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7TH INTERNATIONAL SCIENTIFIC CONFERENCE OF THE FACULTY OF TRANSPORT ENGINEERING

SEPTEMBER 6TH – 7TH 2018
PARDUBICE

FACULTY OF TRANSPORT ENGINEERING 25 YEARS

VII. International Scientific Conference of the Faculty of Transport Engineering

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25 YEARS

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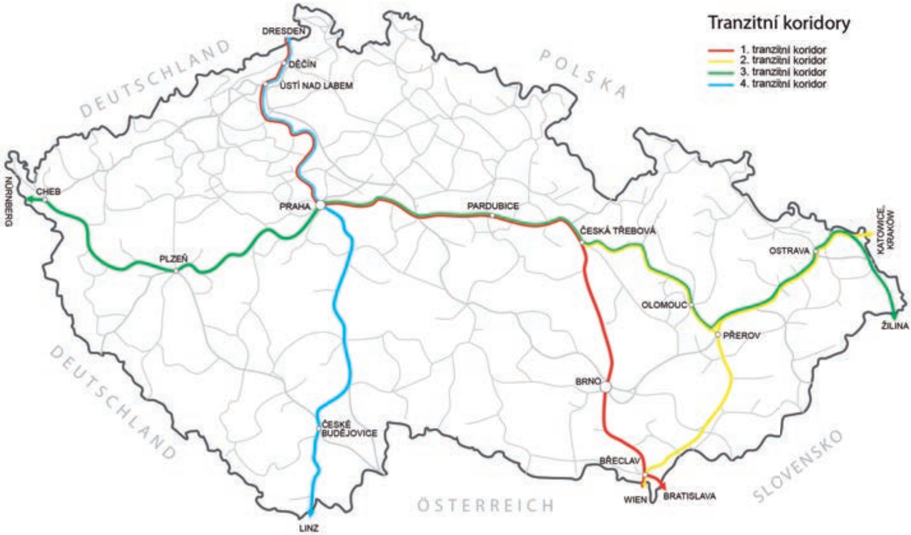

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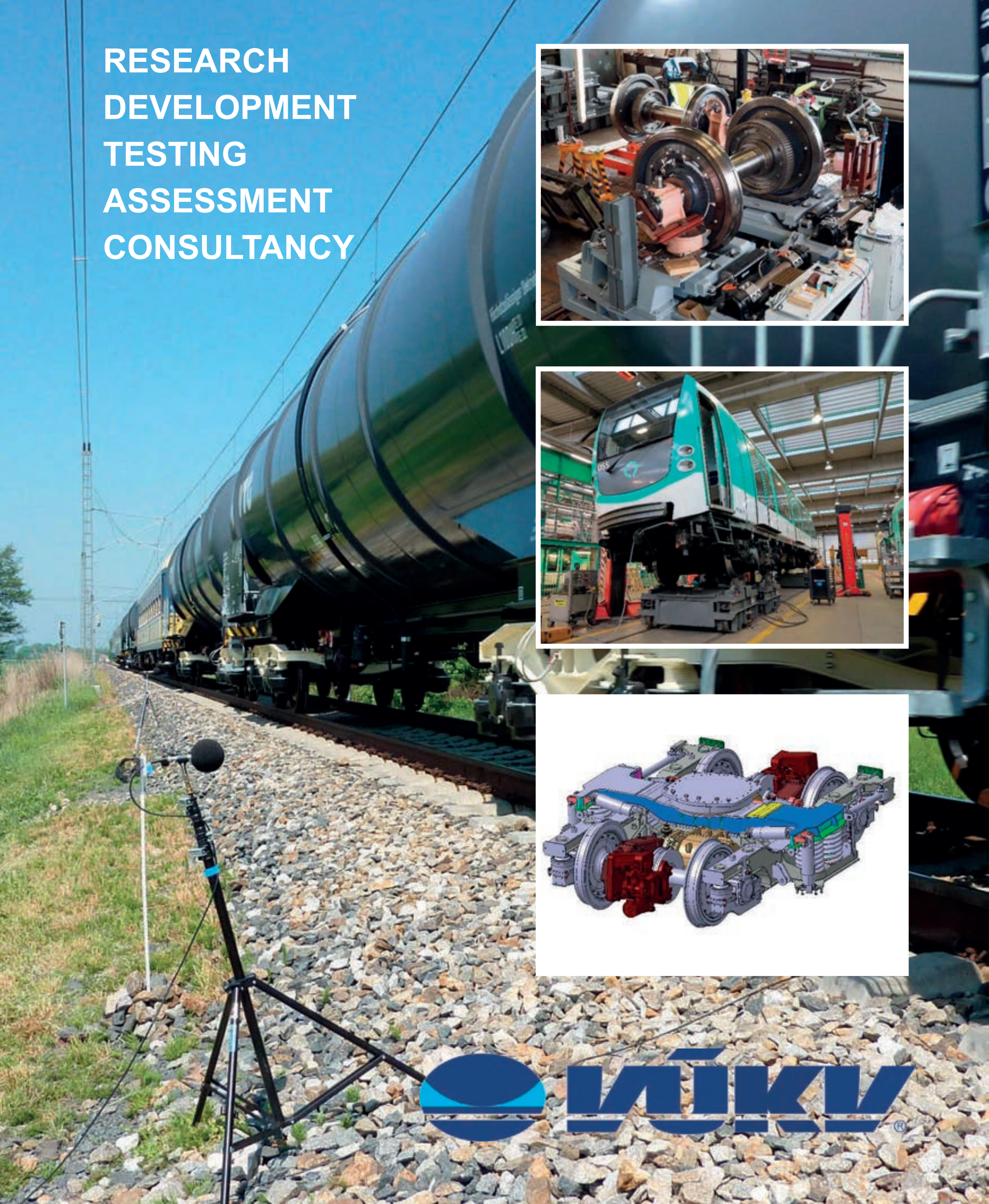
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POSSIBILITIES OF THE TRAFFIC EMISSION MONITORING IN CONTEXT OF THE SMART CITIES CONCEPT

Vladimir ADAMEC[1], Barbora SCHULLEROVA[2], David HERMAN[3], Ales VEMOLA[4]

Abstract

The issue of emission monitoring from transport and the influence on human health is very actually topic. One of the possible measures in concept of Smart Cities and European strategies is using the obtained on-line data by the dynamic software tool such as DataFromSky system. The data is possible to apply for modelling of intensity and emission load from traffic. The software uses real traffic data about monitored traffic area (type of passing vehicles, speed, acceleration etc.). The data are obtained by the drone technology or camera system. Besides, the obtained data is possible to use as a part of system for emission modelling. The aim of paper is to introduce with one of possible approach for emission load assessment in consistent with the concept of Smart Cities.

Keywords

traffic, emission, software, smart cities, modelling

1 INTRODUCTION

The transport always has been an integral part of society. The modern society couldn't exist today without the constant transport of the goods, products and information. However, it also has a negative impact such as air pollution and environmental pollution. This may cause damage to human health from serious illnesses to untimely death. The pollutants also affect vegetation and may cause reduction in agricultural production. They even cause damage to materials and buildings of historical significance. In recent years, the share of automobile transport in the air pollution has significantly grown, particularly in high-traffic urban areas. In 2015, more than 200 thousand new passenger cars have been increase in Czech Republic and for example in Germany more than 3 million [1]. From emissions emitted by traffic is the highest increase recorded for greenhouse gases CO_2 and N_2O (see Graph 1). The newer vehicles there show higher measured values than older types [2-6].

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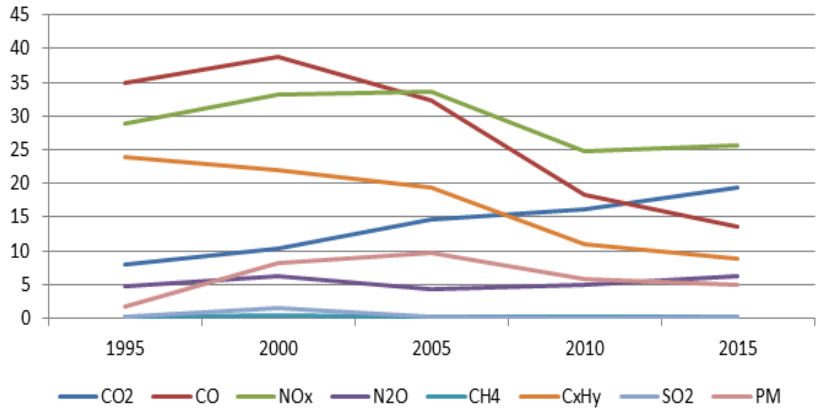

Fig. 1 Percentage share of traffic in total air pollution in Czech Republic [7]

The cause is in the case of CO_2 higher fuel consumption as a result of the increase in the transport performance, in the case of N_2O emissions increasing due to the application of catalytic converters. In the Czech Republic, as well as in the European Union, there is an increase in PAHs. Especially in 2014 there is a relatively significant increase in the sale of the diesel fuel, also the time trends of all monitored pollutants. However, the exceptions with decreasing trend are only CO and CxHy (see Graph 2) [2,8-11].

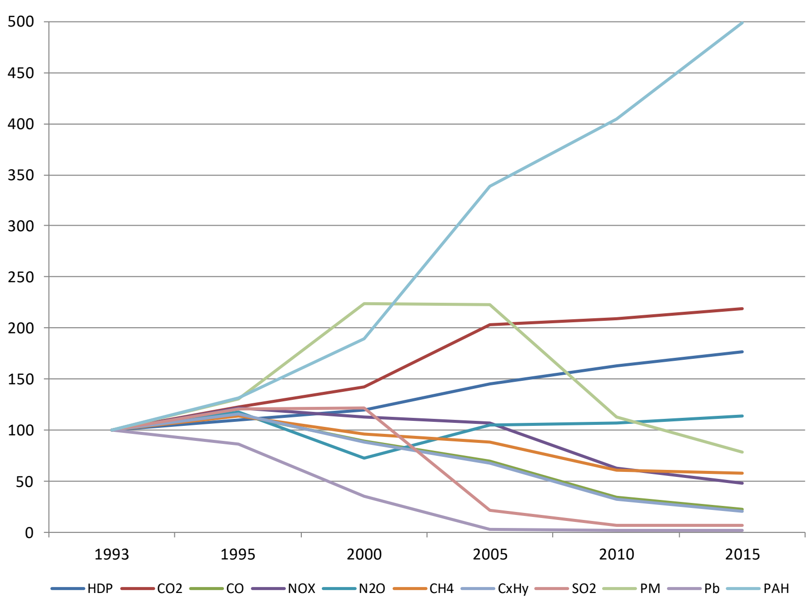

Fig. 2 Index of the emission from traffic development [7]

Negative impacts from traffic, such as air pollution, temperature increase, noise, accidents, and the immobility of the inhabitants are connected with increased untimely death rate and serious illnesses, especially in cities [12, 13]. According to study [14], about 30 % of traffic congestion is caused when drivers are trying to find a free parking space. For example, the results of a study in Barcelona show that every day around a million vehicles spend twenty minutes searching for a parking space, which produces 2,400 tons of CO_2. An example [15] monitors current strategies for introducing cities without cars and promotes more pedestrian and bicycle zones for a healthy city life. It compares these strategies with, for example, the cities of Hamburg, Madrid or Oslo, which have been implementing their plans in the public transport and personal transport is already partly limited here. Also, there is a lot of another measure, such as multimodal transportation apps allowing to choice the best possibilities of travelling, including friendly to environment vehicles [16, 17], using of electric tricycles for transport carries [18] etc.

