validity period of a contract.
4. A PSO contract can be concluded with a railway operator directly or through a tender in accordance with the conditions prescribed by the Regulation. In the case of a direct allocation of resources, the competent authority is in obligation to inform the public on the name of the subject with which the contract has been concluded, as well as to present the contract conditions. In the case of a tendering procedure, the contest has to be open for all operators under the same conditions, righteous, transparent and without discrimination. The PSO compensation is determined according to the methodology provided in the Annex of the Regulation.

The above rules for allocating the resources for passenger transport in road and rail traffic imply much greater capacity of the transport authorities in comparison with the previous period. This capacity now relates to the ability to define the policy and strategy in this area, define all of the conditions for transport, tendering organization and selection of operators, contracting and monitoring.

Bearing in mind that the passenger transport service on the railway can be performed in the local, regional and long-distance traffic, the question is posed concerning the best position of the transport authority bodies: whether it should be at the city, regional/provincial or republic level, or perhaps decentralized in accordance with the territorial community where the services are performed.

3. ANALYSIS OF THE PREVIOUS FORMS OF TRANSPORT AUTHORITIES FOR PSO

Regulation No. 1370/2007/EC does not strictly define the type of authorities competent for PSO. This is the reason why a number of models of competent transport authorities have appeared in the EU practice. Competent authorities (bodies or institutions), their position in the system of the EU countries state government, as well as in those countries which have aligned their systems with Regulation No. 1370/2007 EC, are shown in Table 1.

The table shows that 16 European countries have retained the traditional institutional approach which implies that the competent ministry of transport is, as before, the only transport body (TB) for the railway sector. The same number of countries have decided to adopt a new approach with special and/or local directorates becoming the competent bodies for public transport. Within these countries, three subgroups can be distinguished:

1. countries with TB in the form of a national level agency;
2. countries with TB at both the national and the regional level;
3. countries with TB only at the regional level.

Table 1. Overview of the models of competent authorities for PSO in European countries

Countries	COMPETENT BODY/ORGANIZATION LEVEL			
Belgium, Bulgaria, Croatia, Estonia, Greeced, Hungary, Lithuania, Luxembourg, Montenegro, Norway, Portugal, Romania, Slovakia, Slovenia, Spain	national level MINISTRY			
Denmark, Austria, Ireland, Latvia		national level DIRECTORATE		
Czech Republic (14)*, Finland (1), France (22), Great Britain (3), Italy (15), Holland (13), Poland (16), Sweden (37), Switzerland (26)			mixed level NAT/LOC	
Germany (33)				local level

(14)* – number of PPTs at the local level

The first subgroup comprises 4 countries while the second one contains 9. Despite the fact that in 8 of these countries the ministry is still the TB for certain segments of public transport, the role of special and local directorates is very important. The number of TBs vary greatly from country to country and it ranges from one in Finland (Helsinki TA) to 37 in Sweden. The division at the local level is also varied. Thus, the Czech Republic and Poland have an almost identical number of regional TBs even though Poland is four times the size of the Czech Republic both in terms of territory and population. The third subgroup includes only Germany, which does not have TBs at the national level. Apart from the variations in the models of transport bodies and levels of authority, the mere experience varies as well. This implies that each country individually, given the historical heritage in the railway sector, the level of authority decentralization and other specifities, has to find its own particular model. This paper contains a SWOT analysis of the ministry competent for transport as a body of the transport authority competent for contracting and monitoring PSOs in the Western Balkan countries.

4. SWOT ANALYSIS OF THE MINISTRY OF TRANSPORT AS A COMPETENT AUTHORITY FOR PSO

Is the competent ministry of transport of an adequate form, level and structure to be the transport authority body for contracting, monitoring and controlling the performance of public transport obligations in railway traffic? Above all, is it a form which can allow for constant improvement of this type of public transport services? These questions are answered here in the form of a SWOT analysis, and the results are presented in Fig.1.

When searching for the answers to the questions concerning the strengths, weaknesses, opportunities and threats when the ministry is the competent body, the current organization of competent ministries of transport in the Western Balkans region was taken into consideration, including their structure, human resources and capacities which are very similar for all of the countries in this region. With that in mind, it is very important to emphasize that the manners in which the governments of these countries operate have stemmed from the same legal system and are very similar in themselves, which is yet another important component in concluding that this SWOT analysis relates to this geographical region. Without explaining the present SWOT analysis, the paper will point out to and discuss several significant aspects in the analysis of the suitability of the ministry for PSOs.

The first aspect will be marked as an answer to the question concerning the starting characteristics and positions of the ministry in relation to the tasks set by Regulation No. 1370/2007/EC. These state bodies are undoubtedly in possession of the greatest capacity and competence when it comes to railway traffic. However, they are nowhere near sufficient to perform the role of the transport body adequately. One has to bear in mind that in the former Yugoslavia all of the railway-related issues were solved at the federal level. Today, after more than 20 years, the capacities of the competent ministries are still poorly developed with regard to railway-related tasks, and even PSOs. The existing capacities are being exhausted on the interpretation of legal provisions and transposition of the European legislation, while there are no appropriate capacities that could deal with all the issues related to the policy and strategy of railway development. Even though this lack of necessary capacity and competence needed to define and conduct PSOs could most easily be reduced by cooperating with relevant professional and research institutions, it is obvious that these ministries do not possess neither the will nor the awareness of the need to define the research tasks in this area, nor are they capable of it.

The second aspect relates to the manner in which the ministries operate and the atmosphere within them, which comes from the structural organization of the ministries and the governing approach. Namely, despite the fact that the professionalization of state administration and even the legislature to that effect have been proclaimed, the manner in which these ministries are governed is still characterized by strong political influence. The ministries do not have good interaction with service users, especially at the local and regional level. An inevitable factor in the SWOT analysis is the fact that the state owns the monopolistic railway company for passenger transport. This is quite certainly an aggravating circumstance when it comes to establishing efficient railway passenger transport in the process of restructuring, since the above political influence will lead to the state-owned operator being protected and favoured.

The fourth aspect relates to the degree of regionalization of the country and the subsequent ability of the local self-government units to fund and decide on the issues from the domain of public railway passenger transport. Even though the degree of regionalization differs in the Western Balkan countries (counties, cantons, districts or plain municipalities), what they have in common is the lack of resources for funding PSOs. The question remains open on whether the region borders coincide with the regional railway lines. Without further analysis, it can be assumed that the majority of local and regional lines encompass more than one administrative unit, thus complicating the processes of contracting, funding and controlling PSOs.

The fifth aspect relates to the possibility of coordinating public railway passenger transport with other forms of traffic, primarily public urban and suburban traffic and intercity road traffic. Despite the fact that the ministry is the highest body in the state hierarchy in the area of traffic and transport, it is not

STRENGTHS:

- Specific existing knowledge in relation to the creation of a new body of transport authority
- Already raised awareness of the importance of contracting PSOs in the process of restructuring
- A leading role of the competent ministry and the government in the process of restructuring
- The process of restructuring the historical railway company and the railway sector is just at the beginning
- The determination of the government to restructure the monopolistic company and define mutual rights and obligations
- Although minimal, there still are certain available human resources in the ministry

WEAKNESSES:

- Limited by the daily political activities of the ministry
- Disinterestedness of the ministry in monitoring the performance of PSOs at the local and regional level
- The lack of knowledge and human resources for defining a public interest strategy in railway passenger transport
- The inability to attract experts due to the income constraints
- The problem of coordination with public urban and suburban transport
- A conflict of interest between the function of the owner of the national railway company and representing public interest

OPPORTUNITIES:

- A leading position of the ministry in creating an institutional framework for PSOs at the national level
- Stable funding of public transport from the state budget in comparison with the majority of local and regional bodies
- Improvement of the railway image in the public through transparent funding
- A better position of the ministry for securing foreign expertise in performing PSOs
- The easiest organization of PSOs at the appropriate routes, without problems concerning the overlap of passenger flow and administrative borders and authorities

THREATS:

- The danger of assigning PSOs in line with the political interest
- The favourization of the state company for passenger transport through exclusive rights
- "Turning a blind eye" to contract violations by the national railway company
- Slowness in restructing the national railway company
- Unreal timetable offers and the inability of the national operator to fulfil the obligation
- A lack of financial resources for PSOs which will in turn lead to the protection of the existing monopolist

Fig. 1. SWOT analysis of the competent ministry of transport as the body of the transport authority for contracting and monitoring public transport obligations

the best institution to carry out such coordination. Public transport on the territory of municipalities and cities most often legally belongs to the so-called municipal activities, which are under exclusive jurisdiction of the local self-governments. One should also bear in mind that these municipal activities are subject to tax exemption in the majority of the countries.

5. CONCLUSION

A public service obligation related to passenger transport, its contracting, monitoring and control represents a new task for transport authorities not only in the region of the Western Balkans but also at the European level. The fundamental issue that needs to be solved in its introduction is the concept of PSO and which transport body should deal with it. In the EU countries there is no single specific model, nor is that possible, which makes it necessary for every country to search for the most convenient model with regard to the characteristics and the historical development of the railway system and the country itself.

The paper discusses the adequacy of the competent ministry of transport as the body of transport authority for PSO. When the SWOT analysis figure is scrutinized, there can be observed significant negative sides to this institution in relation to PSO, but also some important advantages in comparison with the other solutions in this phase of restructuring the railway system in the Western Balkan countries. The final decision-making procedure concerned with what kind of a body of transport authority is necessary for certain countries in this region, should include all of the system participants in order to reach a sustainable solution and model through a certain form of participatory analysis, where the main criterion has to be the improvement of the railway service efficiency. To solve the dilemma whether that body should be the ministry or some other type and form of a central state institution, or that this can be done by decentralization and delegation of a part of, or the entire, jurisdiction to the regional authorities, further more comprehensive research that could provide answers to various questions is needed.

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Other Railway aspects

XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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SERBIAN NATIONAL PROVERBS AND SHORT WISDOM SAYINGS AS THE BASIS OF „SERBIA RAIL A.D” ETHICAL CODEX

Aleksandar BLAGOJEVIĆ [1]

***Abstract** – At the beginning of the last year "Serbian rail", section for passengers, enacted an Ethical Codex which defines a determined set of values of the company, as well as the business ethics of its employees. The company's values have been defined by this codex, which is based on the value of labor, honesty and honor. Those values are of key importance to achieve the established strategy, vision and mission of the company. Serbian nation has always been characterized by high moral values and virtues. Numerous are the examples of humanism, morale and heroism in Serbian history. Such high moral values and virtues were the foundational, imposing and doubtless landmarks and guides in everyday life of the people. The oral folk literature termed those values and virtues as "Serbian national proverbs". Those oral proverbs have codified all the popular short wisdom sayings and wisdom of the Serbian people. Serbian proverbs and short wisdom sayings are quoted in this work as the foundation of personal ethics and business ethics. They are also foundational ethical code of every company. Adequate underlining of the meaning and the message contained in certain national proverbs and short wisdom sayings must bring about a full acceptance of the Ethical Codex of "Serbian rail" company by all company's employees. At the same time, that Codex makes the company recognizable on the traffic market of Serbia. The company is recognized by its ethical codex and high business etiquette.*

Keywords – Serbia rail, ethical codex, Serbian national proverbs

1. INTRODUCTION

Discussions involving acceptance or assurance of one's opinions usually involve quoting the national proverbs and short wisdom sayings. Since time immemorial, those proverbs are used in everyday communication. Even in these modern times, they are being used as important and effective language structures. Those short wisdom sayings suggest certain meanings, they provide precision and stringency. Those short wisdom sayings are usually believed to be more than ordinary language since their structure confirms the truth that is beyond need to be proved. The wide usage of the national proverbs can be explained by the poignant character of those, as well as by their descriptive and authoritative expression based on experience and tradition. Vuk Karadžić, the author of the Serbian alphabet, played a great role in preserving those short wisdom sayings. Karadzic notified all those short wisdom sayings and passed them on to future generations to keep them as the national heritage.

In the last decades, we see the development of business ethics. As relatively new applied science, it has been gaining increasing significance in business operation and organization. An organized system of administration is based on ethical principles that make possible to respond to the demands from customers, employees, shareholders and the community at large. Those principles are also important in response to environmental and global societal protection.

Business etiquette is also understood as a set of the following values: honesty, sense for justice, openness and sincerity in business operation. In other words, it is the set of values that drive an ethical business. In accordance with those values is the codex of business ethics which is a documented philosophy that stipulates the rules of business operation as obligatory to every employee in a given company. Those rules also oblige the business subjects and their affiliated branches, as well as the employees, management and others involved in the business.

In the document entitled "the Ethical Codex of Serbian Rail A.D.", which was drawn in 2016, such codex has been defined as follows: "Codex is a set of rules related to professional ethical duties of the employees; it is being adopted for the sake of creating

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necessary conditions for better business operation, improving the moral values, raising the awareness of responsibilities that employees have and responding to the need that employees have for highly ethical conduct not only within the company, but in their relation to the customers, business partners, competitors and others". This codex also regulates and encourages the conduct that the company expects from any employee; not only are employees are expected to recognize those ethical issues, they are also expected to react adequately and thus increase the strategic advantage that the company would have on the market. Ethics, being a very important competitive tool of our company, must permeate the character of anyone within the organization and must be applied everywhere at all times".

2. VISION AND MISSION OF THE "SERBIAN RAIL" AD

Adoption of the Company's Ethical Codex is for the purpose of achieving the company's vision and mission. The vision of any organization is of the vital importance for its operation. It represents the clear banner that gathers all the employees under its wings. The vision also improves coordination of activities and directs those activities to the task at hand. It inspires and raises the corporal awareness. The vision of „Serbian Rail" is to be the choice of the largest number of public transportation users on the Serbian public transportation market, as well as to be a competitive service both at national and international transportation services.

Company's mission must reflect the needs of customers and be widely known and accepted on the market and in public. The purpose of the organization is to provide quality transportation services and become the best of public transportation service. The most important goal is to have customers who are happy with the services provided by the company. Therefore, the highest possible efforts must be put forth to gain a legitimate trust on the part of the customers. The quality of company's operations is being measured by the level of satisfaction of the passengers and all the other buyers of company's services.

3. SERBIAN NATIONAL PROVERBS AND SAYSINGS EXPRESS THE COMMON PEOPLE'S VIEW ON LIFE, MORALITY, LABOUR, DIRECTION, PHILOSOPHY, PAST, PRESENT AND FUTURE

The national proverbs and short wisdom sayings are forms of oral popular traditional literature that communicate much about the people itself, with fewer words and the power of condensed messages. Those short wisdom sayings also express the way we are, who we are, what is our worth, our system of values, our moral norms and attitudes and much more. Those wisdom short wisdom sayings had been evolving in long periods and have become a reflection of our people from the earliest ages to present. They are also a great monument to the national wisdom, character and trials that this nation has gone through.

Author Dj. Stojičić is the one who dedicated most of his time to collecting the national proverbs and short wisdom sayings. He is considered a successor to Vuk Karadžić. Stojičić says that the proverbs are independent, logical thinking units that formulate certain life experiences in forms of norms. Their basis is always a certain common truth of life. Such norms are used to enrich communication with a wealth of condensed thoughts. They can be used in a conversation, as well as in a written form.