There is necessary to have in mind that the negative impacts of the transport are also results of habitant's behaviour and their everyday decisions about their type of transport, the mode of transport and route. Many factors influence this decision: the socio-economic characteristics of population and their relationship to the environment, as well as the characteristics of available transport system (for example travel time, fees, comfort and safety). In connection with the application of reduction measures, the question of their financial difficulty logically arises. However, not all can be quantified only in terms of cost. The realization of measures to reduce of negative impact must be primarily solving conceptually and with regard of the aspects of quality city life (environment, safety and security, well-being, parking, alternative modes of transport, public transport etc.). These conceptual measures, proposing for example the plans for sustainable urban mobility of Smart Cities.

Transport and infrastructure are, therefore, a promising field, in which the latest technologies are used aiming to ensure traffic flow, its reliability and the decrease in the emission load already mentioned. Monitoring emissions is one of the necessary parts of the measures whose goal is to increase the quality of the lives of inhabitants not only in cities. Following text briefly introduces approaches applied in Czech Republic.

2 MONITORING THE EMISSION LOAD FROM TRAFFIC IN CITIES

Currently, the monitoring of emission from traffic, is usually monitored at the specialized stations marked as traffic „hot spots“ focusing specifically on information about the air quality in areas which are significantly burdened by traffic [19]. Also, for modelling of emission are used these obtained data by various software tools supporting the Intelligence Transport Systems (ITS) which allow creating models of line sources, are currently used to monitor the emission load from transport in cities (EMME 4.2, Paramics etc.) [20,22]. These software tools have an additional ability to calculate emissions based on the composition of the vehicle fleet (the share of vehicles from each emission group based on their frequency in real traffic) and the properties of the monitored area (corridor). In the Czech Republic are using software tools like MEFA or ATEM for pollution modelling and air quality assessment [23,24]. In 2008, A Methodical Instruction to Reduce Dust Emissions from Traffic was published, which focuses on solid particles emissions [25]. This methodology uses the TIMIS software tool, which contains a vast database of concentration maps and it is commonly available as a Microsoft Excel module. The emission factors used in this programme are based on studies carried out between 2004 and 2008. These software tools have lot of the advantages, but also disadvantages, such as that they do not allow transferring a real situation with the analysis and assessment of this data and displaying not only in the map data.

The ITS have a lot of opportunities for fulfilment of the requirements of the Smart Cities concept in the area of air quality monitoring. For example, there is possible to evaluate data from the Closed-circuit Television (CCTV) such as the total number of vehicles and the number based on the type of vehicle occurring in a specific area and considering the temperature, speed or density is very important [25]. It is the possibility of short-term or continuous monitoring of the emission load from traffic in cities which allows more efficient traffic planning and control and thus dealing with undesirable situations in which traffic congestion or other collisions occur and the concentration of vehicles in the particular section increases. That is why it is beneficial to apply this measure already in the traffic planning stage, if possible before the renovation or construction of new roads, intersections, buildings etc. A complex problem to deal with is the historic city centres and old built-up areas, which were originally designed for completely different traffic capacities, which are no longer sufficient. That is why measures such as diversion routes, entry of vehicles only with permission, reinforcement of the public transport system etc. are taken. However, these measures are not sufficient in all cities. Therefore, there is also a possibility of monitoring the traffic online with immediate evaluation and if there is a connection with the traffic centre, traffic control is also possible, for example by changing the time intervals at traffic lights intersections, traffic control by the police, changing the driving direction in some streets in critical daytime periods or banning the entry of vehicles in these time periods etc. One possible way of implementing a software tool in the Smart Cities concept is using online monitoring of the traffic and its analysis in selected sections, which are, for example, often affected by high levels of traffic and traffic congestion. Currently, there are existing platforms for on-line air pollution monitoring [26]. The sensors of these measures are static and place on the chosen objects, such as buildings, street lamps etc. Through the moving system such as dron system allows to monitoring the choice area for example during the traffic congestion etc.

3 THE SOFTWARE TOOL DATAFROMSKY AND ITS POSSIBLE USE

This software uses data obtained from aerial photographs and videos, which are taken with cameras installed on high-storey buildings, on drones or other devices with the view of the selected area. Extracting the trajectory data from an aerial video footage is a challenging task due to camera movement, lens distortions, visual variability of the captured traffic scene, occlusions etc. However, from the mathematical point of view, the birdeye images are the most suitable input in case of monocular vision for the accurate localization of ground targets. Therefore, the utilization of aerial images for the collection of telemetry information about each road-user at microscopic level is a very promising approach. It opens many new possibilities, for example in the field of traffic safety, studying of complicated traffic maneuvers or estimating traffic emissions.

The system analyses and processes the data in two stages:

1) Georegistration: Establishing correspondence and mapping between video sequence frames and real world coordinate system.
2) Detection, localization and tracking of objects of interest (vehicles) in the georegistered video sequence.

For the simplicity, the geo-registration process assumes that the road surface is planar and consists of two steps: camera-calibration procedure and the selection of at least for points in the reference image of which the exact positions are known. These points are used for estimation of transformations allows mapping a pixel from image space into coordinate system of an intersection. The precision of mapping is influenced by following factors:

- Quality of camera calibration – undistortion coefficients/model
- Quality of image stabilization - estimation of UAV movement between consecutive images
- The precision of geo-refenced points and its localization in the image space
- Planarity of the road surface

Automatic (re-)identification of objects of interest and its tracking during their passage of an intersection is very difficult task because of complex background, dramatic appearance variations, different light conditions, camera movements etc. Recent very promising state-of-the art methods are based on deep neural networks for both detection and tracking. Trackers for object tracking are typically trained entirely online. A standard approach samples patches near to the expected location of tracked object. These patches are then used to adapt internal classifier, which is used to evaluate patches from the consecutive frame to estimate a new location of the object. Object detection is a task of generating class labels with bounding boxes for one or more objects in an image. Convolution neural network for object detectors like Fast R-CNN, Faster R-CNN exploits the feature extractor output to propose and classify regions-of-interests. To improve robustness and performance, the detection candidates are prefiltered by expected area of road surface and results of moving object detection. The detections are then matched and tracked through the video sequence. To eliminate a localization noise, the object positions are filtered to form smoothed trajectories based on vehicle kinematic models.

It is possible to monitor traffic density as well as collision situations or the time for which a vehicle remains still or how long it takes it to drive through an intersection. The collected data then can be used to directly derive trivial traffic flow properties, such as origin-destination matrices, dynamics of vehicles and counts. Additionally, the results can be applied to improve or inspect accuracy of traffic behaviour models by deriving their parameters or confronting the results of simulations, as have been done by CITILABS in their study of Dynasim model accuracy [27].

The software tool is using real data, which does not need to be modelled using other software tools. The data obtained may be evaluated not only at intersections but also for specific road sections. Here, it is possible to monitor vehicles changing lanes, the time of a vehicle driving through intersections at a set speed or the time for which a vehicle remains in the monitored section in traffic congestion (Fig. 3, 4). With regard to the form of the videos obtained, which is from an aerial view, faces and vehicle licence plates are not visible so there is no possible security violation. If an infrared camera is used, records can even be made in poor lighting conditions such as at non-lit intersections, at dusk or at night. What may become a disadvantage is the distinguishing ability of the software tool, when it distinguishes the type of the vehicle (a passenger car/ a lorry) but it cannot determine whether the vehicle uses petrol, diesel fuel or, for example, the CNG, LPG fuel. Using the drone technologies also has some limitation, which is the flight time, when videos can be made. That is why other options of camera placement for monitoring roads and intersections are currently being explored, for example on high-storey buildings. However, these may not be present at each section to be monitored. That is why the possibility of using high-lift equipment is also being considered [29].

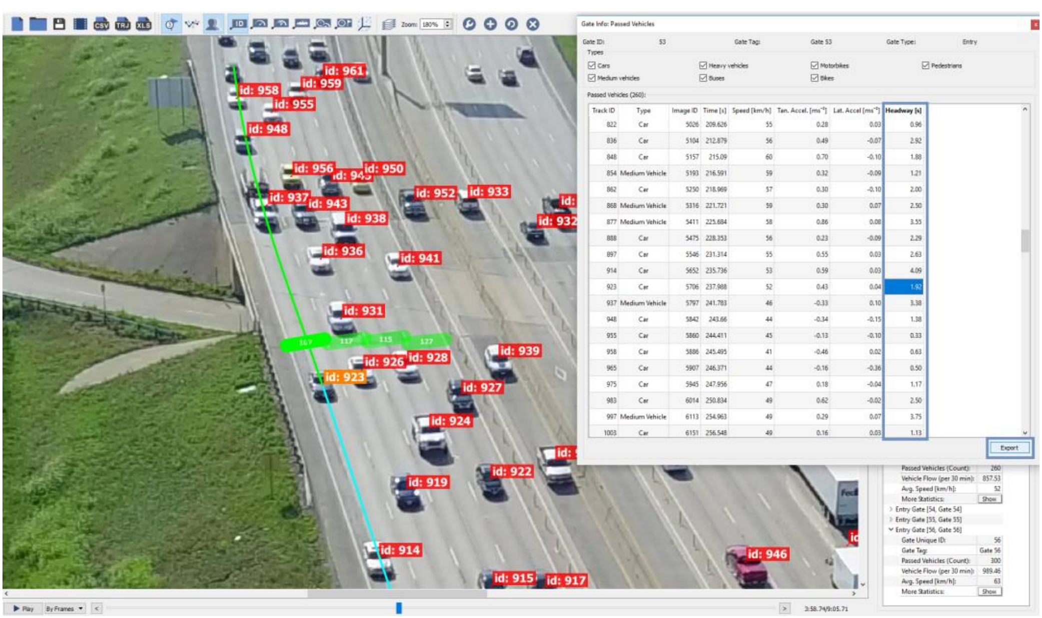

Fig. 3 Identifying of vehicles type [28]

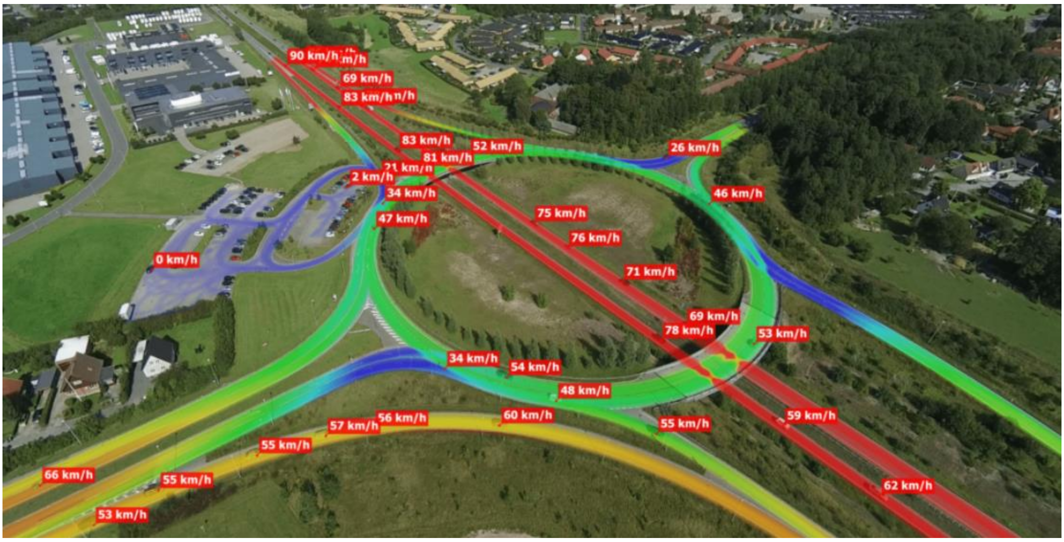

Fig. 4 An analysis of vehicle speed and the intensity of traffic flows [28]

However, in or near cities, congestion occurs especially in specific daytime intervals. Therefore, we can presume that this system may also be used during these time intervals to deal with problematic situations in the section monitored.

4 CONCLUSIONS

Current software allows a lot of possible ways, hot to monitored ait pollution in the cities. The research focuses on a possible connection of the software DataFromSky with the TIMIS software, which is currently, used (Adamec et al., 2006). Another possibility is extending the software functions by modelling the emission load during the analysis of the real data obtained. Ensuring the compatibility with another software tool or carrying out direct calculation modelling increases the efficiency and the possibility of evaluating the immediate situation in real time in the section monitored. The aim is to create a supporting tool for traffic control, which is in accordance with the Smart Cities concept and leads to reducing the emission load from traffic. The issue, not only monitoring and emission reduction, is one of the aim of the Smart Cities concept. That is why other systems are being developed, leading to their fulfilment. The software tool is possible followed other problematic by reducing traffic in cities, such as parking problems and the connected emission increasing. Therefore, such systems are further developed and supplemented by the new technologies, allowing the vehicles detection on the city's parking areas, to inform their visitors to inform drivers etc. [30].

◆◆

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MOISTURE INFLUENCE ON THE GPR-MEASURED RDP VALUES OF GRANITE BALLAST UNDER CLEAN AND FOULED CONDITIONS

Salih Serkan ARTAGAN[1], Vladislav BORECKÝ[2], Jaromir BARTOŠ[3], and Robin KUREL[4]

Abstract
Ground Penetrating Radar (GPR) has recently been a routine non-destructive tool in railway infrastructure diagnostics. One of the phenomena occurring in the ballast structure, which can be detected by GPR, is presence of water. Moisture (water) can be trapped more frequently in the fouled railway ballast sections due to the filling of air voids within the ballast by finer materials hence reducing the drainage capability of the track infrastructure. This paper aims at experimentally assessing the moisture influence of the clean and fouled coarse granite ballast on the GPR signal characteristics.

Keywords
ground penetrating radar, railway ballast, moisture, diagnostics, transport infrastructure

1 INTRODUCTION

Railways are regarded as a cost-efficient and secure mode of transport. Diagnosis of the degraded sections of railway infrastructure and developing a good maintenance strategy is the main task of the railway operators in order to provide a sustainable service.

Railway ballast is the pivotal parameter of track infrastructure, condition of which has a key impact on the overall track stability [1]. Ballast fulfils fundamental functions of resisting vertical, longitudinal and lateral stresses applied to sleepers, keeping the track in position and enabling the immediate drainage of water from the track body [1–3]. In this respect, identification of the condition of ballast is significant for decision making process in efficiently assigning the limited funds for maintenance.

Due to cyclic loading from trains and through weathering processes, ballast structure deforms in time. Among many mechanisms, which result in ballast deterioration, ballast fouling and moisture (water) retention within ballast are commonly encountered issues. Ballast fouling, i.e. pollution of ballast occurs when air voids in the ballast are filled with finer materials because of ballast breakdown and infiltration of other materials from the ballast surface or infiltration from the base of the ballast layer [4].

Unless the track is drained adequately, water accumulation takes place in the track body, which subsequently causes a reduction in shear strength and stiffness of ballast as well as

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increasing the rate of deterioration and fouling process [5]. Influence of water on fouled ballast is much greater than it is on clean ballast since air voids in clean ballast enable drainage of water whereas in fouled ballast finer particles replacing air voids substantially limit the drainage ability of ballast. Early diagnosis of ballast fouling and trapped water within the ballast is therefore vitally important.

This paper aims at experimentally assessing the moisture influence of the clean and fouled coarse granite ballast on the received GPR signal characteristics.

2 GPR TECHNOLOGY

GPR is a probing technique, which sends discrete pulses of electromagnetic (EM) energy to identify variations of electrical properties of the subsurface [6,7] with a central frequency ranging from 10 MHz to 2.5 GHz to reveal the positions and sizes of electrically different layers and objects [8].

GPR has been in use for about 50 years and it is regarded as a strong non-destructive geophysical method in detecting and visualizing the structural and material features under the surface [9,10].

Particularly with the latest developments of the hardware and software, there has been a steady increase in the interest of both practitioners and researchers in this method lately [9]. GPR method is basically composed of antenna transmission of a radio waves (EM energy) into the ground or another medium via short EM pulses. A portion of the transmitted EM energy is reflected by differences in material relative permittivity (RDP) at material interfaces. Such dissimilarities or so-called anomalies appear in the form of changes in soil layers, groundwater surfaces, or buried objects [10]. In Fig. 1, there is a schematic view of GPR profile generation over ballasted track substructure [11].

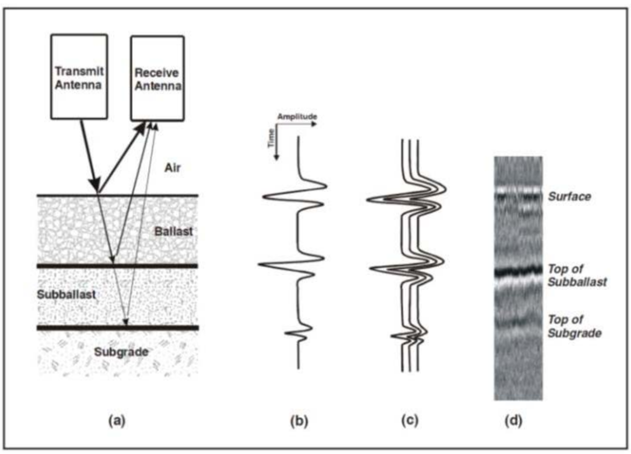

Fig. 1 The generation of a GPR profile with an air-coupled antenna over track bed. a) The transmitted energy is reflected off the boundaries in the substructure, b) A single trace composed of the reflection amplitudes for the reflections in (a), c) Multiple scans are generated in quick succession, d) Adjacent scans are combined to build a B-scan [11].

RDP (or also known as dielectric constant) and the conductivity of a material are the major material properties which govern the transmission and reflection patterns of the EM wave. RDP of a material is the amount of electrostatic energy stored per unit volume for a unit potential gradient by definition [12]. The magnetic susceptibility of a material is assumed not to influence GPR signal significantly [8].

GPR has been used in a great many fields ranging from detection of ice glaciers' thickness to mine detection and from forensic investigations to archeological works. Lately, its potential has been directed to road infrastructure surveys such as pavement layer thickness measurements, detection of voids, layer delamination in bridge deck, measurements of depth to steel dowels, detection of buried objects and utilities, asphalt stripping and scour around bridge piers [8].

A wide spectrum of GPR applications for railway infrastructure has been achieved such as determination of layer (ballast, sub-ballast, subgrade) thicknesses [13], inspection of embankment stability [14, 15], localization of trapped moisture areas within ballast [16], prediction of track modulus from GPR [17], detection of permafrost sections [18–21].

2.1 Known Height Method (KHM)

RDP value (ε_r) of railway ballast provides a preliminary information on the condition of ballast in terms of its fouling level (i.e. clean, fouled, and highly fouled) based on published literature values for that particular type of the ballast. Known Height Method (KHM) was used to compute RDP values in this work. KHM is one of the most common methods to predict RDP values, where the time differences between the reflection amplitudes of air/ballast interface and the ballast/metal plate interface are used. This time difference is widely known as two-way travel time (twt) in GPR glossary. To obtain RDP (ε_r) of ballast, formulas (1) and (2) were used.

$$v_r = \frac{2 \cdot h}{twt} \tag{1}$$

$$\varepsilon_r = \left(\frac{c}{v_r}\right)^2 \tag{2}$$

where v_r is the EM wave velocity through the ballast medium, *h* is the known height of the ballast layer, *twt* is the two-way radar travel time that the EM wave is transmitted to and reflected back from the target or interface of interest (the ballast layer in this case), $\mathcal{E}_r$ is RDP of railway ballast, *c* is the speed of light.

3 EXPERIMENTAL FRAMEWORK

Coarse-sized granite ballast and two types of fouling materials (sand and fine-sized gravel) were used to establish the clean and fouled ballast configurations. For clean ballast and for specific levels of fouling (10%, 30%, and 50% of the air voids in ballast) water was added gradually to introduce the moisture effect within the ballast structure according to the air voids volume of the ballast. GPR acquisitions were collected at each increment of water addition to assess the influence of variation of water itself and the combined effect of the changes in fouling and moisture on EM characteristics of the ballast under various conditions. A half-cut Intermediate Bulk Container (IBC) made of HDPE, equipped with a water drain valve, with base sides of 1 m x 1.2 m and a height of 0.50 m, was used during this experiment (Fig. 2). The thickness of the coarse-sized ballast layer was 25 cm. Vertical indicator sticks with height marks on them were used to measure the height of ballast. Placement and compaction of fouling materials were performed appropriately to form an even material layer. Required amounts of fouling materials corresponding to the desired fouling levels were mixed and distributed evenly into the ballast material. Fouling levels from 0% (clean ballast) to 50% (fouled ballast) were gradually arranged for each of the fouling materials at different times. The gradual increase was realized at increments of 10% of the air voids volume within the coarse-sized ballast material. At the first half of the tests, the increments of water were 10% of the air voids, however, then 5% increments were used to better monitor the influence of the addition of the water on the overall system.