As forms of oral national literature, proverbs are used as undeniable proof of something, while short wisdom sayings, being somewhat shorter than proverbs, with fewer words give exact description and picture of something.

Our proverbs and short wisdom short wisdom sayings and poetic and philosophical formations which for centuries have been speaking the truth about our people since they describe their character traits in more exact terms than any other description. In further text, all quoted defined main values of our company will be accompanied with adequate popular proverbs and short wisdom saying to illustrate how the content and messages of those forms can guarantee the successful operation of the company and define the conduct of its employees in accordance with the adopted Ethical codex.

4. THE MAIN COMPANY VALUES WITH ADEQUATE NATIONAL PROVERBS AND SHORT WISDOM SHORT WISDOM SAYINGS

4.1. To be honest, just, fair, truthful, reliable and objective

Judge not by one's origin, do not consider who is his father and his father's brothers, but judge by the justice of the God of truth. May the justice be done, even if it means that my kingdom will go down. We are to respect others in order for them to respect us. Only a bad person blames others for his mistakes, while the just and fair one tries to rectify his mistakes. Learn to correct your mistakes. Do your best, do not worry about the rest. Half solution to your shortcoming is to get to know it. Submit to your conscience and get hold of your will. The ant and bee learn how to gain wealth by their industrious work. The most peaceful sleep comes from clear conscience. If you aim for the truth, there is nothing you should fear. Money is not the true wealth, but the truth and honesty. It is better not to have money, than to gain it by dishonest means. It is not difficult to deceive an honest person. Respectable name is the greatest prize. There is never a surplus in honesty and the number of children.

4.2. Respect for employees – humane treatment above all

Show respect to others if you want to be respected. A honest man who judges himself rightly, will have the same approach toward the others. It is no difficult effort to deceive an honest person. Have respect for your enemies because they will give you the best account of your shortcomings. Have respect for your parents if they are alive; if they are not, remember them. The word of an honest person is also an advance payment. Nothing is as important as honesty; honesty should not be sacrificed for anything else. Words are to be measured, not counted. The attitude of gratitude is a great thing. It is not a shame if you fall; it is shame if you do not get up. If you have a good brother, make sure to keep your friend who is also like a brother to you. Give a position to a person to see if he is honorable.

4.3. Consciences work performance

It is better to work for nothing, than to be idle for nothing. Working keeps me alive. A good worker is recognized even by his enemies. Silkworm's labor makes silk out of mulberry leaves. The labor looks not for a slothful worker, but for an industrious one. If the man does not give up on his land (to farm it), the land will also not give up on its owner. Be industrious like a bee. If anyone would do as much as it is within his or her power, this world would be much different. Well farmed land is never fruitless. Clean the trash first in front of your own house.

4.4. Develop skills and increase knowledge

While learning one thing well, learn ten more. A good learner makes difference between concepts. No skill comes without difficult efforts. Strong hands will prevail against one enemy; strong knowledge will prevail against thousand enemies. The one who has the will, will always find the way. Whoever wants to learn, he will find school at each corner. Knowledge has more worth than money, it is sharper than a sword and mightier than a gun. A grain of knowledge is better than a load of power. A good tradesman is never too expensive. A good lecture is as precious as gold. The better view is on the top of the hill. The one who has knowledge in his head is more worthy than the one having money in his pocket.

4.5. Orientation to customers

A good start means a good finish. Sweeter than any fruit is the fruit of one's labor. Never trust in miracles because they are impossible. Who needs some fire, he will take it with bare hands. The tool does the work, the tool manager boasts of the results. If the goal is great, the way is not difficult. Believing in success is a half success already. Tongue inflicts heavier wound than a sword. A kind word does not cost you anything. A good man sees good in everyone.

4.6. Rational decision making process

If you keep putting off for tomorrow, the time will go by. Measure three times and then make a cut at once. Think twice, it does not cost you anything. Do not rush. What you say can make you, or break you. Make rush slowly. A decision that cannot be reversed is not a good decision. A man and his donkey know more than a man alone. Talk to everyone before making a decision by yourself. Let your tongue be no quicker than intelligent thinking through a matter. Let a decision wait until the morning. A second of patience means ten years of peace. The end is the judge of the beginning.

4.7. Respect for commercial interests

No worry over much work; much worry over little work. Success from unsuccess is one step away, while years are needed to go from unsuccessful business to a successful one. Everyone on the market do have only one boss – a customer, who can fire anyone in any company, from the director to the doorkeeper, by simply spending his or her money elsewhere. Respect your boss in whose car you are being driven.

4.8. Be a leader

A good listener is also a good decision maker. If you have never been a servant, you will not know how to be the master. If the goal is great, the way is not too difficult. Sheep just make a flock if there is no shepherd to lead them. Judge where you are to be like a sword, and where you are to be like a balm. Anyone can be a captain when the sea has no waves. Better to be rebuked by a wise person, than to be praised by a fool. It is not enough to be strong; being wise is equally important. Anything can be achieved, you just need to wake up one hour earlier.

4.9. Customer is always right

The customer is always right. If you want to know your shortcomings, ask your enemy – he knows them well. Even in inclement weather the passengers make their journeys. It is better to serve a good person, than to give orders to a bad one. Better to keep silent and be sorry, than to speak up and then be sorry later. A nice word can open even an iron door. The rose doesn't come up without thorns. A work done right away carries double value.

4.10. Trust

Trust in success means half success already. Trust in yourself so that others can also trust you. The winners in the battle never counted the number of their enemies. Be of a good report. If we are humane, we can easily work on any task.

4.11. Team work

Solidarity invokes the blessing from God. With brotherly kindness brotherly deeds are done. Where there is much idle talk, the performance is small. In the house of harmonious brothers, even the lead can float on the water. Harmony builds a common house. Harmony is a blessing from God, while disharmony is a curse. Brothers build a house in harmony, while those with no harmony quickly bring it down. Even the mightiest person is uncertain without friends. Better two workers than one. Where there is harmony, the happiness is stronger.

4.12. Be part of the change

To travel a thousand miles, you have to start with the first step. Without a start, there will be no finish. Better good name than a great wealth. A good start means a job half finished. If you want to improve the world in any of its segments, first start with improving yourself. A will makes the way. The house is built from the foundation and repaired from the roof. When you dig a new well, do not cover the old one.

5. CONCLUSION

During their history Serbs were enslaved for centuries by foreign empires. Therefore they had no their national state and national legislation. In those circumstances, they were only able to rely on their own moral and ethical laws which were not written down and codified. That is how the national proverbs and short wisdom sayings became a moral and ethical codex in the Serbian society. Those forms of literature formed recognizable phenomena of ethics, morality, honor, honesty to the population which recognized concrete expressions.

Ethical Codex defines the values of the company and the principles of operation of „Serbain Rail". Those values and principles are of the vital importance as they are defined in the proper and applicable ways. It is therefore an obligation for all employees, particularly for those who manage the company's human resources, to ensure that operations in all circumstances and each segment of the company is being based on the values and principles as defined by the Ethical Codex. Serbian national proverbs and short wisdom sayings give much aid to definition of those principles. The aid in the codex rules also comes from ethno psychology, work psychology, ergonomics and other science disciplines and the results of their researches.

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IMPLEMENTATION OF NEW MODEL FOR REGISTRATION CUSTOMER-BASED TECHNOLOGIES INTERNET INTELLIGENT DEVICE

Zoran PAVLOVIĆ [1]

Abstract *– Training new business Conveying organization for rail passenger transport, requires the introduction of new possibilities of information technology. Information technology can improve business organization and also provide users with faster access to the necessary information. The introduction of new technologies is done in order to prevent technical and technological backwardness of this mode of transport and to facilitate the conditions for increasing market share. The organization must use your existing computer network and to implement new technologies. Expansive development of information technology brings newspapers in the philosophy of business that gravitate towards the automation of various processes. A special place in information technology occupies intelligent Internet devices is a network of various devices that are connected via a wired or wireless Internet network in which they are embedded sensors to enable interaction. On the way to ram devices collect and exchange information directly with one another, with other devices, and the information can be stored and analyzed. The subject of this research to develop a new model that registers the number of users on the basis of which we obtain information how much overhead funds were used in passenger traffic. Ability to store and analyze data can be used for designing new timetable.*

Keywords – Information technology, internet intelligent devices, sensors, the customers, the transport capacity railways

1. INTRODUCTION

The aim is to show how the Internet can improve business joint stock company Serbian train (SV).

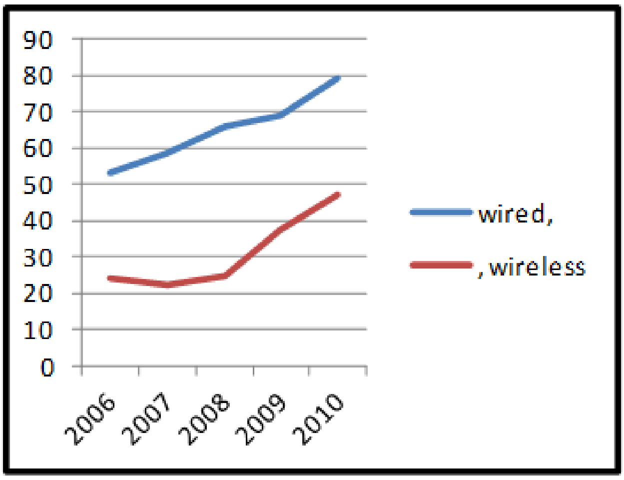

Fig. 1. The graphic use of wireless and wired Internet in organizations

Figure 1 shows the use of wireless and wired Internet in the Republic of Serbia in organizations in the period from 2006 to 2010 [3]. Republic Institute for Statistics found that 100% of the organizations on the territory of the Republic of Serbia use computers and 99.1% have internet access [1]. Regarding passenger kilometers SV compared to the previous year rose by 12.4% [2].

Based on the statistical data and the list of passengers planning strategy SV. The strategy in the application of information technology can be reflected through the use of mobile terminals for ticket issue via the Internet [3].

SV via the Internet can be defined using a multimedia strategy of site transport organizations http://www.srbvoz.rs [4].

As noted above information technologies offer us a variety of options that can directly affect the operations SV. In this work, play an important role internet and devices.

Primarily we need to have information that is relevant. information that may affect the availability of transport capacity. SV ordinances performed on the basis of a list of service users (passengers) on the train

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(which has entered the cell to which the station is traveling).

Based on the processed data leads to the understanding that the utilization of transport capacity (passenger cars, electric trains) for a particular route for a certain train, on a particular day of the week, or for a certain period during the day. When the list of passengers carried by the train crew has an obligation to act in accordance with the regulations of traffic and commercial areas, there is a possibility that the data also to be entered in the table are not accurate or approximate the right number of passengers who came out and got in the car, or furniture.

On entry data in the table can affect the following:

1. Reduced number of train crew (one conductor can not be counted at the same time how many passengers entered or come out at one car,
2. Performance of commercial transactions (when writing and collection of tickets can be late to record the number of passengers flow lasts manipulation)
3. The total traffic operations (extraordinary events, runs, or jumping the passengers and the like).

Other opportunity for a list of passengers is when SV engage employees of another organization. Employees who participate in the census are arranged on each door and fill inventory lists. For this option SV rarely decide because there are additional expenses.

In one and in the second case there is a possibility that the data entered in the census lists were not accurate. When processing the raw data there do not have the same opportunity to the relevant information.

To get the relevant information SV must use the possibilities of information technology, in this case the internet intelligent devices. In further work will be shown a new model of registration of service users in electromotive trains.

2. INTERNET INTELLIGENT DEVICES IN THE APPLICATION FOR REGISTRATION SV CUSTOMER

Innovations in information technology in the future can have a positive influence on the business of SV. Internet intelligent devices (IOT) involves connecting devices on the Internet. Most often associated sensors and actuators [5]. IOT may be regarded as a network of devices that are connected through the Internet. Devices on the market with built-in technology that allows interaction with the internal state of the device itself or with outside influences.

Sensors are various devices that can register and responses to stimuli from the physical environment. The sensors can react to heat, light, sound and pressure. In our case for this paper sensors are needed to go to get the relevant data on the number of services in the electromotive set.

Devices that perform physical tasks are called actuators.

Given that this model is intended only for the registration of service users that are installed in the electric motor is necessary to set the following:

1. Sensor (allows the device to detect movements)
2. Small microprocessors (allows the processing of the collected data received from the sensors)
3. The communication unit (the initial object to read and receive information from other devices) and
4. Power (allows the unit provides electricity to make the device unable to work).

The system, which consists of field sensors that are connected to the wireless network represent the wireless sensor network. Sensors are used to collect raw data. The network processes the received data and generates information.

The characteristics of wireless sensor networks are:

1. High reliability,
2. Relatively high accuracy of the information necessary
3. Flexibility,
4. Low and affordable price and
5. Easy installation and deployment of sensors in space.

The main purpose of wireless sensor networks is the collection and submission of data and information on the network environment in advance given the needs of the user who uses the network.

Table 1 Presents a comparative view of wireless standards

Protocol	IEEE 802.15.1	IEEE 802.15.3	IEEE 802.15.4	PWT
frequency (MHz)	1402-2480	2400	928-2483,5	1910-1930
access channel	FHSS	CSMA-CA	CSMA-CA	TDMA-FDM
number of channels	79	4	10-16	16
Users per channel	7	250	255	12
modulation	GFSK	QAM-TCM	QPSSK	π/4 DQPSK
Speed data transfer	1Mbps	55Mbps	40kbps/ 250kbps	1.152 Mbps
tx Power (MW)	<100	<125	<1000	<2,90,200, 500
reach	10-100m	10m	10m	N/A

Realizing IOT solutions with the help of sensors, devices and the Internet can increase security, provide a lot more information and entertainment on the means of transport [6].

3. MODEL BASED ON IOT TECHNOLOGIES IN SV

After the acquired knowledge on the problem and to determine the basic components that we need to obtain accurate data regarding the number of users who have used electro-motor approach furniture design models.

where the embedded sensors. The sensors are activated only when the door is opened from a central point of the train driver's cabs.

Sensors that are in this way distributed in the train represent a sensor network. The logging data that the sensor is receiving forwarded to the router. The router can perform the following actions:

1. To store data in the file system,
2. To store data in a local database,
3. To store data in external database (intranet and internet)
4. Sending data to the Internet

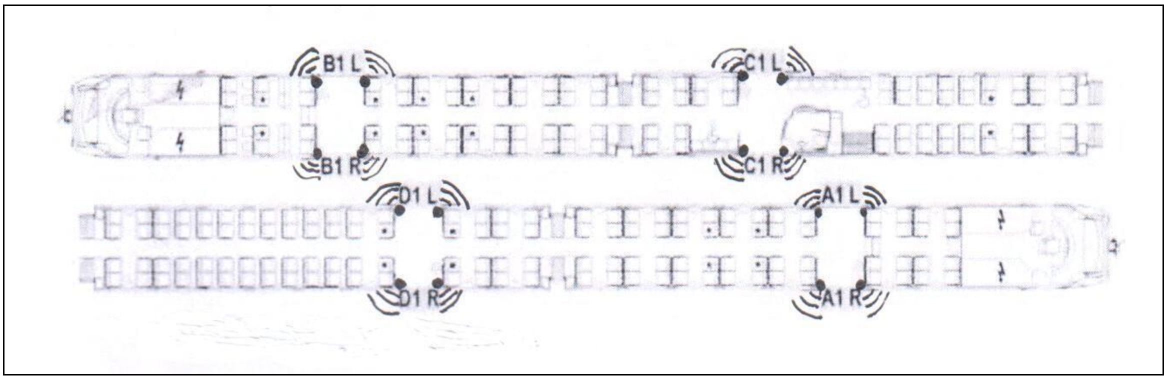

Fig. 2. Graphic sensors that are built into train

The total number of available seats is 465. In order to obtain accurate data apply IOT technology.