Fig. 2 Half-cut IBC with the drain valve

Air-coupled shielded dipole antenna HN-2000 with central frequency of 2 GHz, which was produced by Ingegneria Dei Sistemi S.p.A. (IDS) (Fig. 3), was used during the experiments. K2 Fast Wave and ReflexW software were utilized for data collecting and for post-processing and the interpretation of the data, respectively.

Fig. 3 Air-coupled 2 GHz horn antenna

Several test configurations such as clean dry, clean wet, fouled dry and fouled wet ballast, are illustrated in Fig. 4.

Fig. 4 Test configurations for a) clean dry ballast, b) gradual addition of water to clean ballast via measuring cylinder, c) fully saturated ballast, d) dry ballast fouled with sand, e) wet ballast polluted with sand f) dry ballast fouled with fine gravel

4 RESULTS & DISCUSSION

4.1 Clean Coarse-sized Ballast

The findings for RDP values of gradually water (at 10% increments) included coarser clean ballast are presented in Fig. 5.

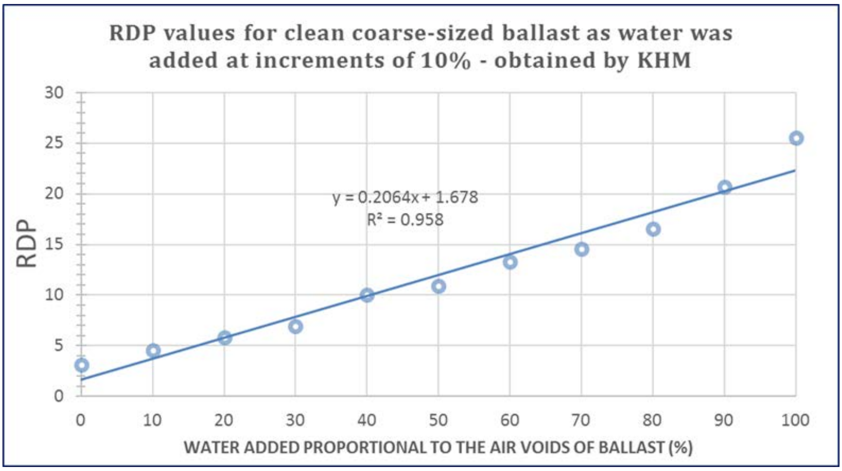

Fig. 5 RDP values for clean coarse-sized ballast at various water contents

At water levels from 0% to 100%, computed RDP values for clean coarse-sized ballast range from 3.090 (no water case) to 25.500 (saturated case). A strong linear trend with the coefficient of determination of 0.958 was observed in Fig. 5. The increase in RDP with increasing water content was also reported by other researchers [3, 22, 23]. After saturation level was reached, GPR data were collected and then water was drained from the IBC. 5 hours after the removal of water, GPR data were collected again. Then, GPR data were acquired in the first, third, sixth, seventh day after discharge of water. Finally, two more tests were carried out in the second and third weeks after removal of water. The corresponding RDP values versus days of GPR measurements are tabulated in Tab. below. RDP of saturated ballast upon the measurement just immediately after water addition was found to be 25.500, which is in line with the results from other studies [3, 22, 23]. GPR data revealed the RDP value of 3.876 just after draining of water. The average value of drained RDP values was 3.152, which is almost the same as the dry clean ballast.

Tab. 1 RDP values vs dry, saturated and drained ballast

Day #	1	2	2	3	5	8	9	16	23
Condition	Dry Clean	Saturated Clean	Just after removal of water (same day)	After 1 day of Removal	After 3 days of Removal	After 6 days of Removal	After 7 days of Removal	After 2 weeks of removal	After 3 weeks of removal
RDP	3.090	25.500	3.876	3.203	3.146	3.146	3.125	3.139	3.150

4.2 Coarse-sized Ballast Fouled by Sand

RDP values were computed for coarse-sized ballast at specific rates of sand fouling namely at 10%, 30%, and 50%. The results are demonstrated in Fig. 6. RDP values for coarse-sized ballast fouled by 10% sand increased from 3.271 to 24.699, as water was added gradually from 0% to 90%, respectively. A strong linear trend with the coefficient of determination of 0.9343 was observed in Fig. 6a. RDP values for coarse-sized ballast fouled by 30% sand are found between

3.538 to 19.774, as water was included progressively from 0% to 70%, respectively. A good linear trend with the coefficient of determination of 0.8939 was observed in Fig. 6b. RDP values for coarse-sized ballast fouled by 50% sand fell into the range from 4.229 to 14.374 as water was added to the IBC step by step from 0% 50% respectively. A strong linear trend with the coefficient of determination of 0.9608 was noted in Fig. 6c.

a)
b)
c)

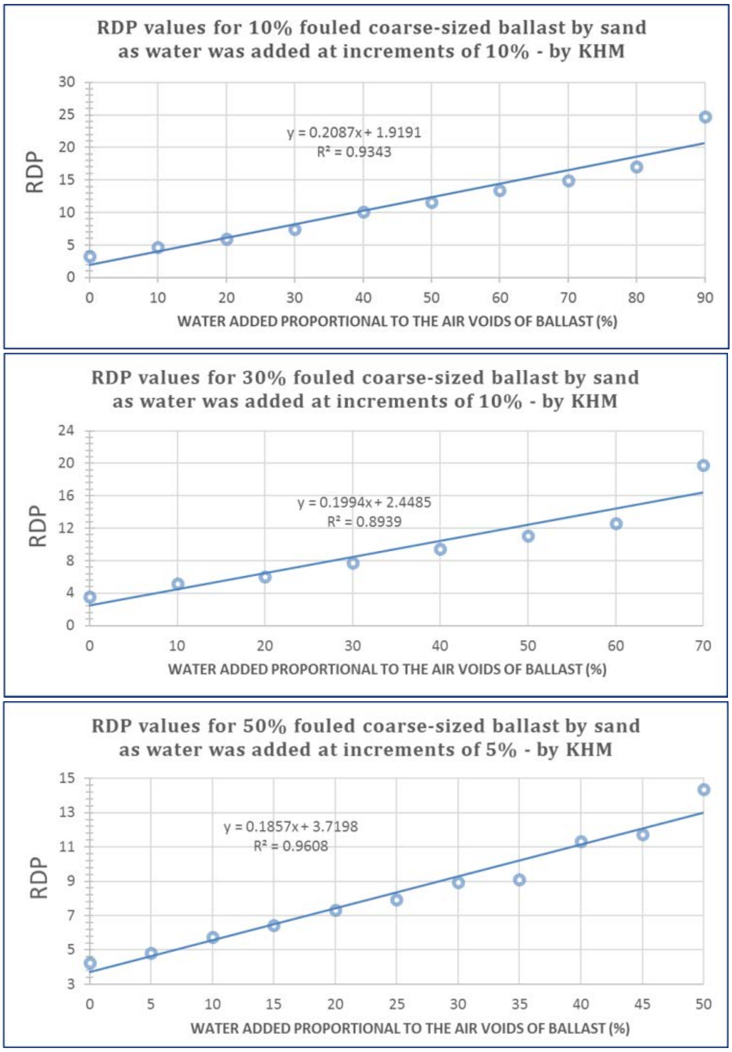

Fig. 6 RDP values for fouled coarse sized granite ballast under gradual water addition at specific levels of sand fouling a) 10%, b) 30%, c) 50% sand fouled ballast

4.3 Coarse-sized Ballast Fouled by Fine-Sized Gravel

Coarse-sized ballast was polluted by gravel at specific percentages of fouling i. e., at 10%, 30%, and 50%. Calculated RDP values are given in Fig. 7. RDP values for coarse-sized ballast fouled by 10% fine gravel range from 3.260 to 16.159, as water was added gradually from 0% to 75%, respectively. It should be noted that after 75% of water addition, no clear reflection from the metal plate was received due to high attenuation. Therefore, the results after 75% water addition were not reported. A strong linear trend with the coefficient of determination of 0.9846 was found in Fig. 7a. RDP values for coarse-sized ballast fouled by 30% fine gravel are computed between

3.523 to 17.650, as water was included progressively from 0% to 70%, respectively. A strong linear relationship with the coefficient of determination of 0.9635 was noted in Fig. 7b. RDP values for coarse-sized ballast fouled by 50% sand ranged from 4.135 to 13.021 as water was added to the IBC step by step from 0% to 50% respectively. A strong linear trend with the coefficient of determination of 0.9978 was noted in Fig. 7c.

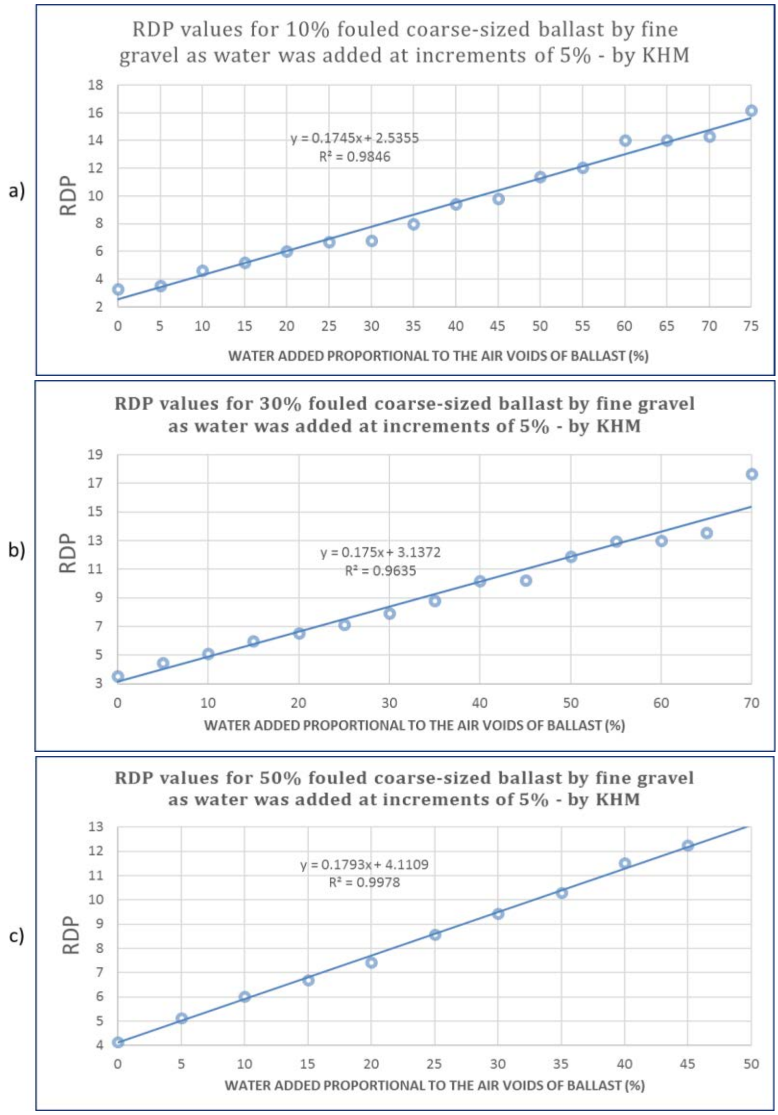

Fig. 7 RDP values for fouled coarse sized granite ballast under gradual water addition at specific levels of fine gravel fouling a) 10%, b) 30%, c) 50% fine gravel fouled ballast

5 CONCLUSION

The influence of moisture (water) in the clean and fouled coarse granite ballast on the GPR signal characteristics are assessed. RDP values of ballast under wet clean and wet fouled conditions by means of KHM were computed. A basis for the prediction of the RDP values of wet clean and wet fouled ballast by comparing the RDP values with the added volumetric percentage of water for a specific fouling level is obtained. Introducing water into clean and fouled ballast increases RDP value meeting the theoretical expectations since the RDP of water is 81.000, which is remarkably higher than the ballast and fouling materials. RDP of saturated clean coarse granite ballast was found to be 25.500, whereas the average value of drained ballast (3.152) was observed to have similar values with the dry one (3.090). For clean ballast and for fouled ballast at each fouling level, increase in the water level led to a rise in RDP values of the mixture of ballast and fouling material. RDP values tend to increase with increasing fouling levels as well. RDP values can be estimated for various water contents by using the linear relationships observed in Figs. 5, 6 and 7.

This research has been realized at the laboratories of Educational and Research Centre in Transport, Faculty of Transport Engineering, University of Pardubice with the GPR set of Department of Transport Structures.

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MSE WALL DESIGN FOR BRIDGE ABUTMENT BY DETERMINATION OF CRITICAL PARAMETERS

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Abstract
Bridges are essential and very important element of transportation structures. Therefore, their design and performance become important aspect of transportation projects. Bridge abutments are constructed over retaining structures. In this paper, design of mechanically stabilized wall supporting bridge abutment is investigated with respect to load and resistance factor, - considering different fill material and reinforcement properties.

Keywords
MSE wall, geosynthetic, geotextile, bridge abutment

1 INTRODUCTION

Mechanically stabilized earth walls (MSE) are started to be using instead of traditional retaining walls, because of their economic advantages and ease of construction. Mechanically stabilized earth walls are also less susceptible to settlements that may occur throughout their service life. Therefore, construction of MSE walls are started to be encountered in case of railway and highway projects. Failure of MSE walls during operation not only causes economical loss but also lives. Due to potential catastrophic effects in case of failure, many researchers have studied how to design MSE walls. Feng Chen et al. [2014] conducted stability analysis of reinforced soil wall constructed over thick clay layer using stress reduction method. T.S. Quang et al. [2009] presented a new method to design and stability analysis of reinforced earth wall, which is a multiphase approach, which accounts soil – strip failure condition. Ömer Bilgin [2009] studied various conditions, which affect reinforcement length. He used American association of state highway and official method (AASHTO) (2002) in his study. J.Han and D. Leshchinsky [2010] investigated effect of distance between two reinforced walls and wall's height. They also considered quality of backfill soil. Results are presented considering critical failure surface, tension loads on reinforcement and development of earth pressure. A. Sengupta [2012] numerically investigated possible reason for a failure of reinforced earth wall and concluded that, failure occurred due to overestimated strength of foundation soil. Yonggui Xie and Ben Leshchinsky [2015] investigated optimum reinforcement density in case of MSE walls as bridge abutments. L. Belabed et al. [2011] compared effect of possible failure wedges and earth pressure distribution into reinforcement loads and safety of the reinforced earth wall. V.A. Barvashov and I. M. Iovlev [2010] established a new calculation method

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for reinforced soil mass, especially for soil nails. Ben Leshchinsky [2014] conducted a parametric study to reveal effect of reinforcement density, strength of reinforcement and setback distance of footing to the behaviour of MSE wall. H. Ahmadi and M. Hajialilue-Bonab [2012] studied effect of reinforcement depth, reinforcement number and place of footing to reinforcement depth, reinforcement number and place of footing to behaviour of reinforced soil wall. G. D. Skinner and R. Kerry Rowe [2004] researched effect of reinforced earth wall constructed over yielding foundation with abutment and traffic loading. Richard J. Bathurts et al. [2005] introduced a new method to calculate reinforcement loads. D. Leshchinsky et al. [2014] presented a framework for limit state design of geosynthetic reinforced walls. R. Baker and Y. Klein [2003] presented how to design a reinforced soil walls with fully integrated limit equilibrium method.

It is seen from literature that, most of the researchers study internal design of reinforced earth walls. However, the bridge abutments were considered by very few researchers. Therefore, in this paper, reinforced earth wall, which is supporting a bridge abutment, is designed according to US Federal Highway Association (FHWA-2009) method. Forces acting on bridge abutment, reinforcement are evaluated. Forces acting on bridge abutment, external and internal stability of MSE wall are evaluated with respect to different abutment set back distance, reinforcement length, reinforced soil properties and retained soil properties in this paper.

2 METHOD

In order to design reinforced wall, load and resistance factor design (LRFD) methodology is used as described in FHWA. Loads that may cause failure of structures are increased with relevant load factors, while loads that act against failure are decreased by relevant load factors. Those load factors are determined according to maximum strength state of structure, minimum strength state of structure and service state of structure. Therefore, forces acting on structure are determined for all cases. After all those forces are determined, the most unfavourable conditions are taken into consideration. Unfavourable conditions are determined as taking maximum strength state of loads that may cause failure, while taking minimum strength state of loads that are against failure.

In order to conduct this research, a hypothetical reinforced wall and bridge abutment are considered. The selected design height of the wall is 6 m. The relevant dimensions of the footing and the chosen dead and live loads due to bridge is shown in Figure 1. The relevant values related to footing dimensions and height of the wall is given in Table 1.

Tab. 1 Relevant dimensions for footing and MSE wall

Item	Dimension
b_1 (m)	0.5
b_2 (m)	0.5
b_3 (m)	0.5
b_4 (m)	0.3
b_5 (m)	1.6
h_1 (m)	0.5
h_2 (m)	1.2
h_3 (m)	1.5
h_b (m)	0.024
h (m)	3.2
b_f (m)	3.4
H_a (m)	5
d (m)	1
H (m)	6

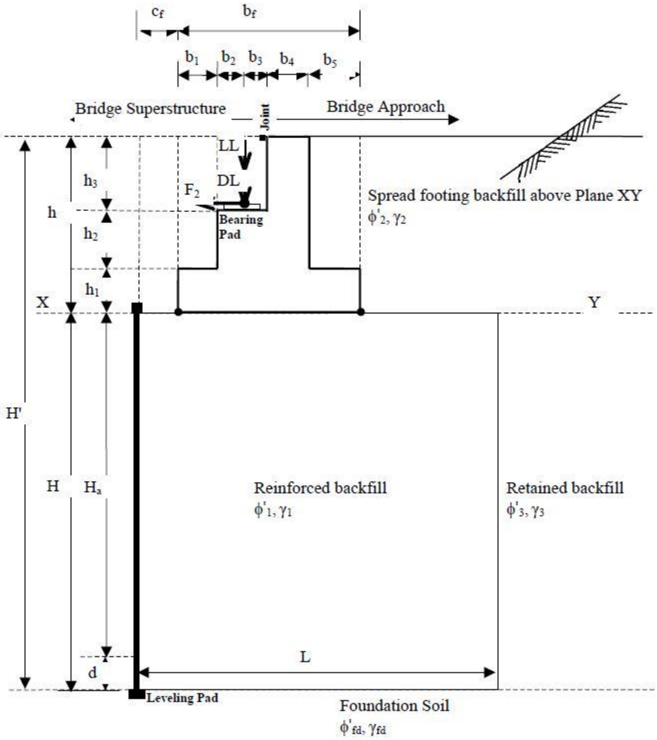

Fig. 1 Cross Section of MSE wall

Loads from bridge abutment which are shown in Figure 1, are also given in Table 2.

Tab. 2 Loads from bridge abutment

Load Type	Magnitude
Dead Load DL (kN/m)	155
Live Load LL (kN/m)	83
Friction Load F_2 (kN/m)	12

Foundation soil properties are chosen in order that they represent unfavourable condition in case of bearing capacity. Unit weight of foundation soil equals to 14.5 kN/m^3. The selected angle of friction is 27^0. Reinforced and retained soils' properties are changed to understand their effect on behaviour of reinforced wall with footing. Reinforcement length (L) and set back distance of footing (c_f) are also changed. Values considered for c_f and L in this paper are given in Table 3. It should be noted that reinforcement length is determined with respect to design height (H) of MSE wall.

Tab. 3 Setback distances for footing and reinforcement length

c_f (m)	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5
L	0.7H	0.8H	0.9H	1H	1.1H	1.2H	-	-

Reinforced soil and retained properties are chosen such as that each one of them represent weak, average and strong strength conditions. Strength conditions are defined with angle of friction and unit weight of soil together. Selected values are given in Table 4. Table 4 also shows unit weight and angle of friction for spread footing fill. Chosen unit weight of footing is 24 kN/m^3, which is common unit weight for concrete structures.

Tab. 4 Soil properties for base case

	γ [kN/m^3]	**Φ[^{0}]**
Reinforced Soil	14.5	27
	16	37
	17.4	47.38
Retained Soil	14.5	27
	16	37
	17.4	42
Spread Footing Fill	17.4	47.38

Since general description and dimensions of the considered project are given, we can begin to calculate forces acting on reinforced soil wall. In order to calculate forces, it would be better construct force diagram. Constructed force diagram is given in Figure 2.

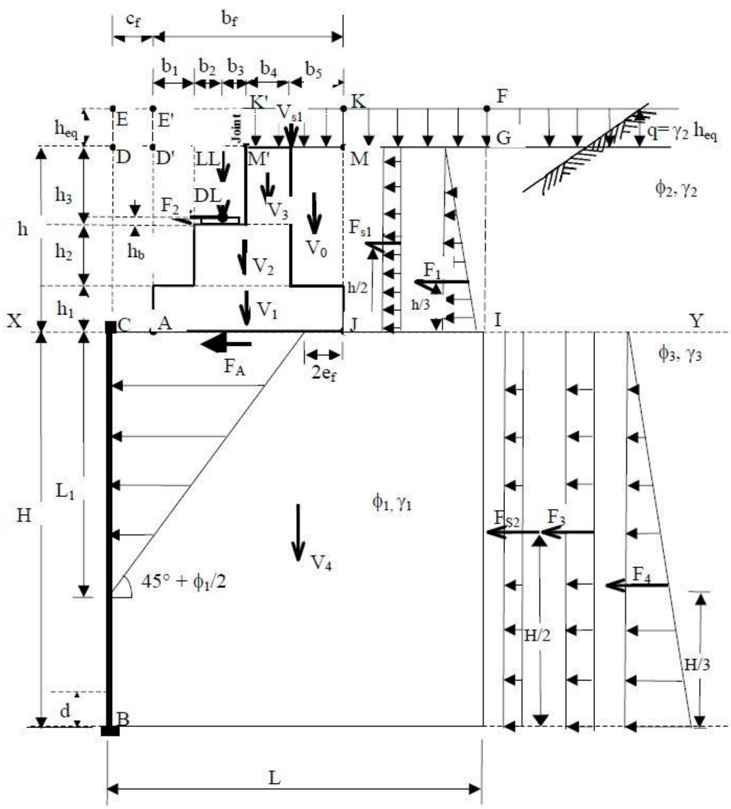

Fig. 2 Cross section of MSE wall with loads

The presented forces, which are acting on reinforced wall, can be computed as given in Table 5. Load factor is also given in Table 5 for each load part of the structure.