Figure 2 shows a set of train where you can see the sensors that are installed next to the door reserved for input / output of the service user. As already mentioned sensors react to movement. You can see that on one side has four doors and a total of eight sensors.

Implementation of the system is based on devices and technologies IOT. Sensors should be installed electromotive furniture 413/417.

Basic information that is required of us are as follows:

1. Electromotive furniture is intended for use in regional and suburban passenger traffic,
2. The maximum speed of 160 km / h,
3. Electromotive furniture consists of 4 parts (two driver's cabs and two trailers)
4. The vehicle can operates in conjunction, to 3 and a composition composed of
5. Electromotive furniture is equipped with air conditioning, a vacuum toilet system, passenger information systems, video surveillance.

Of great importance is the capacity to work electromotive suites and is:

1. Seats 224
2. Switching seats 11 and
3. Places for standing (4 persons / m^2) 230

Figure 3 shows the location of the train by the door

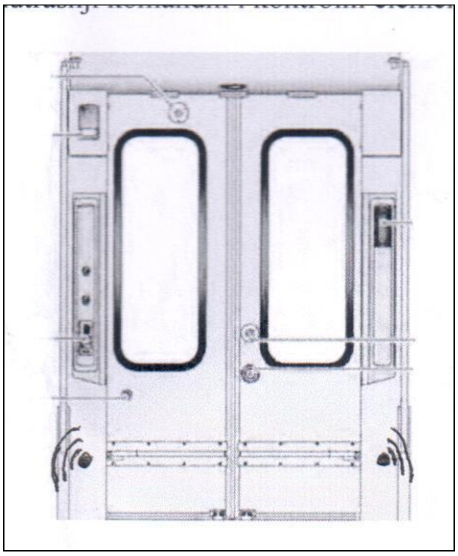

Fig. 3. Show the sensor implanted near the door

Routing refers to determining the path from end to end, how the information came to the destination [7].

4. CONCLUSIONS

Implementation of the system based on devices and technologies IOT addition to obtaining information on the number of service users has a contribution to the development and automation of processes in SV. Existing information and communication technology should be improved with new solutions that we offer IOT systems.

The model is presented in this paper can improve operations SV, planning increased traffic on the line where they set up a large number of passengers using the train as a means of transport. In many developed countries where the traffic is more dedicated IOT technologies.

The data that may be stored in a computer can be used in the design of the new timetable, which is necessary to analyze the summarized data on the number of passengers service user on certain days or months.

The resulting data can be immediately forwarded via the Internet to the internal network so i dispatchers operators COL center can see and track the number of used seats in the train that would enable the timely purchase of reservation of seats in the cells where gravitates and where it is expected a larger number of users. When the train used to the maximum it is necessary to restrict the sale and notify users of the service on a special train departure, if there is the available transport capacity or refer you to another train was on schedule.

The solution that is proposed in this paper enables business improvement SV, linking and tracking flows of service users. In this way, we can anticipate a relation in which a small number of users who use the train as a means of transport. In this way, SV reduce their costs, which are reflected through savings in maintenance, depreciation and exploitation on routes where higher costs than the income derived from the sale of tickets and the provision of related services in trains and stations.

The aim of this paper is to bring IOT devices and technology that is becoming more common in our society. The development of education relating to information technology and training employees through various seminars there is a possibility for a new feasible ideas.

The model is presented in this paper can be applied to other means of transport. The city rail when departures on schedule very frequent, costs are high, in this way in addition to obtain information about the number of passengers the service user can be competitive in the transport market in the number of places available and utilized. In this way, should be extended to boost the transport capacity and provide quality service and also increase the share of the transport market and the revenue that is the basis of modern and profitable business using IOT devices and technologies.

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ASSESSING THE EFFECTIVENESS OF TECHNICAL MEASURE ON SERBIAN RAILWAY CROSSINGS

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Abstract – *In this paper numerical example are provided to evaluate countermeasure at selected crossings in Serbia. In this way will be shown how the developed statistical models for estimation of Accident Frequency and Accident Severity on Serbian railway crossings can be used to assess the effects of the measures that would be used for a particular crossing.*

Keywords – Railway Crossing Safety, Accident Modification Factor, Active Traffic Control Devices, Passive Traffic Control Device.

1. INTRODUCTION

There are generally three different types of countermeasures that engineers can use to make crossings safer: 1) crossing closure or grade separation, 2) improving crossing geometry (changing road and railway crossing angle, improving type of surface, improving sight distance, 3) upgrading traffic control devices (light signals, half-gates, full gates, extended half-gates, four half-gates, separators, video surveilance, crosing ligtning) [1]. Experts in traffic sometimes have to make tough decisions regarding investments in road safety. Specifically, engineers can be expected to choose between a range of technologies and/or measures to rehabilitate the perceived safety problems when: 1) has little information on the effects of measures on security, 2) information is known, but from different regions, states, or countries from which direct generalization may not be suitable, 3) when technology and/or rates relatively untested and 4) when there are not enough funds that would enable full and careful testing of each of the possible measures through studies before and after the introduction of the measure.

Laughland et al. (1975) [2] introduced the concept of Collision or Accident Modification Factor (CMF or AMF) to reflect the safety benefits associated with different countramesures and to represent the expected changes in collisions after the implementation of countermeasures.

A wide variety of statistical methods have been proposed to estimete the countramesure effect. These metods include the cross-sectional stydu (CS); before–after study (BA); simulation study (simul); on-site engineering evaluation (eval.); survey of motorists perceptions (survey), attitudes, and preferences about measure. Table 1 lists nine measures from the relevant literature, that may offer improvement in safety at railway crossing and expected effects.

Most of these sources are based on data from the US, Canada and South Korea. For their possible application in our conditions should certainly apply some of the calibration factor. The application of these factors is known in the literature. For example, Harkey 2005. [3] investigated the literature from various regions, including North America, Australia and Europe. He was recommended to use at least 20% experience from North America to present the effects of certain measures. Analysts are faced with various problems in this aspect when it comes to this issue. Besides the issue of generalization of previous studies on other populations, there is the question of whether all the studies have the same weight and how to evaluate them in relation to different methodologies conducted research. Methodology for this assesment is given in [4].

Tab. 1. Some of the railway crossing measures and the

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Tab. 1. Some of the railway crossing measures and the expected effects

No	Countermeasure		Sources	Expected effects
1.	From signs to flashing lihgts	Flashing lights are the basic active warning devices used to inform highway users of the approach of a train to a crossing.	Hauer and Persaud (1987) BA [5]	AMF = 51%
2.	From signs to 2-quadrant gates	Automatic gates provide an additional level of control and are normaly used in conjuction with flashing lights.	Hauer and Persaud (1987) BA [5]	AMF = 79%
3.	From flashing light to 2-quadrant gates	Automatic gates provide an additional level of control and are normaly used in conjuction with flashing lights.	Hauer and Persaud (1987) BA [5]	AMF = 60%
4.	Full road 2Q gate	A full road two-quadrant gate is installed to block the entire road such that it prevents vehicles from maneuvering around the deployed gates.	Austin and Carson (2002) CS [6]	Presence of gate shown to be statistically significant; AMF derived from model found to be 0.05.
5.	Four-quadrant gate	A four-quadrant gate is installed at the crossing such that it prevents vehicles from maneuvering around the deployed gates.	Carroll et al. (2002) BA [7]	47 train movements before and 2550 after revealed a 100% reduction in violations.
6.	Constant warning time	Warning time refers to the time between device activation and arrival of a train at the crossing; a constant warning time system provides warning time constantly regardless of train speeds such that excessively long warning times are eliminated.	Berg et al. (1982) Eval. [8]	Long warnings resulted in drivers disregarding information; no AMFs obtained.
7.	Lighting	Lighting is installed to illuminate the crossing at night.	Mather (1991) BA [9]	Small sample of night time crashes (18) before to after (2); thus, AMF for night time crashes is around 0.167.
8.	Violation detection	A violation detection system such as video cameras is installed at the crossing such that when crossing violations are detected, safety solutions are provided.	Carroll et al. (2002) BA [7]	Crossing violations reduced between 36%–92%,while crashes reduced by 70%–100%; conservative AMF inferred is 0.30
9.	Separator	Separators are physical obstacles that are placed in the middle of road on both sides of the level crossing, to supplement the system with 2Q gates, in order to prevent violations of the 2Q gates .	Carroll et al. (2002) BA [7]	Reduce the number of motorist violations by an additional 75 %. AMF = 0.23
			Ko et al. (2003) BA [10]	Reduction in violations from 25 to 1 was statistically significant.

2. ASSESSING THE EFFECTIVENESS OF SELECTED TECHNICAL MEASURES

In this section, numerical examples are provided to evaluate countermeasure at selected crossings in Serbia. This application demonstrates how the proposed model can be used to estimate countermeasure effect for specific crossings. In this way will be shown how the developed statistical models for estimation of Accident Severity and Accident Frequency can be used to assess the effects of the measures that would be used for a particular crossing. This models are presented in [11] and [12].

For the purpose of ilustration upgrading warning devices from signs to 2-quadrant gates, countermeasure are considered.

2.1. Assessing the effectiveness of selected countermeasure according to Accident Severity and Accident Frequency models on Serbian crossings

2.1.1. Assessing the effectiveness of selected countermeasure according to Accident Severity model

In this section upgrading warning devices from signs to 2-quadrant gates countermeasure at a particular crossing are considered according to Accident Severity model.

It should be noted that the characteristics of level crossings in accordance with variables that are accepted models of Accident Severity and Accident Frequency.

First, the ratio of the probability (RRR_1) is calculated before and after the introduction of measures for less severe accidents (y = 1):

$$RRR_1 = exp(-\beta_{1;0} + \beta_{1;1}VOSIG - \beta_{1;2}VOBR + \beta_{1;3}SIRPP + \beta_{1;4}MBRZ + \beta_{1;5}EXPO - \beta_{1;6}BRKOLB - \beta_{1;7}KATPRM) \quad (1)$$

$$RRR_1^p = exp(-5.76 + 1.33 \cdot 1 - 1.28 \cdot 0 + 1.26 \cdot 1 + 0.22 \cdot 8 + 0.08 \cdot 12 - 0.87 \cdot 0 - 0.39 \cdot 1) = 0.43 \quad (2)$$

$$RRR_1^n = exp(-5.76 + 1.33 \cdot 0 - 1.28 \cdot 0 + 1.26 \cdot 1 + 0.22 \cdot 8 + 0.08 \cdot 12 - 0.87 \cdot 0 - 0.39 \cdot 1) = 0.114 \quad (3)$$

$$AMF_{ijm} = \frac{RRR_1^n}{RRR_1^p} = \frac{exp(0)}{exp(\beta_{1;1} \cdot 1)} = exp(-\beta_{1;1}) = exp(-1.33) = 0.264 \quad (4)$$

where:

$RRR_1^p -$ ratio of the probability $y = 0$ and $y = 1$ before introduction 2-quadrant gates,

$RRR_1^n -$ ratio of the probability $y = 0$ and $y = 1$ after introduction 2-quadrant gates,

$\beta_{1;1} -$ constant; $\beta_{1;1} - \beta_{1;7} -$ regression parameters.

Independent variables are VOSIG $-$ warning devices road signs; VOBR $-$warning devices full gates; SIRPP $-$ crossing width; MBRZ $-$ maximal train speed at a given crossing; EXPO $-$ AADT $\cdot$ daily trains; BRKOLB $-$number of tracks; KATPRM $-$ railway category.

$AMF_{ijm} -$ the expected reduction of less severe accident on particular crossing i for given countermeasure j from the model Accident Severity m.

As a result, according to Accident Severity model, it can be expected 74 % reduction of less severe accidents after the upgrading crossings from signs to 2-quadrant gates.

Then, the ratio of the probability (RRR_2) is calculated before and after the introduction of measures for more severe accidents (y = 2):

$$RRR_2 = \exp(-\beta_{2;0} + \beta_{2;1}VOSIG - \beta_{2;2}VOBR + \beta_{2;3}SIRPP + \beta_{2;4}MBRZ + \beta_{2;5}EXPO - \beta_{2;6}BRKOLB + \beta_{2;7}KATPRM) \quad (5)$$

$$RRR_2^p = \exp(-5.55 + 0.65 \cdot 1 - 1.93 \cdot 0 + 1.2 \cdot 1 + 0.12 \cdot 8 + 0.05 \cdot 12 - 0.36 \cdot 0 + 0.74 \cdot 1) = 0.245 \quad (6)$$

$$RRR_2^n = \exp(-5.55 + 0.65 \cdot 0 - 1.93 \cdot 0 + 1.2 \cdot 1 + 0.12 \cdot 8 + 0.05 \cdot 12 - 0.36 \cdot 0 + 0.74 \cdot 1) = 0.129 \quad (7)$$

$$AMF_{ijm} = \frac{RRR_2^n}{RRR_2^p} = \frac{exp(0)}{exp(\beta_{2;1} \cdot 1)} = exp(-\beta_{2;1}) = exp(-0.65) = 0.52 \quad (8)$$

where:

$RRR_2^p -$ ratio of the probability $y = 0$ and $y = 2$ before introduction 2-quadrant gates,

$RRR_2^n -$ ratio of the probability $y = 0$ and $y = 2$ after introduction 2-quadrant gates,

$AMF_{ijm} -$ the expected reduction of more severe accident on particular crossing i for given countermeasure j from the model Accident Severity m.

As a result, according to Accident Severity model, it can be expected 48% reduction of more severe accidents after the upgrading crossings from signs to 2-quadrant gates.

2.1.2. Assessing the effectiveness of selected countermeasure according Accident Frequency model

In this section upgrading warning devices from signs to 2-quadrant gates countermeasure at a particular crossing are considered, according to Accident Frequency model.

First, accident number probability at particular crossing is calculated before the introduction of measures.

The following steps are developed:

Step 1: Calculate expected number of accidents on particular crossing, according to ZIP model, before introducing measure:

$$\lambda_i = exp(-1.668 + 1 \cdot 0.984 - 0 \cdot -1.394 - 0 \cdot 0.530 + 12 \cdot 0.020 + 8 \cdot 0.122 - 0 \cdot 0.370 - 1 \cdot 0.228 + 0 \cdot 0.188) = 0.40 \quad (9)$$

$$p_i = exp(-1.159 + 1 \cdot 2.012 - 0 \cdot 0.579 - 0 \cdot 22.4 - 12 \cdot 0.0578 + 8 \cdot 0.0776 + 0 \cdot 0.462 - 1 \cdot 3.860 + 0 \cdot 3.771) = 0.049 \quad (10)$$

According to: $N_{pijk} = (1 - p_i)\lambda_i = (1 - 0.049)0.4 = 0.38$ (11)

where:

$\lambda_i -$ the expected probability of accidents on crossing i before introducing measure, according to count model,

$p_i -$ the expected probability of accidents on crossing i before introducing measure, according to zero model,

$N_{pijk} -$ number of assesment accident on crossing i before introducing j, for model k.