Tab. 5 Forces acting on MSE wall and their load type

Force	Formula	LRFD Load Type
V_0 (kN)	$(\gamma_2)*(h_2+h_3)*(b_5)$	EV
V_1 (kN)	$(\gamma_c)*(b_f)*(h_1)$	DC
V_2 (kN)	$(\gamma_c)*(b_2+b_3+b_4)*(h_2)$	DC
V_3 (kN)	$(\gamma_c)*(b_4)*(h_3)$	DC
V_4 (kN)	$(\gamma_1)*(H)*(L)$	EV
V_5 (kN)	$(\gamma_2)*(h)*(L)$	EV
V_s (kN)	$(q_F)*(L)$	LS
V_{s1} (kN)	$(\gamma_2)*(h_{eqF})*(b_4+b_5)$	LS
DL (kN)	-	DC
LL (kN)	-	LL
F_1 (kN/m)	$(1/2)*(K_{a2})*(\gamma_2)*(h^2)$	EH
F_2 (kN/m)	-	FR
F_3 (kN/m)	$(K_{a3})*[(\gamma_2)*(h)]*H$	EH
F_4 (kN/m)	$(1/2)*(K_{a3})*(\gamma_3)*(H^2)$	EH
F_{s1} (kN/m)	$(K_{a2})*[(\gamma_2)*(h_{eqF})]*(h)$	LS
F_{s2} (kN/m)	$(K_{a3})*[(\gamma_2)*(h_{eqM})]*H$	LS
F_A	F1+F2+Fs1	-

Load types are used to determine necessary load factor coefficients. Definitions of those load types may be given as follows:

- EH - horizontal earth loads,
- EV - Vertical pressure from dead load of earth fill,
- DC - components and attachments,
- FR - friction load, and
- LS - live load surcharge.

K_a stands for active lateral earth pressure and can be calculated as;

$$K_a = tan^2(45 - \frac{\emptyset}{2}) \quad (1)$$

Load factor values are given in Table 6 for maximum strength, minimum strength and service condition.

Tab. 6 Load factors for different load types

Load Factors according to AASHTO						
Load combination	EV	DC	LL/LS	ES	EH	FR
Strength I (max)	1.35	1.25	1.75	1.5	1.5	1
Strength I (min)	1	0.9	1.75	0.75	0.9	1
Service I	1	1	1	1	1	1

Since it is demonstrated how to compute forces, we may calculate overturning and resisting moments around toe of footing (Point A) and toe of MSE wall (Point B). Moment calculation formulas are given in Table 7.

Tab. 7 Calculation of moments required for the design of MSE wall

Moment (kN/m)	Point A	Point B
M_{V0}	$\gamma_2*(h_2+h_3)*b_5*((b_5/2)+(b_f-b_5))$	$\gamma_2*(h_2+h_3)*b_5*((b_5/2)+(b_f+c_f-b_5))$
M_{V1}	$\gamma_c*b_f*h_1*(b_f/2)$	$\gamma_c*b_f*h_1*(c_f+(b_f/2))$
M_{V2}	$\gamma_c*(b_2+b_3+b_4)*h_2*(b_1+((b_2+b_3+b_4)/2))$	$\gamma_c*(b_2+b_3+b_4)*h_2*(c_f+b_1+((b_2+b_3+b_4)/2))$
M_{V3}	$\gamma_c*b_4*h_3*((b_4/2)+b_1+b_2+b_3)$	$\gamma_c*b_4*h_3*(c_f+(b_4/2)+b_1+b_2+b_3)$
M_{V4}	-	$\gamma_1*H*L*(L/2)$
M_{V5}	-	$\gamma_2*h*L*(L/2)$
M_{Vs}	-	$q_F*L*(L/2)$
M_{Vs1}	$\gamma_2*h_{eqF}*(b_4+b_5)*(((b_4+b_5)/2)+b_1+b_2+b_3)$	$\gamma_2*h_{eqF}*(b_4+b_5)*(c_f+((b_4+b_5)/2)+b_1+b_2+b_3)$
M_{DL}	$DL*(b_1+b_2)$	$DL*(c_f+b_1+b_2)$
M_{LL}	$LL*(b_1+b_2)$	$LL*(c_f+b_1+b_2)$
M_{F1}	$0.5*Ka_2*\gamma_2*h^2*(h/3)$	$0.5*K_{a2}*\gamma_2*h^2*((h/3)+H)$
M_{F2}	$F_2*(h_1+h_2+h_b)$	$F_2*(h_1+h_2+h_b+H)$
M_{F3}	-	$K_{a3}*\gamma_2*h*H*(H/2)$
M_{F4}	-	$0.5*K_{a3}*\gamma_3*H^2*(H/3)$
M_{Fs1}	$(K_{a2})*[(\gamma_2)*(h_{eqF})]*(h)*(h/2)$	$K_{a2}*\gamma_2*h_{eqF}*h*(h/2)+H)$
M_{Fs2}	-	$K_{a3}*\gamma_2*h_{eqM}*H*(H/2)$
M_{FA}	-	$(F_1+F_2+F_{s1})*H$
		$(F_1+F_2+Fs_1)*(H-(L_1/3))$

Calculation of loads and moments are shown until this point. Since all the forces and moments are given, stability calculations may be made. Stability checks will be started from footing. After that, external stability of the MSE wall will be given. Internal stability check will be final stage of the design.

2.1 Stability Check for Footing

Stability check of footing is made in three steps. In the first step, eccentricity of footing under given loading conditions is found and compared with limiting eccentricity value. Since, footing is also under effect of horizontal forces, sliding check is done at second step. Finally, bearing capacity of the footing is compared with maximum bearing capacity determined by FHWA (2009).

The overturning and resistive moments around Point A and vertical force acting over footing should be computed without considering live loads in case of limiting eccentricity check. Those moments and vertical loads can be computed using formulas given in Table 8.

Sliding forces acting on the footing are equal to forces acting on the footing. Resisting forces are calculated as friction force between footing and reinforced soil. Therefore, vertical loads should be determined. Computed resisting forces should also be factored. Load factor for resistive sliding force is given as 0.8 by FHWA. Computation of safety of footing against sliding can be done as described in Table 9.

Tab. 8 Calculation of eccentricity of footing

M_{oa}	**$M_{F1}+M_{Fs1}+M_{F2}$**
M_{ra}	$M_{V0}+M_{V1}+M_{V2}+M_{V3}+M_{DL}$
M_a	$M_{ra}-M_{oa}$
V_a	$V_0+V_1+V_2+V_3+DL$
a_{nl}	M_A/V_A
e_f	$0.5*b_f-a_{nl}$
Critical Values	
M_{oa-c}	maximum strength condition
M_{ra-c}	minimum strength condition
M_{a-c}	$M_{ra-c}-M_{oa-c}$
V_{a-c}	minimum strength condition
a_{nl}	M_{a-c}/V_{a-c}
e_f	$0.5b_f-a_{nl}$
e	$b_f/4$

Tab. 9 Calculation of sliding forces acting on bridge abutment

F_A	**$F_1+F_{S1}+F_2$**
V_A	$V_0+V_1+V_2+V_3$ +DL
V_N	$V_A*\tan\phi_1$
V_F	ϕ_s*V_N
CDR	V_F/F_A
Critical Values	
Minimum strength condition	
Maximum strength condition	
$V_{fmin}>F_{Amax}$	YES/NO
CDR	V_{fmin}/F_{Amax}

During calculation of bearing stress of footing, live loads are taken into consideration because, live loads impose additional stress. The calculation process is similar to computation of limiting eccentricity. Calculation steps for bearing capacity of footing are given in Table 10.

2.2 External Stability of MSE Wall

Since stability of footing is evaluated, external stability of MSE wall can now be evaluated. External stability analysis of MSE wall can be done by considering limiting eccentricity, sliding resisting and bearing capacity of the wall.

Limiting eccentricity of the MSE wall consists of computing overturning moments, resistive moments and acting vertical force along MSE wall. Limiting eccentricity check can be done by following the methodology given in Table 11.

Tab. 10 Calculation of bearing stress exerted by bridge abutment

M_{oa}	**$M_{F1}+M_{F2}+M_{Fs1}$**
M_{ra}	$M_{V0}+M_{V1}+M_{V2}+M_{V3}+M_{DL}+M_{LL}+M_{VS1}$
M_A	$M_{ra}-M_o$
V_{ab}	$V_0+V_1+V_2+V_3+DL+LL+V_{S1}$
a_{wl}	M_A/V_{ab}
e_f	$0.5b_f-a_{wl}$
$b_{f'}$	b_f-2e_f
σ	$V_{ab}/(b_f-2e_f)$
L_1	$(c_f+(b_f-2e_f))*\tan(45+\phi_1/2)$
Critical Values	
M_{oa-c}	maximum strength condition
M_{ra-c}	minimum strength condition
M_{a-c}	$M_{ra-c}-M_{oa-c}$
V_{a-c}	minimum strength condition
a_{wl}	M_{a-c}/V_{a-c}
e_f	$0.5bf-a_{wl}$
$b_{f'}$	b_f-2e_f
σ	$V_{ab-c}/(b_f-2e_f)$
q_r	335

Sliding of the MSE wall means horizontal translational movement of the wall. Safety against sliding of depends on magnitudes of horizontal forces acting on MSE wall and resistive forces between wall and foundation soil. Safety against sliding can be checked by following Table 12.

Tab. 11 Calculation of eccentricity of MSE wall

Item	**Formula**
Un-factored Soil Weight in Block CDMJ in the abutment footing area	$W= h*(bf+cf)*\gamma_{sfb}$
Load factor for soil weight in block CDMJ [EV]	
Factored Soil Weight in block CDMJ in Abutment footing area	
Un-factored LL Weight on Block CDMJ in Abutment Footing	$LL=(b_f+c_f)*\gamma_{sfb}*h_{eqF}$
Load factor for LL on Block CDMJ [LS]	
Factored LL weight on block CDMJ in abutment footing area	
Vertical weight due to soil weight and LL in block CDMJ	
Vertical weight from abutment footing including soil on heel and LL	$V_{Ab}=V_0+V_1+V_2+V_3+DL+LL+V_{S1}$
Vertical weight from abutment footing including soil on heel and no LL	$V_A=V_0+V_1+V_2+V_3+DL+V_{S1}$
Net load, P, on base of spread footing from the bridge (with consideration of LL) Pwl	$P_{wL} =V_{ab-h}*\gamma_{sfb}*(b_f+c_f)$
Net load, P, on base of spread footing from the bridge (no LL) Pnl	$P_{nL} =V_{ab-h}*\gamma_{sfb}*(b_f+c_f)$
Moment arm of net load Pnl from Point B	$L_p=a_{nL}+c_f$
Resisting Moment at Point B due to net load P	$M_{PnL}=P_{nL}*(l_p)$
Vertical Load at the base of MSE wall without LL	$V_B=V_4+V_5+P_{nL}$
Resisting moments about Point B without LL surcharge	$M_{RB}=M_{V4}+M_{V5}+M_{PnL}$
Overturning moments about Point B	$M_{OB}=M_{FS2}+M_{F3}+M_{F4}+M_{FA}$
Location of the Resultant force on base of MSE wall from point B	$b=(M_{RB}-M_{OB})/V_B$
Eccentricity at base of MSE wall	$e = L/2-b$
Limiting Eccentricity	
Is the Resultant within limiting Value of e_l	
Critical Values Based on Max/Min	
Overturning Moments about Point B $M_{ob,c}$	maximum strength condition
Resisting moments about Point B $M_{Rb,c}$	Minimum strength condition
Net Moment about Point B	$M_{Rb-c}-M_{ob-c}$
Vertical Force $V_{B,c}$	Minimum strength condition
Location of Resultant from Point b	M_{B-C}/V_{B-C}
Eccentricity from Centre of Footing	$e_l=L/2-b$
Limiting Eccentricity	$e=L/4$
Is the Limiting Eccentricity Satisfied	

Tab. 12 Calculation of sliding forces acting between MSE wall and foundation soil

Item	Formula
Lateral Load on MSE wall	$H_m=F_1+F_2+F_3+F_4+F_{S1}+F_{S2}$
Vertical Load at base of MSE wall without LL surcharge	$V=V_4+V_5+P_{nL}$
Nominal sliding resistance at base of MSE wall	$V_{Nm}=\tan\phi_d*(V_4+V_5+P_{nL})$
Factored sliding resistance at base of MSE wall	$V_{Fm}=\phi_s*V_{Nm}$
Is $V_{FM}>H_m$	
Capacity Demand Ratio	V_{Fm}/H_m
Critical Values Based on Max/Min	
Minimum V_{FM}	
Maximum H_M	
IS $V_{fmin}>H_{mmax}$	
Capacity Demand Ration V_{fmmin}/H_{mmax}	

The last step to evaluate external stability of MSE wall consists of evaluating safety against bearing capacity of foundation soil. Load bearing capacity of foundation soil is compared with vertical loads due to MSE wall. Safety against bearing capacity of MSE wall can be determined by using Table 13.

2.3 Internal Stability of MSE Wall

Stability check of footing and external stability of MSE wall is evaluated until now. In order to finish design of MSE wall, internal stability of it should also be checked. Internal stability of MSE wall covers, safety against pull – out of reinforcements from soil and safety against rupture of reinforcement. It should be noted that, pull – out occurs when acting tensile forces are higher than the reinforcement can transfer to soil. Reinforcement fails when tensile forces higher than its strength. Therefore, we will establish relationships to calculate tensile forces acting over the reinforcement and check if it can carry those loads safely.

First step can be taken as determining placement of geosynthetics for internal stability check. In this study, first layer of geosynthetic is placed to depth of 0.4 meter. Following layers are placed at 0.4-meter intervals. After that, vertical stresses are determined for each reinforcement layer. Horizontal stresses are computed from vertical stresses. Additional horizontal stresses are computed due to footing and surcharge loads. All computed forces are summed to find total force acting on geosynthetic layer. After determination of forces acting on geosynthetic, pull – out capacity of each layer is determined by formula (2).

$$P_r = F^* \alpha \sigma_v L_e C \tag{2}$$

In this formula P_r represents pull-out capacity, L_e represents length of reinforcement in resisting zone, C equals to reinforcement effective unit parameter and F^* stands for pull out resistance factor.

Tab. 13 Calculation of bearing stress exerted to foundation soil by MSE wall

Item	**Formula**
Component 1	
Base width of stress distribution based on 1H:2V distribution and Pwl acting on $b_f'=b_f-2e_f$	$(b_f-2e_f)+(c_f+H/2)$
Bearing Stress Due to P_{wl}	$P_{wl}/(b_f-2e_f)+(c_f+H/2)$
Component 2	
Vertical load at base of MSE wall including LL on top	$V=V_4+V_5+V_S$
Resisting Moments at Point B on MSE wall	$M_{RB}=M_{V5}+M_{VS}+M_{V4}$
Overturning moments at Point B on MSE wall	$M_{FS2}+M_{F3}+M_{F4}$
Net Moment at Point B	$M_B=M_{RB}-M_{OB}$
Location of Resultant from Point B	$b=M_B/V$
Eccentricity from centre of Wall	$e_L=0.5L-b$
Limiting Eccentricity	L/4 or L/6
Is resultant eccentricity within limiting value of e_L	
Effective width of base of MSE wall	$B'=L-2e_L$
Factored bearing stress due to MSE wall	$V/(L-2e_L)$
Total bearing Stress due to Component 1 + 2	$\Delta\sigma_v+\sigma_v$
Factored bearing resistance q_r	
Is $\sigma_{max}<q_r$	
Capacity Demand Ratio	q_r/σ_{max}
Critical Values Based on Max/Min for Component 2	
Overturning moments about Point B, M_{OB-C}	Maximum strength condition
Resisting moments about Point B, M_{RB-C}	Minimum strength condition
Net moment about Point B	$M_{B-C} = M_{RB-C} - M_{OB-C}$
Vertical force, V_{Bb-C}	Minimum strenght condition
Location of resultant from Point B	$b = M_{B-C}/V_{Bb-C}$
Eccentricity from center of wall	$e_L = 0.5*L – b$
Limiting eccentricity	$e = L/4$
Is the limiting eccentricity criteria satisfied?	
Effective width of base of MSE wall	$B' = L-2e_L$
Bearing stress	$\sigma_{v-c} = V_{Bb-C} / (L-2e_L)$
Compute critical total bearing stress	
Total bearing stress due to Component 1+2	σ_{vmax-C}
Factored bearing resistance, q_R	307
Is bearing stress < factored bearing resistance	
Capacity : Demand Ratio (CDR)	$q_R:\sigma_{vmax-C}$

3 RESULTS

Design of MSE wall according to FHWA (2009) is introduced to reader. Performance of the MSE wall will be evaluated and compared with respect to abutment distance to wall facing, reinforced soil properties, reinforcement length and retained fill properties.

3.1 Effect of Abutment Distance

Abutment distance is measured from wall facing to the near edge of the footing. That distance is varied from 0.15 meter to 0.50 meter with 0.05 increments.

Calculations according to FHWA (2009) showed that changing place of footing does not affect eccentricity of footing, stress due to footing and sliding on footing. Sliding resistance of footing is computed as 256.298 kN/m while, driving force is computed as 45.827 kN/m. Bearing stress of footing is computed as 183.233 kN/m. This value is lower than the bearing stress limit stated in FHWA. Eccentricity of the footing is calculated as 0.383 m while its limit value is computed as 0.85 m.

When the external stability of MSE wall is investigated with respect to increasing footing distance from wall, it is seen that eccentricity of wall decreases slightly from 1.713 to 1.705 as distance increases from 0.15 m to 0.50 m. Decrease of eccentricity is seen when distance equals to 0.40 m. After that threshold value, wall eccentricity remains constant. Sliding force acting on MSE wall and, bearing stress exerted by MSE wall to foundation soil linearly decreases as the footing move away from the wall. Change of sliding force and bearing stress can be seen in Figure 3 given below.

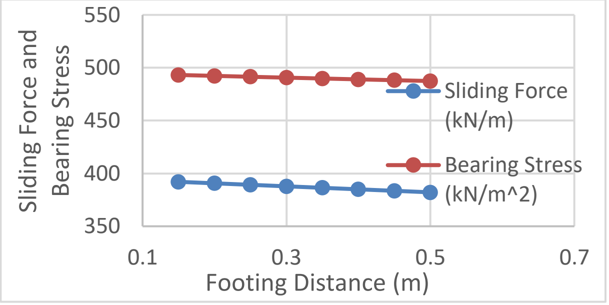

Fig. 3 Change of sliding force and bearing stress between MSE wall and foundation soil

Pull – out capacity of the first reinforcement layer is computed as 99.28 kN/m while it is calculated as 486.92 kN/m for the last reinforcement layer for all cases. Computations showed that, maximum reinforcement tension loads decrease as the footing distance increases. Maximum tension load decreases from 22 kN/m to 20 kN/m for the first reinforcement layer, while it decreases from 25.05 kN/m to 24.87 kN/m for the last reinforcement when footing distance is increased to 0.50 m from 0.15 m.

3.2 Reinforced Soil Properties

Three different cases are selected to determine effect of reinforced soil properties such as unit weight and angle of friction. Those two parameters increased or decreased together because they are related to each other. 27^0, 37^0 and 47^0 degrees is selected as angle of friction for case 1, case 2 and case 3 respectively. Unit weights are chosen as 14.5 kN/m^3, 16 kN/m^3 and 17.4 kN/m^3 respectively for case 1, case 2 and case 3.

It is seen that computed eccentricity is not affected from reinforced soil properties. Eccentricity of footing is calculated as 0.38 m and it is lower than limiting eccentricity, which equals to 0.85 m for all the cases. Computed bearing stress due to footing also remained constant with respect to change in reinforced soil properties. However, in case of sliding resistance, it is seen that, sliding resistance increases as the reinforced soil properties increases. Increase can be seen in Figure 4.

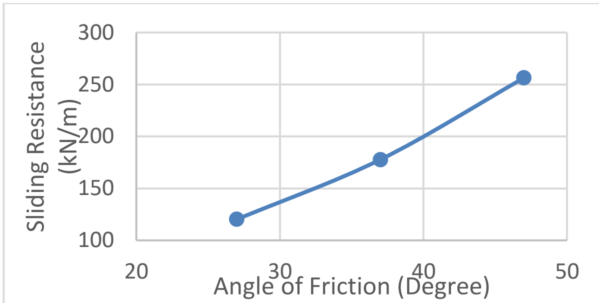

Fig. 4 Change of sliding resistance with respect to angle of friction of reinforced soil

Since forces causing sliding are constant and computed as 45.83 kN/m, it is clear that ratio between resistive forces and sliding force increases. This ratio is called capacity/demand ratio and it increases from 2.62 to 5.59 as angle of friction increases from 27^0 to 47^0.