Step 2: Calculate expected number of accidents on particular crossing, according to ZIP model, after introducing measure:

$$\lambda_i = exp(-1.668 + 0 \cdot 0.984 - 0 \cdot -1.394 - 0 \cdot 530 + 12 \cdot 0.020 + 8 \cdot 0.122 - 0 \cdot 0.370 - 1 \cdot 0.228 + 0 \cdot 0.188) = 0.150 \quad (12)$$

$$p_i = exp(-1.159 + 0 \cdot 2.012 - 0 \cdot 0.579 - 0 \cdot 22.4 - 12 \cdot 0.0578 + 8 \cdot 0.0776 + 0 \cdot 0.462 - 1 \cdot 3.860 + 0 \cdot 3.771) = 0.0061 \quad (13)$$

$$N_{nijk} = (1 - 0.00661) \cdot 0.150 = 0.149 \quad (14)$$

where:

$\lambda_i -$ the expected probability of accidents on crossing i after introducing measure, according to count model,

$p_i -$ the expected probability of accidents on crossing i after introducing measure, according to zero model,

$N_{nijk} -$ number of assesment accident on crossing i after introducing measure j, for model k.

Step 3: Calculate AMF according to number of assesment accident on crossing i before and after introducing measure j, for model k:

$$AMF_{ijk} = \frac{N_{nijk}}{N_{pijk}} = \frac{0.149}{0.38} = 0.392 \quad (15)$$

where:

$AMF_{ijk} -$ the expected reduction in number of accident on particular crossing i for given countermeasure j from the model Accident Frequency k.

As a result, according to Accident Frequency model, it can be expected 60.8 % reduction in accidents after the upgrading crossings from signs to 2-quadrant gates

3. CONCLUSION

In this paper numerical examples are provided to evaluate countermeasure at selected crossings in Serbia. This application demonstrates how the proposed model of Accident Severity and Accident Frequency can be used to assess the effects of the measures that would be used for a particular crossings.

Upgrading warning devices from signs to 2-quadrant gates countermeasure at a particular crossing are considered. As a result, according to Accident Severity model, it can be expected 74 % reduction of less severe and 48% reduction of more severe accidents after the upgrading crossings from signs to 2-quadrant gates. According to Accident Frequency model, it can be expected 60.8 % reduction in number of accidents after the upgrading crossings from signs to 2-quadrant gates.

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INFLUENCE OF BOZIC BRAKE ON DEVELOPMENT OF RAIL TRAFFIC

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Abstract *– The paper gives a brief view of development of rail traffic in the world before the invention of Serbian engineer Dobrivoje S. Bozic. At that time, undeveloped braking system of railway vehicles was a significant obstacle for further development of rail traffic. The problems that existed in braking of railway vehicles before the introduction of Bozic's innovations are analyzed. Bozic's solution and its influence on the development of pneumatic braking systems of passenger? and freight railway vehicles is described. In this invention, Bozic is the first in the world who designed, made, implemented and patented the distributor with three pressures in the brake system of railway vehicles. This innovation has significantly contributed to faster development of railway vehicles, as well as the entire rail traffic.*

Keywords – Dobrivoje Bozic, Bozic brake, braking, railway Vehicles.

1. INTRODUCTION

Invention of the steam engine in 1782 of Scottish inventor James Watt significantly contributed to the rapid development of industry, and especially traffic and transport. The development of rail transport is closely linked to the success of the first steam vehicle on the tracks, designed by the Richard Trevithick in 1804 (Fig. 1). This vehicle is hauled a certain number of laden wagons, wherein the moving speed was about 10 km/h.

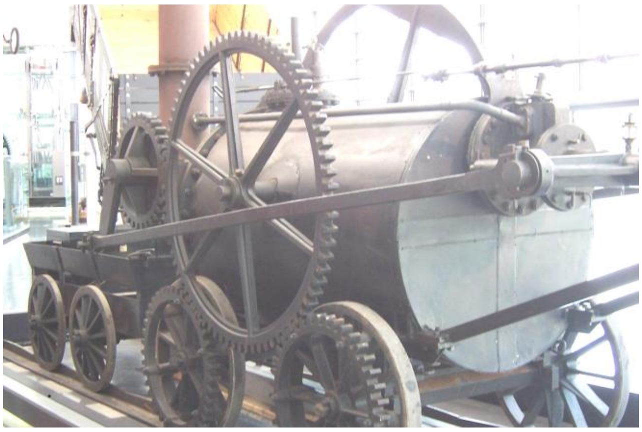

Fig.1. The first steam vehicle on the tracks, designed by the Richard Trevithick in 1804

During the 19th century, in almost all of Europe, railways changed the existing network of stagecoaches (Fig. 2).

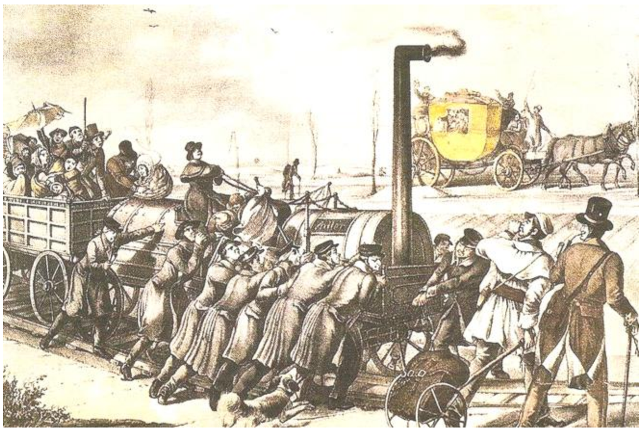

Fig.2. The stagecoaches and railway during the 19th century

The first railway line for public rail traffic was built in 1825 in England on relation Darlington – Stockton (Fig. 3). English engineer George Stephenson designed and made a first stem locomotive that was hauled 22 passenger and 12 freight wagons, apart from participating in building this railway. This locomotive was called "Locomotion" and its maximal speed was 16 km/h (Fig. 4a). Stephenson was personally driving this locomotive which was not equipped with a cabin and a place for driver (Fig. 3). Due to the significant outcomes in development, 1825 was considered as the beginning of the organized railway traffic, while the

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name "locomotive" entered into the official use.

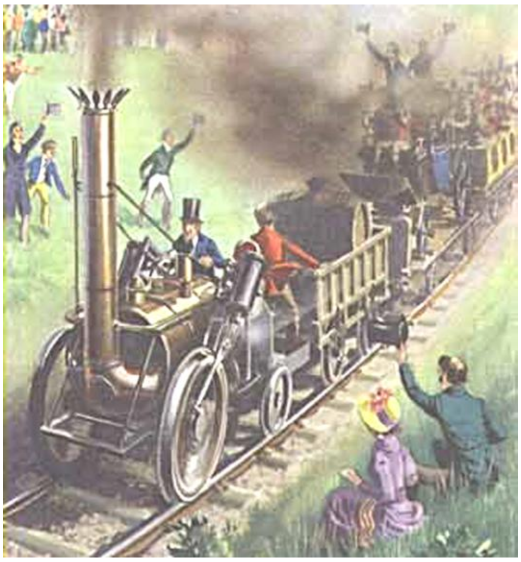
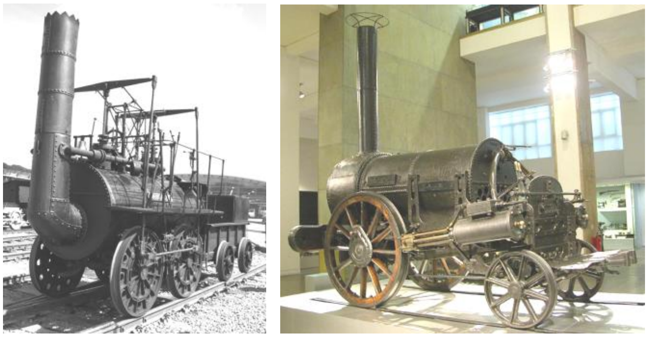


Fig.3. The beginning of the organized railway traffic in 1825

Numerous disadvantages and technological development caused that "Locomotion" very soon become outdated and unsafe. The first railway accident occurred in 1828, when a boiler of "Locomotion" exploded, and the train driver was killed.



a) "Locomotion" *б) "Rocket"*

Fig.4. The museum exhibits of Stephenson's locomotives

The substantial progress was achieved in 1827, when a Frenchman M. Segen invented the boiler with pipes. Two years later (1829), George Stevenson applied this invention on his famous locomotive "Rocket" (Fig. 4b), whose maximal speed was 47 km/h, which was incredible for that time.

After a certain time from development of steam locomotives, the development of electric locomotives and locomotives with internal combustion engines started. The first electric locomotives were made in Germany in 1879 and America 1880. With the advent of the diesel engine in 1897, which was designed by German inventor and engineer Rudolf Diesel, the development of diesel locomotives commenced. Although they had been designed before the diesel locomotives, electric locomotives had slower development until the end of the Second World War.

As in case of locomotives, there was race in the development of braking system of railway vehicles. After "Westinghouse" brake in America, in Germany is appeared the brake "Knorr", and in Switzerland brake "Oerlikon". While the Stephenson with his inventions enabled trains to move, Westinghouse, Knorr and others developed air brakes which had significant disadvantages until the appearance of the Serbian engineer Dobrivoje Bozic.

By signing the Congress of Berlin 1878, Serbia was pledged to build a railway line Belgrade – Nis – Vranje, that practically meant a merger of Ottoman and Austro-Hungarian empires. The railway line Belgrade – Nis was a part of a planned line Berlin – Baghdad. The completion of this line marks the beginning of the existence of Serbian Railways. The festive train passed the first Serbian railway on 4 October 1884, and after eleven days the official rail traffic on line Belgrade – Nis started.

For construction of the railway line Belgrade – Nis, Serbia contracted the so-called Bontoux concession. Immediately after the first contact with a major Western capital, one of the biggest financial scandals in Serbian history appeared. Inspired with the events of the downfall of Bontoux General Union for construction and exploitation of railways, even Emil Zola wrote the novel "Silver". In relation to this concession, prof. Slobodan Jovanovic wrote: "Spoilage of our political natures began immediately under the influence of foreign gold" [1].

2. BRAKING OF RAILWAY VEHICLES

The movement of train takes place under the influence of its total mass and different forces (traction forces, resistance forces, braking forces, etc.) (Fig. 5) [2].

Fig.5. The train movement under the influence of its total mas and forces of traction, resistance, braking, etc.

The braking system of railway vehicles has a role to slow and stop the train. The fact that even today the trains are moving faster uphill than downhill testifies about the size of technical problem of safe braking of mass of several thousand tons.

In the beginning of the development of railway vehicles, the braking force changed to manual one, after which the American entrepreneur and engineer George Westinghouse designed pneumatic brake. Despite this, until the First World War the trains braked manually in Europe.

At the conference of the winning countries of the

First World War in 1923, France submitted a proposal in which Westinghouse's brake was recommended. At the same conference, the representative of former Yugoslavia recommended the general reception of Bozic brake, as much better solution. Finally, this Bozic's patent was, after numerous tests, accepted in 1928.

Until the advent of Bozic's invention, braking of railway vehicles was performed directly (non-automatic), according to the scheme shown in Fig. 6.

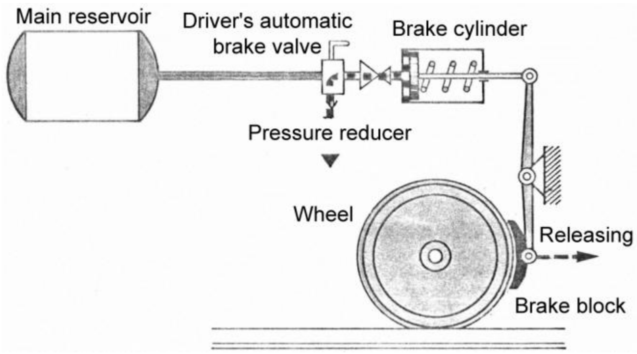


Fig.6. The direct (non-automatic – exhaustible) brake

In direct (non-automatic or exhaustible) brakes, air from the main reservoir via the air-operated equipment is arriving to the brake cylinder. These brakes have single-stage releasing, which means that once started, releasing can not be interrupted. In this case, the distributor of brake has the two distribution pressures: the main instalation – auxiliary reservoir. In these brakes, if the train is braked to any degree, as soon as the main installation is little supplemented, the brakes will fully stop with braking. At the same time, the auxiliary tank will not be completely supplemented because pressure in the main installation has not reached its maximum value. If the process of ''braking – releasing'' is repeated several times in succession, the braking force will be increasingly diminished as the pressure in the auxiliary reservoir is decreasing, i.e. the amount of compressed air is exhausted (Fig. 7).

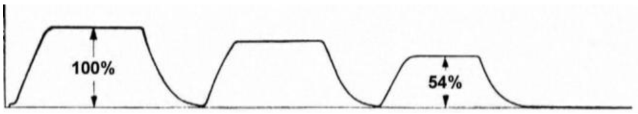


Fig.7. The exhaustible brakes – change of air pressure in brake cylinder

The big drawback of these brakes is that in the case of rupture of the train there will be no automatic braking. Beside that, at running on long downhills there is a risk that brake will not be able to provide sufficient braking force. The huge disadvantage of these brakes is that they do not have regulation of size of the braking force in relation to the mass and speed of the vehicle. Also, they do not have synchronization of braking from the first to the last vehicle, so individual vehicles were very often collided or train was ruptured.

3. CONTRIBUTION OF DOBRIVOJE BOZIC TO DEVELOPMENT OF BRAKING OF RAILWAY VEHICLES

From the previous chapters it is obvious that the biggest contributions to the development of railway gave English, French, German, and American engineers. However, the braking of railway vehicles was not resolved in an appropriate way. Further development of railway (increase of running speed and mass of railway vehicles) was not possible without solving this problem.

Dobrivoje Bozic (Fig. 8) was born on 23 December 1885 in Raska, Serbia. His invention was created in the period 1911–1914 when he worked in railway workshop in Nis. He designed and patented braking system of railway vehicles in which three pressures distributor was first applied (main installation – control cylinder – brake cylinder) [3].

Fig.8. Dobrivoje Bozic

With Bozic's distributor with three pressures (Fig. 9), the problem of gradual releasing of railway vehicles was resolved for the first time. Also, the risk of ineffectiveness of previous brakes with two pressures that, due to discharge (exhaustion) of the auxiliary tank on long downhills , do not achieve the necessary braking force, is eliminated with Bozic's solution (Fig. 10).

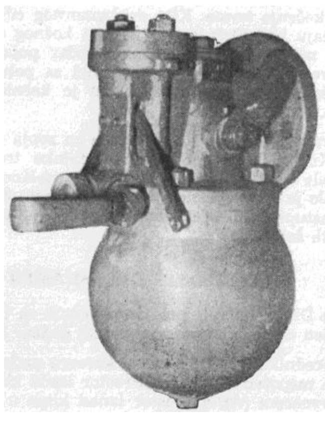


Fig.9. Bozic's distributor

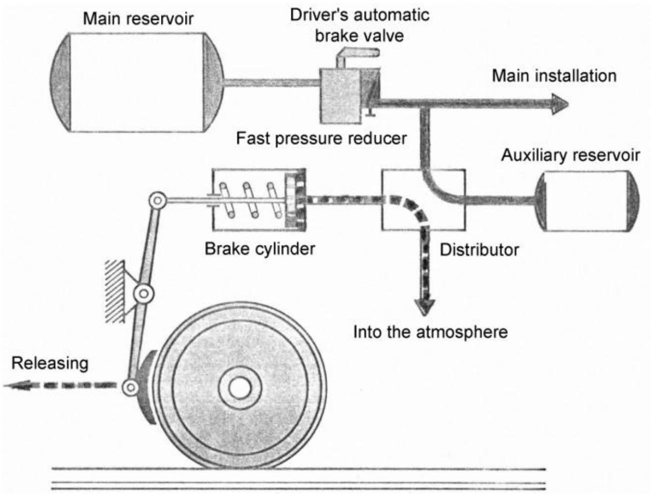


Fig.10. The working principle of indirect (automatic – exhaustible) or Bozic brake

In Bozic's brakes reducing the braking force can be performed gradually. These brakes are also called the inexhaustible, because the auxiliary tanks are being refilled for entire time of braking and releasing, so that pressure in the brake cylinder remains constant (Fig. 11).

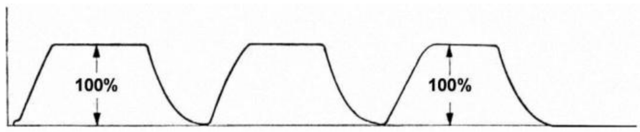


Fig.11. The inexhaustible brakes – change of air pressure in brake cylinder

Bozic's distributor was designed so that for each load of vehicle, the pressure in the brake cylinder was adjusted automatically. This is accomplished with a special beam scale device in distributor of pressure. In this way, empty or poorly loaded railway vehicles are braked with smaller force and more laden vehicles with greater force. It is important to note that in that time other countries were developing the brakes with two braking cylinders. In the case of empty wagon, only the one brake cylinder is in function.

Because of its interest, large companies tried to criticize Bozic's patent through their representatives, but all subsequent constructions of braking system were based on his simpler, safer and cheaper solution. The three Bozic's pressures are used even today.

In addition to the previously implemented and internationally accepted patents, Bozic designed and proposed a device based on the principle of centrifugal regulator which, at low speeds of the train, bring down the pressure in the brake cylinder on the appropriate measure. This would prevent blocking of the wheels at braking, and therefore the formation of so-called flat spots on the wheels of railway vehicles. This proposal would enabled problem solution of change of the braking force depending on the running speed of railway vehicles.

Although in this manner the braking distance of railway vehicles is significantly reduced, Bozic's proposal had not been accepted at that time. The main reason for that is probably because at that time there was not enough knowledge about the theory of contact of two rounded bodies. The science and engineering practice explained and accepted this Bozic's stance until many years later, and today it is in the application at modern railway brakes.

4. CONCLUSION

With his inventions Dobrivoje Bozic enabled safer, better and cheaper braking of railway vehicles. This has led to a further and more rapid development of rail traffic throughout the whole world. Based on all previous considerations it can be concluded that Bozic's contribution to the development of brakes of railway vehicles is at the planetary scale, and in many cases it was far ahead of time in which he had created it. With full right it can be say that Dobrivoje Bozic was the forerunner of the development of ABS braking system (Anti-lock Braking System), which is today widely used in the road vehicles.

Finally, it can be concluded that the development of rail traffic is not a mertit of one man, but it is a result of several generations of engineers and technicians from several countries. In that sense, thanks to the mechanical engineer Dobrivoje Bozic, Serbia has a very significant place. He is one of the examples of world inventor and victims in the same time, although he changed the world for the better.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Serbian Ministry of Science and Technology for supporting this paper through project TR35038.

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '16

MEASURES APPLIED TO THE STATIONS IN ORDER TO IMPROVE THE PASSENGER TRANSPORT SERVICES IN RAILWAY TRANSPORT

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Abstract *– In order to make the railway transport protagonist of the passenger transport, it is required to improve the passenger service. First, it should be done in the city areas, its municipalities and in suburban settlements from which the greatest number of passengers is transported to big centers. Therefore, it is required to adapt existing stations and have new ones and in that way offer additional possibilities to the passengers to use the fast and comfortable traveling by rail. This paper considers the condition of the platforms in stations of single-track and double-track railway lines. Then, from the safety and utilization suitability aspect, the basic characteristics (advantages and disadvantages) of particular solutions are considered. At the end, paper defines the possible corrective measures in the stations in order to improve the railway service in passenger transport. When defining the corrective measures, the technical and technological parameters of passengers transport service quality are used as basis.*

Keywords – station, platform, railway transport, service quality, passengers safety

1. INTRODUCTION

The quality of passenger services determines, in great deal, the position of railway transport in public passenger transport system. In order to increase the level of quality in railway transport, it is required to improve the passenger services, first of all in the areas from which the greatest number of passengers travels to big centres. In order to offer the additional opportunities to the passengers for fast and comfortable transport by rail, it is necessary to adapt the existing stations and to have new ones.

From the transport service users and/or passenger's aspect, the qualitative solutions for the adaptation of the stations should be offered. These solutions must meet more criteria (station accessibility, possibility to travel directly without connections, advance purchase of train tickets etc.) which comply with the certain European standards, above all those related to the use of public transport by aged population and disabled persons.

The condition for maintaining safe station is platform infrastructure which includes platforms, access roads, underpass (pass under the railway), elevator, security marks (the limits for the persons' movements at the platform - yellow line beside the platform edge along its entire length, which warns the persons who are at the platform in which extent they can move safely and not to be endangered by train which is running the tracks next to the platform) and signalling marks (signal mark for the place of stopping). Platform at the station must also have the eaves, wastebasket, benches, Timetable board, etc [7].

2. TECHNICAL AND TECHNOLOGICAL ELEMENTS FOR STATION ADAPTATION

Station is the official place on the railway line intended for limited passenger transport (passengers' boarding and getting off) [1].

Platform is the place at the station intended for the passenger's movements. There are external (access) platforms and inter-platforms (track platforms) [3].

For the complete safety of passengers, the platform infrastructure must be dimensioned adequately and in appropriate position. The minimum length of the platform in the station should not be less than the length of the longest train which operates on tracks or which stops at the station.

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1.1. Position of the platforms in the stations of double-track

In order to provide the passengers safety during boarding the train and getting-off the train, in the stations with two platforms, the operation of the trains in opposite directions should be regulated in the way when passenger train is standing in the station, other train does not operate along adjacent track (this can be provided by implementation of protection signals) [1]. This technical solution for platforms causes the difficulties during the trains operation, therefore the passengers have to be duly informed about the operation of train at adjacent track (written notice, information via Public Address System or verbal notice given by official staff). If there is no safety fence between the tracks, the safety of passengers can be slightly jeopardized.

The complete safety of the passengers is provided by construction of inter-platform. Also, it is not necessary to regulate the transport of the trains operating in opposite directions. According to this, the trains can operate in the station at the same time, and this is very important for the organization of technological process of train transportation, or for Timetable respecting (maintaining).

The Figure 1 shows an example for the platform position in the station of double-track, with following features:

- two platforms are on the external side of tracks,
- platforms are parallel,
- the platform can be reached by access road.

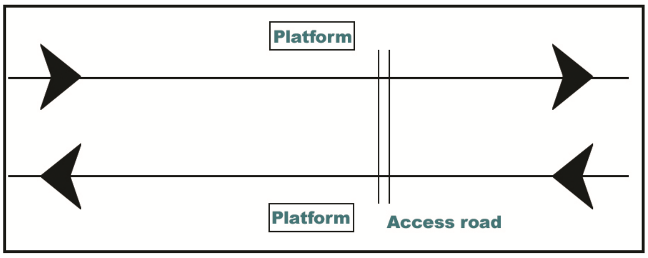

Fig.1. Layout of the platform position in the station with double-track (example 1)

Disadvantages of this solution are:

- passengers are not safe when passing from one track to the other one,
- passengers are not safe during the train bypassing,
- demanded organization of train transportation along an irregular - adjacent track.

This solution has no advantages.

Figure 2 shows an example for the platform position in the station of double-track, with following features:

- two platforms are on external side of the tracks,
- platforms are not parallel,
- the platform can be reached by access road.

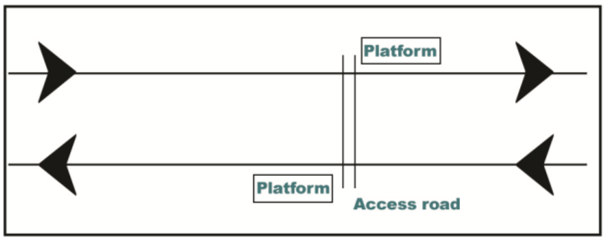

Fig.2. Layout of the platform position in the station of double-track (example 2)

Disadvantages of this solution are:

- passengers are not safe when passing from one track to the other one,
- demanded organization of train transportation along an irregular - adjacent track.

The advantage of this solution is the safety of the passengers during bypassing the trains.

Figure 3 shows an example for the platform position in the station of double-track, with following features:

- two platforms are on the external side of tracks,
- platforms are not parallel,
- the platform can be reached by underpass.

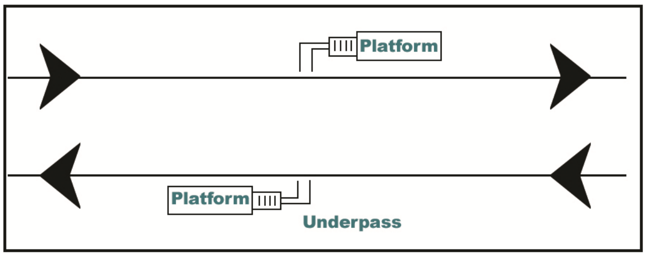

Fig. 3. Layout of the platform position in the station of double-track (example 3)

Disadvantage of this solution is the demanded organization of train operation on irregular-adjacent track.

Advantages are:

- safe passing of passengers,
- passengers are safe during train bypassing.

Figure 4 shows an example for the platform position in the station of double-track, with following features:

- platform is placed between the tracks,
- the platform can be reached by access road.

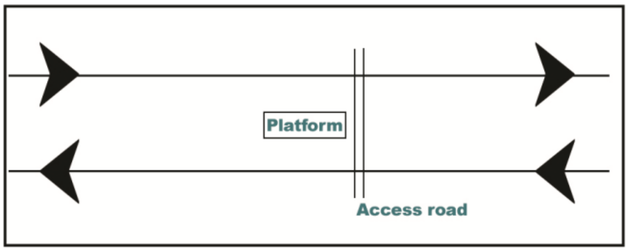

Fig. 4. Layout of the platform position in the station of double-track (example 4)

Disadvantages of this solution are:

- passengers are not safe when passing from one track to the other one,
- passengers are not safe during train bypassing.

The advantage is easier organization of train operation on irregular - adjacent track.

Figure 5 shows an example for the platform position in the station of double-track, with following features:

- platform is placed between the tracks,
- the platform can be reached by underpass.

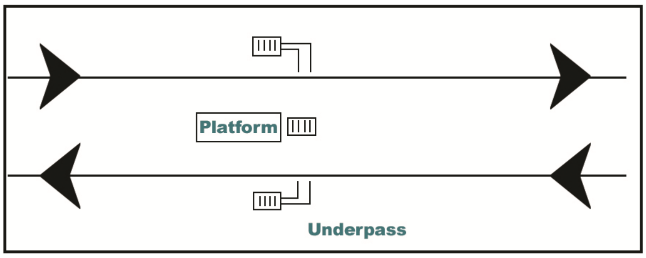

Fig. 5. Layout of the platform position in the station of double-track (example 5)

There are no disadvantages in this solution.

Advantages are the following:

- safe passing of the passengers,
- passengers are safe during train bypassing,
- easier organization of trains operation on irregular - adjacent track.

Constructing only one platform will result in the great savings in the expenses for the purchase of eaves, speakers, benches, wastebaskets, fire-extinguisher, video surveillance system and other equipment.

1.2. Position of the platforms in stations of single-track

Due to the safety of the passengers on single-track railway lines, access to the station should be provided on both sides through the underpass. Also, the possible drafts for the construction of the second track have to be respected in the future and the platform should be placed on the side so that it would be between the tracks after eventual construction of the second track is made.

Figure 6 shows an example for the platform position in the station of single-track, with following features:

- platform is on the external side of track or railway line,
- the platform can be reached by access road, from both sides of line.

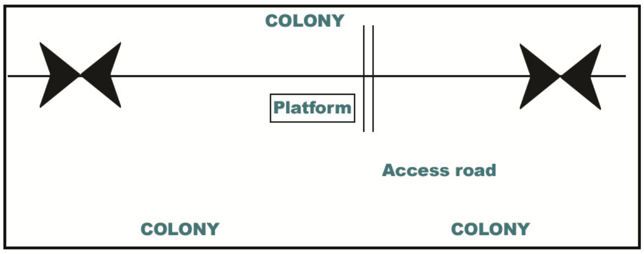

Fig. 6. Layout of the platform position in the station of single-track (example 1)

Disadvantage of this solution is that the passengers are not safe during passing the railway line.

This solution has no advantages.

Figure 7 shows an example for the platform position in the station of single-track, with following features:

- platform is on the external side of track or railway line, that is to say inter-platform, considering future track,
- the platform can be reached by underpass from both sides of railway line.

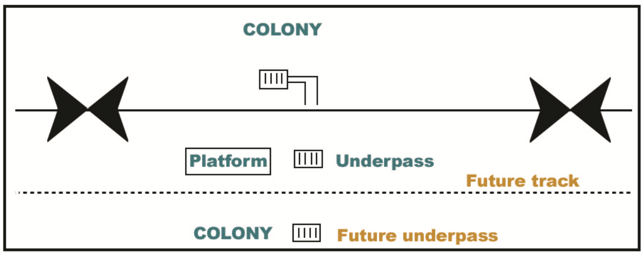

Fig. 7. Layout of the platform position in the station of single-track (example 2)

This solution has no disadvantages.

The advantage is the safe passing of the passengers.

Public Address System for the passengers` information (information about the arrival and departure of trains, train delays, trains length, warnings on freight trains transportation etc.), with acoustic system (sound) and Image Notice on displays contributes to the quality of transport services. Information over the speakers and displays are necessary for disabled persons (especially for those with problems in hearing and seeing). The size, colour and brightness of the notices on displays must be appropriate and standardized, with automatic adjustment of the volume as per the noise in the station.

The length of the eaves has to be adjusted to the length of the trains and number of passengers who are in the station accordingly. If the eaves is short, and there are no information on displays about the length of the arriving train, the passengers will get on the train and get off the train mostly through the door closest to the eaves (especially in the period of bad weather conditions). The consequences can be the longer stay of the train in the station and delays.

The access to the stations has to be arranged in appropriate way, or adjusted to the passengers who come by cars. This means that nearby the railway stations or stops should be constructed the car parking for passengers who come by their cars and who continue their trip by train.

3. COMMERCIAL SERVICES IN RAILWAY TRANSPORT FOR PASSENGERS PURPOSES

Installing the automatic devices for ticketing sale, passengers are offered by many opportunities (possibility to buy a train ticket at any time, multilingual users` interfaces, suitability for disabled persons, possibility in cash payment, by credit cards, by cell phones etc.).

In development of the information electronic portals where passengers can get other information of railway passenger transport too (connection possibilities, Timetable, train delays etc.), the quality of railway services is additionally improved. In order to protect these devices from vandalism, it is necessary to provide the video surveillance system.

Also, in order to improve the railway transport services, it is useful that travel tickets are valid for travelling to all stations and stops in narrow areas of big cities, so that passengers have no need to extend their trips and make the additional payments for the tickets in narrower city areas.

4. CONCLUSION

Stations are official places exclusively intended for getting in and getting off the passengers in trains for passenger transportation. The condition for the safe functioning of the stations is platform infrastructure. Naturally, the most important part of platform infrastructure either are platforms, external (accessible) or inter- platforms (track platforms).

In the stations of double-track, the best solution for the platform position is the inter-platform, because it makes easier the organization of passenger's trains transportation.

With reference to safety performance, the most acceptable solution for access to the platform, either single-track or double tracks railway lines, is the underpass.

For the better servicing of the users of transportation - disabled persons, it is necessary to adjust the platform infrastructure and to technically equip the rolling stock so that they meet their needs.

The condition of the platform infrastructure, its flexibility towards the passengers and equipment of stations significantly affect the quality of the services in railway transport, and by itself, affect passenger's decision on the type of transport mode they will use.

In order to attract passengers, the railway, in addition to numerous organizational and technical measures, should adapt the platform infrastructure, as this part of infrastructure is the first one the passengers face with, and mostly according to its condition, passengers will form opinion about the railways and the services they offer.

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THE EFFECT OF AGING TEMPERATURE ON CARBON BLACK REINFORCED TERNARY RUBBER BLEND IN RAILWAY INDUSTRY

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***Abstract** – Rubber has had a very long history in railway service. Because of its excellent physical characteristics, the production of rubber springs is one of the most important usages of rubber. The rubber elastic element is used as a component of the elastic wheel of the urban transport vehicles, of the suspension system or as a part of the railroad infrastructure. Rubber products are always explored to specific conditions. Aging temperatures play important role in changing the mechanical behavior of rubber compounds for railway vehicles. The effect of thermal aging (100°C for 72 h and 168 h) test carried out to investigate the effect of aging times on the tension properties of rubber blend composites based on polyisoprene (NR), polybutadiene (BR) and styrene butadiene rubber (SBR) (NR/BR/SBR=25:25:50) compounds filled with different carbon black (CB) loading. The obtained results of six different compositions for NR/BR/SBR rubber blend with 0, 20, 40, 60, 80 and 100 phr of CB were analyzed. Tensile strength (Ts) and elongation at break (Eb) of the compounds decreases with time of aging increases.*

Keywords –* NR/BR/SBR *rubber blends, carbon black, mechanical properties, thermal aging, railway industry.

1. INTRODUCTION

Polymer blend is prepared to meet performance requirement that cannot be satisfied by the current available commodity polymer or properties lacking in the component polymers [1]. Blending of rubbers also enhance the physical properties of the final vulcanized product [2]. The properties of polymer blends can be controlled by regulating blend morphology, blend compositions and processing condition [3]. A standard tire formulation for trucks as well as cars is a physical blend of natural rubber/styrene-butadiene rubber (NR/SBR) or natural rubber/butadiene rubber (NR/BR) blends. Natural rubber and styrene/butadiene rubber have been blended for a long time for many purposes such as lowering the compound cost [4]. Reinforcement of elastomers is of great importance for the structuring of materials in new technologies. Reinforcement of elastomers is a particularly complicated process if cross linked material contains more than one type of precursor cross linking. By creating a multi-phase system, characteristics of individual phases can be partly preserved or significantly changed due to the influence of intermolecular interactions. Therefore, the urban transport vehicles, of the rubber blend as a part of the railroad infrastructure are directed towards the use of existing starting polymers and the obtainment of new types of elastomeric materials based on new modified macromolecules.

The aim of this study is to determine the effect of carbon black content on the mechanical properties of rubber blend under different conditions of thermal aging NR/BR/SBR (25/25/50) and possible application in railway vehicles.

2. EXPERIMENTAL

Materials: Polyisoprene rubber, NR SMR-20 was

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supplied by Malaysia; polybutadiene rubber, BR SKD N with 94% of 1,4 *cis* content – was supplied by Njižnjekamsk (Russia); Styrene butadiene rubber, SBR Europa Intol 1783, is an emulsion styrene-butadiene rubber with 23.5% bound styrene was supplied by Versalis (Italy). The carbon black type N-330 (primary particle size 28-36 nm) - Volgograd (Russia). Content of filler was 0 - 100 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 25/25/50 (w/w/w). 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 mixer K-0 INTERMIX (Francis Shaw), volume 1 L, rotor speed of 8-88 rpm and laboratory roll mill (14201-Buzuluk Komarov) dimension 400 x 200 mm at a speed of rollers n_1/n_2 = 17.4/14 and a temperature between 60-70°C, according to the procedure ASTM D318489. Compounds were conditioned at 25°C during 24 h prior to property assessments. Rheometer curves were carried out using an Alpha technologist Rheometer MDR 2000 according at 160°C and are their used to determine the start of cross linking t_{s2}, optimum of cross linking t_{C90}, as well as the maximum and minimum torques (M_{max} and M_{min}). The cross linking was carried out in an electrically heated hydraulic press (E-604 Metroohm Herisau) under a pressure of 20 MPa and 150°C. The scorch time (t_{s2}), the optimum cure time (t_{c90}), the curing rate index (CRI), and maximum torque (M_{max}) 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.

To investigate the influence of thermal aging on the mechanical properties, the obtained reinforced elastomeric materials were performed in an air circulating oven operated at 100°C during 72 and 168 h. The tensile properties (TS and E_b) and hardness were measured before and after the aging studies.

3. TABLES, FIGURES AND PROGRAM LISTINGS

The essence of cross linking is a chemical reaction between the rubber macromolecules, which in the presence of selected fillers, softeners, activators, curing agents, accelerators and retarders form a crosslink. Cross linking of rubber macromolecules represent topologically critical phenomenon, when the ensemble of linear chains forms a three-dimensional crosslink's of macromolecules. Optimizing raw material composition of cross linked materials containing nanoparticles of filler must include the possibility of realizing the mixing components, cross linking and removing the finished product from the mold in real technological facilities of the tire industry, not just the final properties of the material.

The applications of polymeric materials in the manufacture of electrical insulations, gaskets and sealants, corrosion protections, gas-transporting pipes, hydrophobic layers and many other special products require the assessment of material strength under hard conditions of operation.

3.1. Cure characteristics

The cure characteristics as function of the CB loading of the ternary NR/BR/SBR (25/25/50) rubber blends are show in Figure 1-3. The higher M_{max} (Figure 1) for filled rubber blend are indicated that stronger interactions between nanofiller and polymer matrix are obtained. It is believed that, the smaller the particle size is, the larger the surface area will be.

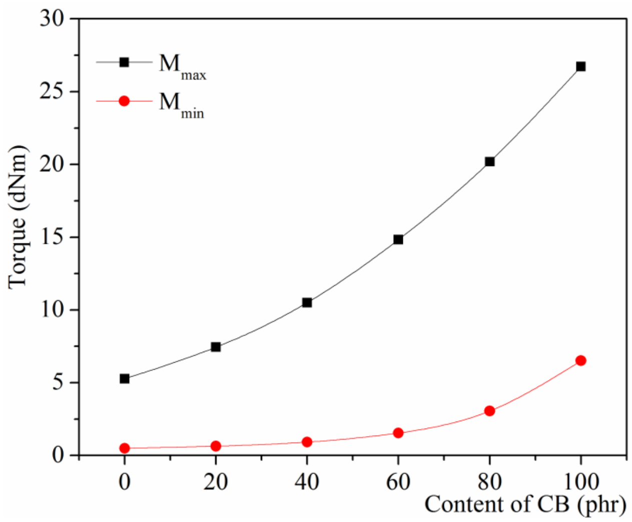

Fig. 1. The effect of loading CB on M_{max} and M_{min} in ternary NR/BR/SBR rubber blend.

According to CB surface, the scorch time (t_{s2}) and optimum cure time values (t_{c90}) of CB filled composites is higher than unfilled (Figure 2). The fact that the cure process of SBR rubber macromolecules is a slower compared to the NR and BR rubber macromolecules, a higher activation is needs to produce proper content of cross link points.

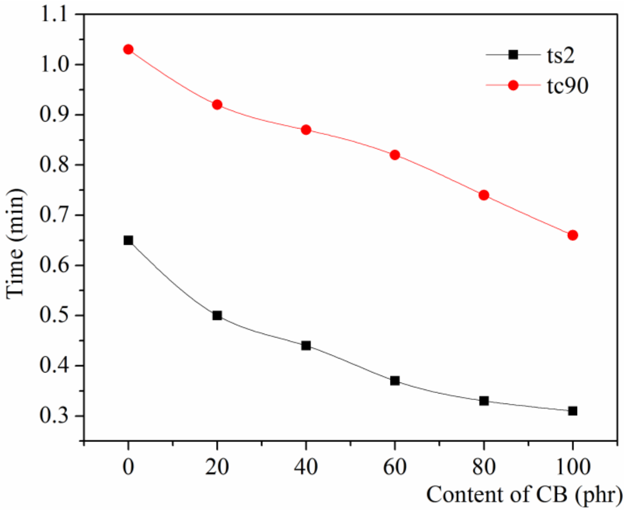

Fig. 2. The effect of loading CB on t_{s2} and t_{c90} in ternary NR/BR/SBR rubber blend

For each system, the CRI decreases with CB content increase (Figure 3)

2.

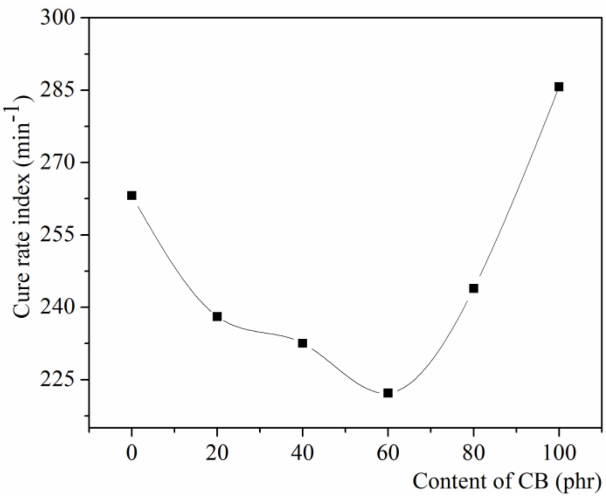

Fig. 3. The effect of loading CB on CRI in ternary NR/BR/SBR rubber blend.

This influence supports the activation of the cure reaction up to the content of 60 phr. At higher loading, a deactivation of the cure process was observed. This can be explained by critical volume fraction of CB which are have a tendency of agglomeration. It can be concluded that the values of the minimum (M_{min}) and maximum (M_{max}) torque, with increasing nano filler content are increase. The values of M_{min}, i.e. resistance that provides a cross linking system rotor rheometer, determine the safety of curing processing system at a given temperature. The values during the scorch time of cross linking (t_{s2}) and optimum networking (t_{90}) with cured systems based on NR/BR/SBR ternary rubber blends are decrease, with CB content increase, i.e. cross linking process became faster. Lower values of the scorch time indicate that a "period dissolving" of the compound reduces, i.e. cross linking process starts sooner.

3.2. Thermal aging

The aging process of rubber compounds are irreversible. Tensile strength is reduced and the longer the aging process, the greater are the changes. However, thermal aging of rubbers can be very complicated because there are two competitive processes taking place almost simultaneously during the aging process: crosslinking and chains scission [5]. Cross linking will lead to an increase in the elastic modulus and a consequent decrease in the extensibility of the material, whereas chain scission will result in the loss of the elastic modulus. Elevated temperatures usually promote oxidative aging. In some samples tensile strength increases after aging as a result of the further process of cross linking. It was found that the sulfur of polysulfide -C-S_X-C- bond lead to further cross linking.

During aging process rubber's mechanical properties become worsen, due to changes in the basic structure of the polymer. Mechanical properties of CB nanoparticles reinforced ternary NR/BR/SBR rubber blend before and after thermal aging (100°C for 72 h and 168 h) are shown on Figures 4-6.

The tensile strength values before aging of NR/BR/SBR/CB ternary rubber blend increase with CB content increase, according to CB reinforcement effect. The maximum value is obtained for the NR/BR/SBR/CB sample containing 80 phr of filler and then decrease (Figure 4).

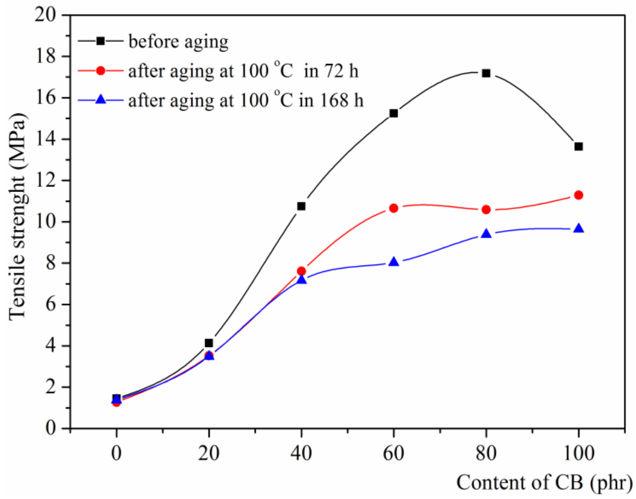

Fig.4. Tensile strength of CB nanofiller reinforced ternary NR/BR/SBR rubber blend before and after aging (100°C for 72 h and 168 h).

The optimal charging for rubber is assumed that all agglomerates fillers are dispersed to the aggregate. As shown in Figure 4 with the aged time increase the tensile strength is decrease. The aging of rubber vulcanizates has been generally assessed from changes in tensile properties resulting from conditioning at elevated temperatures for specified periods of time.

Also, elongation at break values are (Figure 5) decreases with tightening of the conditions of accelerated aging process. During the aging, the elongation at break for ternary NR/BR/SBR (25:25:50) rubber blend with 100 phr of CB nanoparticles is reduced much more than that for any of the other samples. The reduction of value for elongation is explained by the degradation process of cross linked materials and by reducing the polymer molecular weight due to breakage of elementary chains, which reduces the elasticity of the material.

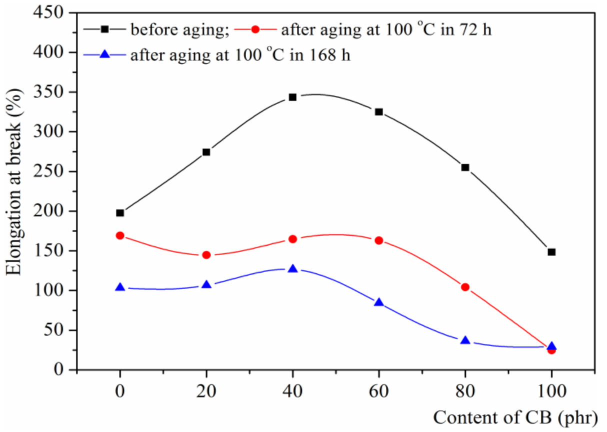

Fig.5. Elongation at break of CB nanofiller reinforced ternary NR/BR/SBR rubber blend before and after aging (100°C for 72 h and 168 h).

Hardness (Figure 6) of all tested samples increases with tightening of the conditions of accelerated aging process. The hardness of rubber during the aging process increases.

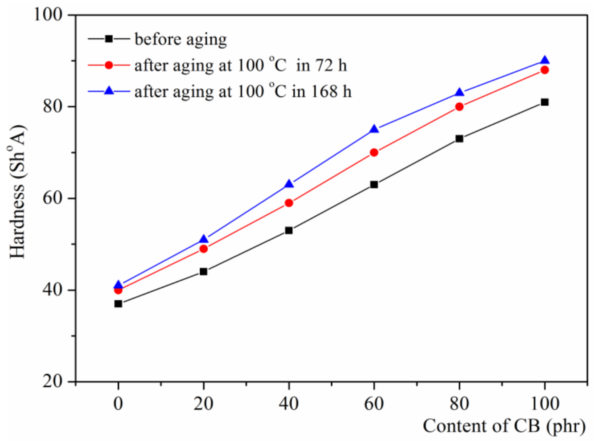

Fig.6. Hardness of CB nanofiller reinforced ternary NR/BR/SBR rubber blend before and after aging (100°C for 72 h and 168 h).

4. CONCLUSION

Some conclusions can be drawn as follows:

- ✓ By monitoring crosslinking regime in systems obtained from NR/BR/SBR ternary rubber blend, it was found that when CB content increase, the values of the minimum (M_{min}) and maximum (M_{max}) torque are increase.
- ✓ The scorh time (t_{s2}) and optimum cure time (t_{90}) in a NR/BR/SBR ternary rubber blend are decrease with CB content increase, i.e. ternary rubber blends are crosslink faster.
- ✓ The tensile strength and elongation at break are decrease, but hardness values are increases with aged time increase.
- ✓ The change in mechanical properties are dependent on the aging temperature, time and the CB content; higher changes in mechanical properties are noticed at longer aging time and higher CB content.

Aging temperatures play important role in changing the mechanical behavior of rubber compounds for railway vehicles. Therefore, NR/BR/SBR/CB (25/25/50/60) reinforced rubber blend are the most thermal resistance and suitable for railway vehicles.

ACKNOWLEDGEMENT

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XVII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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SURVEY AND FORECASTING THE ATTENDANCE OF RILA MONASTERY FOR THE PURPOSE OF "PROJECT ON CONSTRUCTION OF INNOVATIVE TRANSPORT INFRASTRUCTURE"

Mirena TODOROVA [1]

Abstract – *The paper presents the idea of developing "Project on construction of innovative transport infrastructure". A short historical overview on the narrow-gauge railway line existing in the last century is made and the current access to Rila Monastery is analyzed. The advantages of new infrastructure and possible options – without a project and with building a monorail and a lift, are examined. For the project purpose a survey on visits to the cloister and its surroundings is carried out including determination of the structure of visitors' flow. The forecast of passenger flows is developed for up to 30 years ahead based on a regression multi-factor model. The factors, which influence on forcasting, are also forcasted – visits of international tourists, Bulgarian tourists and students. The final integral forecasts: pesimistic, realistic and optimistic, developed according setting will be used for evaluation of infrastructure options.*

Keywords – transport infrastructure, forecasting, passenger flow, traffic, monorail.

1. INTRODUCTION

One of the most visited historic and religious sites in Bulgaria is Rila Monastery, which is located in Southwest Bulgaria. Rila Monastery is one of the most important cultural monuments in Bulgaria, a symbol of the country. It was announced to be "national historic monument" in 1927. In 1976 the monastery became a national historic reserve. Since 1983 it has been a cultural monument under the auspices of UNESCO. The entry of Rila Monastery in the World Heritage List has increased the interest in it as an exceptional universal value.

Now the main and only link to Rila Monastery is Road III-107, which begins from the town of Rila passing through the village of Pastra. The road to Rila Monastery is of a third-class type as classified according to the national road network. It connects Rila Monastery with the international road E79 and through it with Struma motorway. The speed is limited up to 70 km/h. Since the altitude of Rila Monastery is 1147 meters, the route has many turns, which is a prerequisite for serious accidents.

The situation in the 20th century was different. The narrow-gauge (600 mm) railway line from Kocherinovo to Rila Monastery was built in 1924 with the main purpose to transport wood at the distance of about 40 km. The regular operation for passengers was opened 17 years later. The total number of passengers transported by the narrow-gauge Kocherinovo - Rila Monastery railway in 1947 was 237,437.

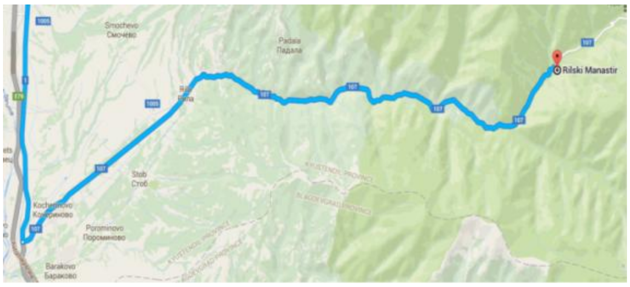

Fig.1. Route of the road to Rila Monastery

However, during the next years rail transportation decreased significantly due to the reduction of timber harvesting in the region and decreased number of pilgrims visiting Rila Monastery while the access to the settlement by car was improved. In 1959 the number of passengers was about 130,000. The average number of people departing from the end station amounted to 123, which was a good flow for a 600-mm railway line operated by only three trains a day with 20 seats in a normal passenger carriage. In 1960 the operation of the railway line was closed due to its unprofitability. During the next 2 years the track was dismantled. Currently the route of the railway line to Rila Monastery is a tourist path.

There have been various initiatives to restore the railway line but so far no one has been implemented.

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In 2015 Rila Monastery entered the list of the 500 most visited sites in the world, showing a steady tendency of growing number of tourists. Consequently, car traffic has increased leading to pollution and preconditions of road accidents. That is why it is feasible to develop a student project to build innovative transport infrastructure that will improve the access to the monastery.

2. PROJECT DESCRIPTION

There are different innovative transport implementations such as glass elevators, lifts and various types of railways. Monorails have been implemented in many countries. Urban railways are divided into hanging monorail (in Japan and Germany, e.g. Bahn in Duseldorf, Chiba Monorail' Urban), and monorail urban standing railways (Tama Monorail, Daegu Monorail, Sydney Monorail, etc.). String Transport Systems, which have not been implemented practically yet, are innovative and much more cost-effective.

For the presented project, still under development, it is necessary to choose a type of infrastructure, which will attract tourists, reduce road traffic, and make a parking lot available as provided in the Master Plan of Rila Monastery National Park until the end of the programming period 2014-2020.

The construction of such innovative infrastructure has the following advantages:

- The present infrastructure remains intact;
- Silent and fast transport to the end point;
- Weatherproof and energy independent;
- Ability to transport large groups of people;
- Environmental protection, reduction of pollution;
- Decrease of accidents possibility

To achieve the project objectives, the following route alternatives will be considered:

First option: minimum (without project OWP). It keeps the traffic of cars, buses, etc. through the villages and Rila Monastery National Park where the road passes.

Second option: In this case, it should be invested in a hanging monorail, using solar energy converted into electricity, going from the town of Rila to Rila Monastery, with a length of 20.80 km, maximum speed of 50 km/h and a typical height of 5 to 16 m above the ground level. It is necessary to build a depot and a parking lot and deliver rolling stock needed. It is provided to attract a large passenger flow and eliminate the need to build a parking lot on the territory of Rila National Park.

Fig.2. Hanging monorail "Shaft" in Krasnogorsk region, Russia

Third option: to build a lift using solar energy converted into electricity and going from the town of Rila to Rila Monastery with a length of 20.80 km, average speed of 35 km/h. It is necessary to build a parking lot.

3. FORECASTING THE NUMBER OF VISITS TO RILA MONASTERY

At the first page, 40 mm from upper edge, the title of the paper, bold, 16 pt, centered, all caps (up to 15 words). Beneath the title, type the name and surname (surname in capital letters, centered) of the author and in the following lines the names and surnames (surnames in capital letters, centered) of co-authors should be given.

The forecast of number of visits reflects both on the infrastructure occupation and revenues received. The nature of traffic in Rila-Rila Monastery section is mainly determined by the number of visitors to Rila Monastery National Park.

Tourism is the most important activity in Rila Monastery National Park. In 2001 it was visited by 495,000-570,000 people, one third being international tourists. Of the Bulgarians, 12% were on school trips; about 6% lived in nearby settlements and 49% came from other parts of Bulgaria.

The calculation of the number of visitors in Rila Monastery National Park Management in Plan 2004 - 2013 were made using the method of representative statistical samples based on a single season of field work and subsequent statistical data extrapolation. One-day visitors make up the largest group of tourists; at least two-thirds spend in the park less than a day without sleeping. They usually visit from two to three sites as 90% of all tourists visit Rila Monastery. Over 80% of international tourists are members of groups for organized tours. Others are accompanied by a Bulgarian who is their host and guide.

The vast majority (about 2/3) of Bulgarian tourists visiting Rila Monastery describe the reasons for their visit as a need of "fresh air and nature" ("enjoyment of the contact with nature") and "leisure and entertainment". The third main reason is "to visit sacred places". About 50% of visits are performed in summer, mainly in July and August.

At least two-thirds of visitors enter the park by vehicles using the road through the village of Pastra. The availability of only one access means that to reach places in the park beyond the Rila Monastery, the whole traffic has to pass through its area.

In 1986 Rila Monastery was awarded Golden Apple prize as a tourist destination being visited by over a million tourists. From 1990 to 1995 the number of visits fell down by almost half, remaining constant until 2001 when it began to increase again.

Based on the analysis with forecasting the number of visitors to Rila Monastery in the forthcoming years, a multi-factor regression model is applied using the data of the National Statistical Institute (NSI) and the information of visits for the period 2008-2014. The following groups of visitors have been taken into account as influencing factors – international tourists, Bulgarian tourists and students on school trips.

$$Y = a + B_1.X_1 + B_2.X_2 + B_3.X_3 \quad (1)$$

where: X_1 – visits of foreigners in Bulgaria;
X_2 – annual costs of tourist journeys;
X_3 – number of students at comprehensive schools.

The determination of the past period, which is the basis of forecast models, is based on the "depth in time" of data availability. The developed forecasts are based on an approach considering the adjustment with obtaining the final integrated forecast of the entities surveyed: pessimistic, realistic and optimistic. This approach makes possible to use various forecasts separately or use average forecast through implementation of a weighted average forecasted level.

3.1. Forecasting the visits of international tourists to Bulgaria

This forecast has used data of international tourists who visited Bulgaria from 2008 until now, which was retrieved from the Bulgarian National Statistical Institute (NSI). The approach applied is based on obtaining estimates of the number of visits as an independent variable, i.e. obtaining a trend using the Method of the least squares and the built-in function of Exel "Add TrendLine". The equations describing forecasts are given in Table 1 and diagrams of forecasts are in Fig.3.

Tab. 1. Equations describing the forecasts

	Forecast	Equation
1	optimistic	$X_1 = 8E + 6.e^{0,021.n}$
2	realistic	$X_1 = 137580,3.n + 7939372,38$
3	pessimistic	$X_1 = 57791.Ln(n) + 8018907,7$

Where: n - serial number of the year.

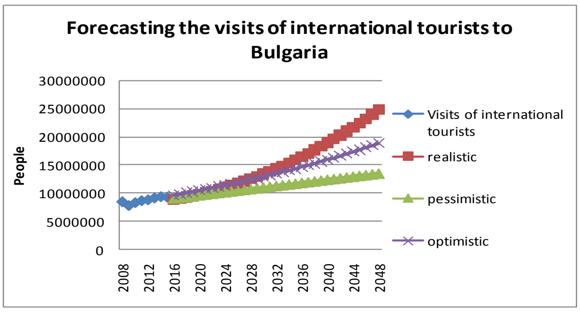

Fig.3. Forecast of the visits of international tourists

3.2. Forecasting the change of annual costs on tourist trips

Statistics does not contain any travel data of population except for the costs allocated to such trips. Due to that reason this factor is included as a travelling marker. The data are for the examined period from 2008 until now. The Method of the least squares is used and the equation describing the forecast is as follows:

$$X_2 = 767998n^{-0,02} \quad (2)$$

3.3. Forecasts of the number of students

The parameter examined is forecasted as a value dependent on the size of the population "P" and using data for the period from 2001 until now. Forecasting is made using software "StatGraf" and obtaining Polynomial Regression:

$$X_3 = 5,392E7 - 14,5018.P + 9,8575E - 7.P^2 \quad (3)$$

The R-Squared statistic indicates that the model as fitted explains 99.0539% of the variability of students. To determine whether the order of the polynomial is appropriate, first it is noted that the P-value on the highest order term of the polynomial equals 3.73981E-8. Since the P-value is less than 0.05, the highest order term is statistically significant at the 95% confidence level. Unfortunately, despite the result, the equation cannot be used because of the large deviation, which it gives with population decrease and that is the trend in Bulgaria at present. It is why equation with R-Squared 79.4% will be used: although being more inaccurate, it gives more reliable forecasts:

$$X_3 = 4E - 18.P^{3,382} \quad (4)$$

The National Statistical Institute of Bulgaria has developed three variants of target demographic forecast for the country in perspective up to 2060: *Variant I* (targeted) is equivalent to the forecast developed for Bulgaria by Eurostat. It is defined as realistic and in compliance with the regulatory requirements of the European Union. *Variant II* is for relative acceleration and *Variant III* is for relative deceleration. The developed forecasts have a converged nature and reflect the general trends in demographic development of the EU member states.

Using the forecasts developed in the way described above and the dependence obtained, it is possible to forecast the number of students at schools (Fig. 4)

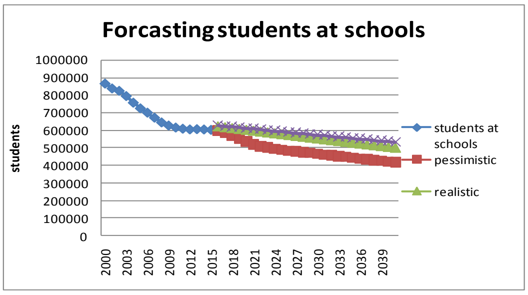

Fig.4. Forecast of the number of students depending on the size of population

3.4. Forecasting the total number of visits

In order to obtain the coefficients of the regression multi-factor model, function Regression of Exel Data Analysis package is used. The results are given in Table 2. The value of multiple correlation coefficient 0.833 (Table 2) shows that the relationship between statistics of Y and the independent variables is large.

Tab. 2. Parameters of the regression model

Regression Statistics	
Multiple R	0,8797
R Square	0,7738
Adjusted R Square	0,4346
Standard Error	10427,24235
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	744003543	248001181	2,2809	0,31928265
Residual	2	217454766	108727383		
Total	5	961458309			

Coefficients	
Intercept	558045,2023
Variable X1	0,0221
Variable X2	-0,0049
Variable X3	0,1169

The assessment of relevance and adequacy will not be checked because due to the small number of initial data it cannot meet the criteria. There is not enough information that the resulting equation is adequate but due to the small number of data it will be accepted that the equation describes accurately enough the initial data. Using the forecasts made for independent factors and the resulting equation in Fig. 5, the

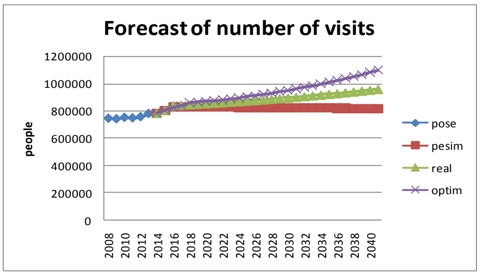

Fig.5. Forecast of number of visits for 30years

forecasts of visits to Rila Monastery are determined in visitors per year.

While determining the necessary carrying capacity of infrastructure according to the second and third options, it should be taken into account that the number of visits varies a lot by months and days. With the optimistic forecast, on certain days it is obtained that visitors are 11,000-12,000 per day.

4. CONCLUSIONS

The proposed transport infrastructure must be capable to provide the necessary capacity of transportation so as to absorb the flow of visitors even in the busiest days. It is why after traffic forecasting, the economic calculations will consider options with investments consistent over the years to increase the number of rolling stock to provide transport with the optimistic forecast and corresponding construction of a single or double railway line according to the Second option: hanging monorail. The answer for economic feasibility of the project and the type of infrastructure will be given by estimates of revenue evaluation with the realistic forecast of visits. The final assessment of the need to build new transport infrastructure will be based on the economic indicators using the pessimistic forecast of visits to Rila Monastiry.

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The Graduates and the Future of Railway

RESEARCH OF PRODUCTIVITY INDICATORS FOR RAILWAY WAGONS IN BUSINESS TRADE CONDITIONS OF RAILWAY COMPANIES

Student: Rade CVIJANOVIĆ [1]
Mentor: Branislav BOŠKOVIĆ [2]

Abstract *– Restructuring of railways is an on-going process in Europe during the past twenty years, with the aim of increasing its productivity. In business trade conditions, significance of productivity in management is increasing. Bearing in mind that today's work indicators and indicators of freight wagons were adjusted to conditions of monopolistic status of national railway companies, this paper commenced research and suggests new indicators of work and of freight wagons productivity with the aim of their better utilization and increasing of competitiveness of railway companies in transport market. Proposed indicators for the Railways of Republic of Srpska were calculated and obtained results were discussed in purpose of comparison with other European railway companies.*

Keywords - Freight wagons, Productivity, Indicators.

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SIGNIFICANCE AND REGULATION OF SERVICES OF PUBLIC INTEREST

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Mentor: Branislav BOŠKOVIĆ [2]

Abstract *– The main objective of transportation policy in the EU as well as in Serbia is to provide an efficient, safe and high-quality passenger transport. With regard to the fact that the constant battle is being fought in the market for more profit, it is not always possible to provide better service to the public because it would not be profitable enough. This is the reason why the government strives to make transportation possible for all its citizens by subsidizing transportation companies for routes that are in the public interest. The government does it by way of Public Service Obligation (PSO).*
The objective of this paper is to point out the importance and regulation of the Public Service Obligation on the railway. Service of General Interest fulfill the daily needs of citizens that are necessary for normal functioning of society, of which PSO is a narrower concept. It is an arrangement in which a governing body offers to a transportation company by contract to operate on nonprofitable routes with appropriate compensation by the state. The most important regulation which arranges PSO is Regulation 1370/2007 EC which is discussed in this paper. The difference between state aid and subsidies which are necessary for the functioning of the transportation system is also defined. Finally, the way in which the EU and the Balkan region faced this problem and how they solved it is also presented.

Keywords - Public service obligation, Railway, Subsidies, Comparative analysis.

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DYNAMIC OF RESTRUCTURING PROCESS OF INCUMBENTS RAILWAY COMPANIES IN EUROPE

Student: Nikola STANOJEVIĆ [1]
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Abstract – Restructuring of railway companies in Europe was a consequence of declining transportation market. The goal of restructuring process, conceived by European law, is to reform and improve railway companies by putting them on free market. The structure of this process is described in detail in European Union Directives in which the companies were managed by models of vertical integration, separation or holding. The dynamic of companies restructuring is realized unevenly throughout Europe. From that point of view proper analysis was conducted in means of time factor and length of the restructuring process, then by geographic factor in which the restructuring process was observed in companies of western, eastern, central and southern Europe. Also, the restructuring of railway companies was compared to GDP, depending on level of political decentralization as well as their European integration process.

Keywords - Restructuring, Incumbents, Models of Organizations.

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CONCEPT OF INTEROPERABILITY OF THE RAILWAY SYSTEM IN EUROPE

Student: Miroslav PROKIĆ [1]
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Abstract *– The subject of this paper is to analyze the concept of interoperability of the railway system in Europe. The analysis is based primarily on the study of directives and other regulations and documents of the European Union, as well as other available literature - scientific papers whose themes are interoperability of railway systems and other systems.*
The creation of a single railway market in the EU and the introduction of competition between railway operators on the railway infrastructure is not possible without establishing interoperable railway system of European countries. The uninterrupted or continuous train traffic throughout the European railway network requires compliance characteristics of the infrastructure and vehicles and efficient interconnection of the information and communication system infrastructure managers and operators on the network. From this compliance and interconnection depends on the efficiency and competitiveness of railways in the transport market. In doing so, interoperability refers not only to the harmonization of technical capacity between the elements of the railway system, but this concept also includes the legal and of organizational harmonization
Directives, as part of EU secondary legislation, define a legal framework of the concept of interoperability. All Member States are required to transpose the directives into national law. At the same time, with these is created a need to develop European standards and specifications to be applied as a national. Documents are the bearers of these standards are called technical specifications for interoperability. In addition to carrying out procedures in assessing interoperability, it is necessary to form a so-called notified and designated bodies.
The paper explains the concept of interoperability in the wider context of the Railway, provides an overview of the development of the concept of interoperability through directives handle it, explains the concept of interoperability of European railways, especially the technical specification of interoperability and his impact on the development of the railway industry.

Keywords – *interoperability, railway, Technical Specification of Interoperability - TSI*

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MODEL OF ACCESS CHARGES FOR THE USE OF RAILWAY INFRASTRUCTURE AS A MECHANISM OF SUSTAINABILITY OF RAILWAY COMPANIES ON TRANSPORT MARKET

Student: Vladimir MALČIĆ [1]
Mentor: Ratko ĐURIČIĆ [2]

***Abstract** – By liberalization of the railway market, it is necessary to introduce a fee for the use of railway infrastructure as an element of establishing relations between infrastructure managers and transport operator. The fee also representing means of establishing a balance in business between the existing actors in the railway system, and a balance is especially important for today's crisis when sustainability of the railway system and its parts is under question.*

The paper is aimed to create the compensation models and to define the mechanism of action of fees. The tool used in the paper is the simulation, which enabled the verification of fee impact as input values in business, and the sustainability of the newly established railway companies with contemporary market conditions.

***Keywords** – Access Charge, Model, Sustainability, Simulation*

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INDEX OF AUTHORS

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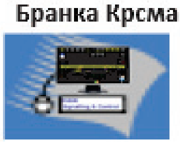

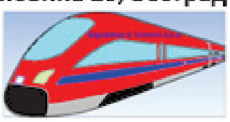

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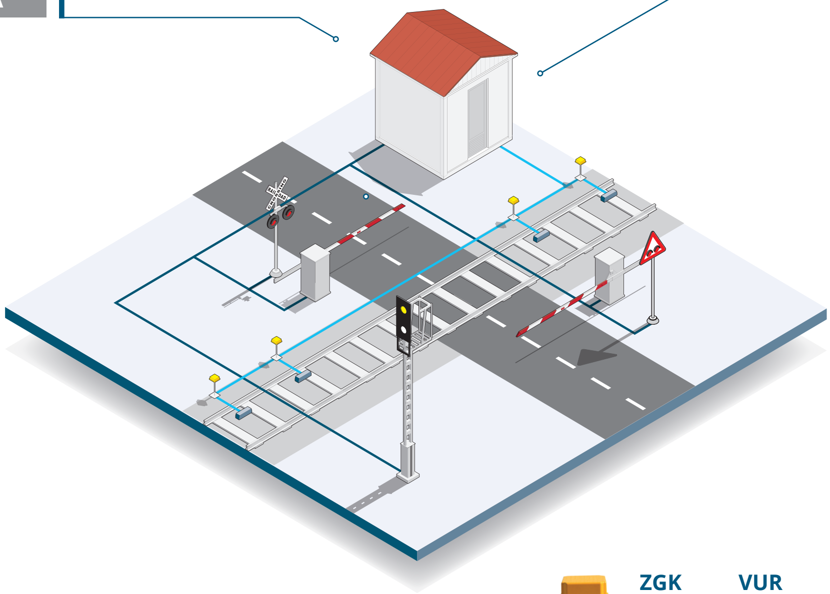

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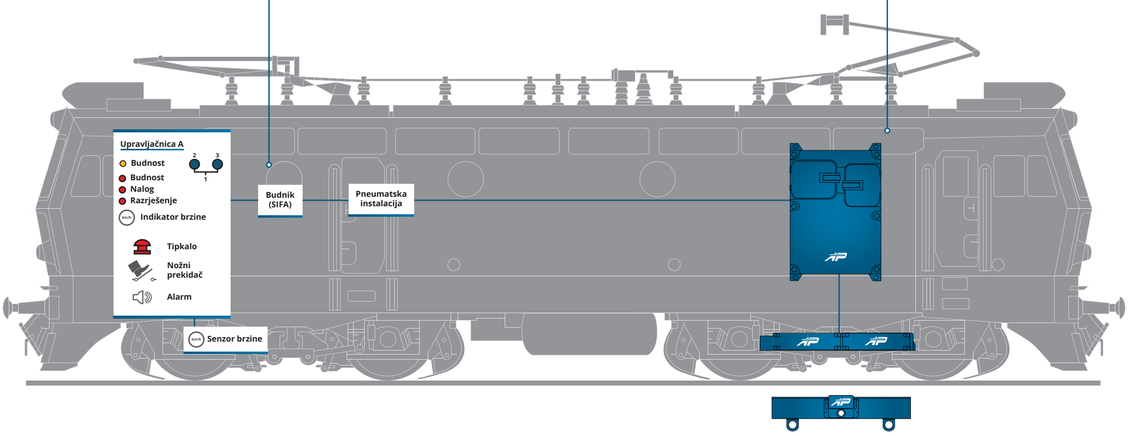

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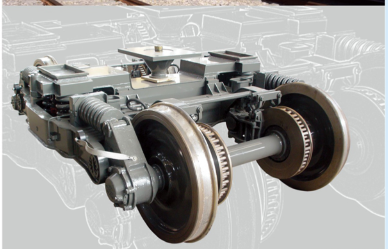

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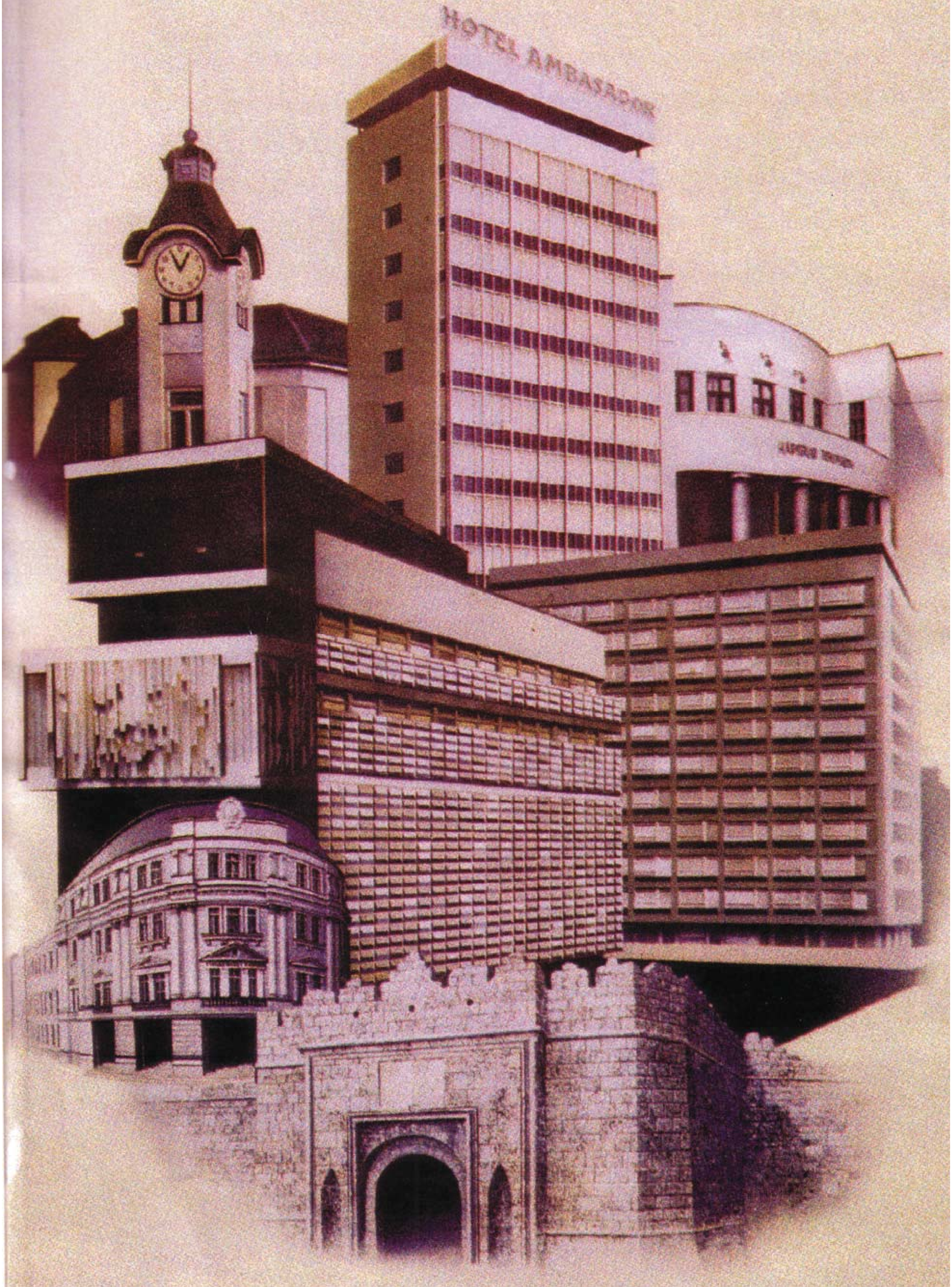
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