When external stability of MSE wall is taken into consideration, it is seen that using stronger fill for reinforcement area positively contributes to limiting eccentricity, sliding and bearing resistance of MSE wall. It is seen that eccentricity of MSE wall decreases from 1.89 m to 1.71 m. It should be noted that limiting eccentricity is calculated as 1.05 m for MSE wall. It is also seen that, as the quality of reinforced soil increases, resistance against sliding increases and less stress is exerted to foundation soil. Change of resistance against sliding and bearing stress may be seen in Figure 5.

When internal design of MSE wall is investigated under different reinforced soil properties, it is seen that, as the reinforced soil gets stronger, pull-out capacity increases. Pull out capacity of first layer reinforcement is computed as 17.42 kN/m for the weakest reinforced soil properties, while 46.19 kN/m maximum tension load is computed for same reinforcement layer and same reinforced soil properties. However, as the reinforced soil gets stronger, maximum tension load on reinforcement decreases and pull out capacity increases. This behaviour may be seen in Figure 6.

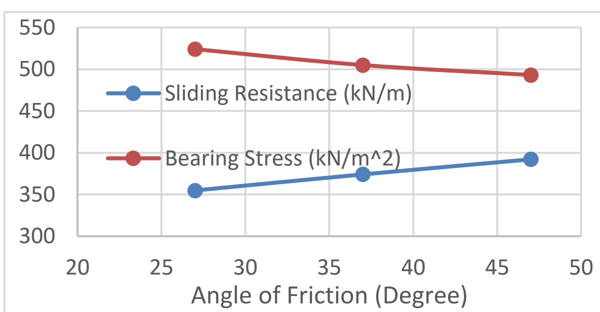

Fig. 5 Change of sliding resistance and bearing stress with respect to angle of friction of reinforced soil

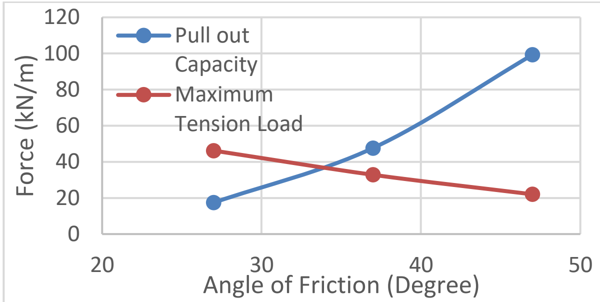

Fig. 6 Change of maximum tension on reinforcement and pull out capacity

3.3 Reinforcement Length

FHWA (2009) specifies minimum reinforcement length as 0.7H of height of the MSE wall. Therefore, reinforcement length is varied between 0.7H to 1.2H in this research. Results showed that reinforcement length does not affect footing's sliding resistance, bearing stress and eccentricity. However, it is seen that increasing reinforcement length has positive effect on MSE wall. Limiting eccentricity of MSE wall increases to 1.8 m from 1.05 m as reinforcement length increases to 1.2H from 0.7H. It should be also stated that, eccentricity of wall decreases at the same time. Change of limiting eccentricity and eccentricity of wall can be seen in Figure 7.

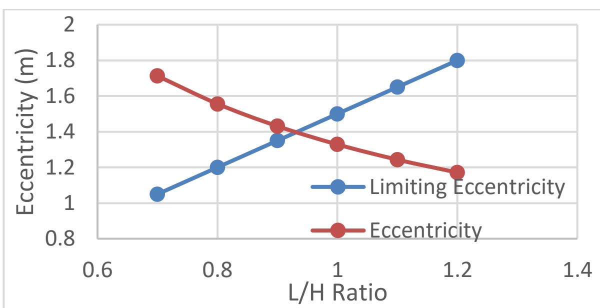

Fig. 7 Change of limiting eccentricity and eccentricity of MSE wall with reinforcement length

Similarly, resistive moments against overturning also increases as reinforcement length increases. Resistive moment is calculated as 1656.30 kNm/m for 0.7H and increases to 4867.50 kNm/m for 1.2H reinforcement length. Increase of reinforcement length decreased bearing stress exerted to foundation soil. Change of bearing stress with respect to reinforcement length may be seen in Figure 8.

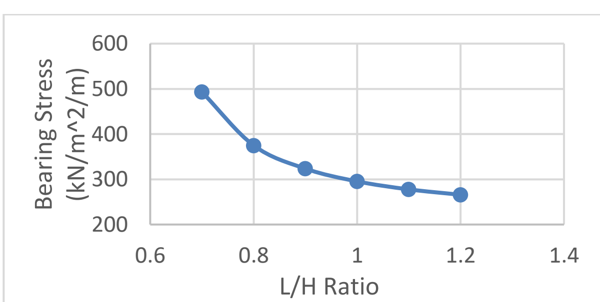

Fig. 8 Change of bearing stress exerted to foundation soil with reinforcement length

It is clear according to Figure 8 that bearing stress does not decrease linearly as reinforcement length increases.

When internal stability of wall is considered, it is seen that, maximum tension on geosynthetic layers does not change with respect to reinforcement length. However, pull out capacity increases linearly. Change of pull out capacity is showed in Figure 9 for the first layer and last layer of reinforcement.

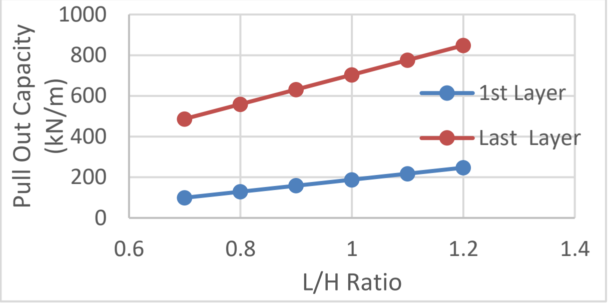

Fig 9. Pull out capacity change for the first and last layer of reinforcement with respect to reinforcement length

According to Figure 9, pull out increment is higher in case of the last layer of reinforcement. Pull out capacity is computed as 99.28 kN/m and 486.92 kN/m for the first and last layer reinforcement for 0.7H reinforcement length respectively. When reinforcement length increases to 1.2H, computed pull out capacity increases to 247.05 kN/m and 848.14 kN/m for the first layer and last layer of reinforcement respectively.

3.4 Retained Fill Properties

Effect of retained fill properties to MSE wall design was also analysed in this research. Three different cases were selected according to unit weight and angle of friction. Unit weight and angle of friction are chosen as 14.5 kN/m^3 and 27^0 for case 1, 16 kN/m^3 and 37^0 for case 2 and 17 kN/m^3 and 42^0 for case 3. Change on those properties does not affected design criteria for abutment.

If effect of retained fill properties is evaluated, it is seen that, as retained fill gets stronger, lower driving forces are observed for both over turning moment and sliding. That behaviour causes more reliable design of the MSE wall. Change of overturning moment with respect to angle of friction can be seen in Figure 10.

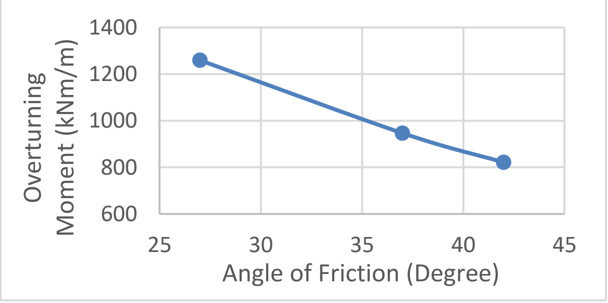

Fig. 10 Change in magnitude of overturning moment with angle of friction of retained fill

Eccentricity of wall decreases to 1.14 m from 1.71 m as angle of friction decreases. Overturning moment decreases to 821.22 kNm/m from 1259.1 kNm/m at the same time. Sliding force decreases to 258.24 kN/m from 422.88 kN/m, which causes an increase of capacity demand ratio from 0.93 to 1.52. Since overturning moment and eccentricity of MSE wall decrease, effective foundation area of MSE wall increases, which yields less bearing stress exerted to foundation soil. Therefore, bearing stress exerted to foundation soil decreases to 310.63 kN/m from 493.16 kN/m. Calculations also showed that, retained fill properties does not affect internal design of MSE wall. Therefore, no change of maximum tension or pull out capacity on reinforcement layers was computed according to FHWA (2009).

4 CONCLUSION

In this research, FHWA (2009) code is followed to design a MSE wall, which supports a bridge abutment. Abutment distance to wall, reinforcement length, reinforced soil properties and retained soil properties are changed to analyse their effect on design of MSE walls according to FHWA code. Following conclusions can be deduced from the results of this research:

- Design parameters of bridge abutment are independent from retained fill properties and reinforcement length;
- Using stronger reinforced soil zone increases resistive forces, while stronger retained fill decreases driving forces;
- Increasing reinforcement length is the most efficient way to sustain minimum safety conditions for both external and internal design of MSE wall.

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COMPARISON SEA AND RAIL TRANSPORT OF CONTAINER

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Abstract

Container transport of goods between China and Europe, respectively between China and the Czech Republic, is an important part of trade between these countries and its volume is still increasing.

This contribution contains analysis of the current state of two modes of transport, namely maritime and rail transport between the Far East and Europe, respectively between the Far East and the Czech Republic. Both of these modes of transport are environmentally friendly and should be used for transport of goods in the future.

One part of this contribution contains comparison of selected aspects. Selected aspects are prices, time of transport and safety.

Comparison of the two modes, maritime and rail transport is reasonable, because prices, time of transport and safety are important for a decision, which mode of transport to use.

Keywords

container, maritime transport, railways, environment, safety

1 INTRODUCTION

This contribution presents a comparison of shipping containers using maritime transport and rail transport between the Czech Republic and the People's Republic of China. An important part is an analysis of specific conditions for containers in maritime transport and in rail transport in order to compare these two modes of transport, including identification of possible perils.

Growth of the People's Republic of China's economy follows a fact that the People's Republic of China produces about 25% of total world production of goods nowadays, compared to 1990, when this figure was around 3%. This development is also caused by a fact that many world-wide companies producing different kind of goods decided and still decide to place their producing plants into China due to cheap price of labour force there. Therefore, need of transport of goods between China and Europe and in the opposite direction is growing. Although transport between Asia and Europe will ever continue to be important, pressure on reducing costs leads to relocation of producing plants to other countries like Bangladesh or Cambodia. [1]

Imports from China (especially textile, electronics etc.) to the Czech Republic are several times higher than exports. This is valid also for other countries in Europe and all over the world. [2]

A major part of goods between China and the Czech Republic is transported by maritime transport, but amount of goods transported by rail increases. Air transport has a small share.

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2 TRANSPORT OF CONTAINERS BETWEEN CHINA AND EUROPEAN PORTS

In recent years, over 20 million TEUs have been shipped between Asia and Europe yearly (see Fig. 1). Trend of a curve follows rapid growth especially from 2002. This corresponds to growth of Chinese economy in this period, of course, with exception of temporary fall in 2009 as a result of global financial crisis.

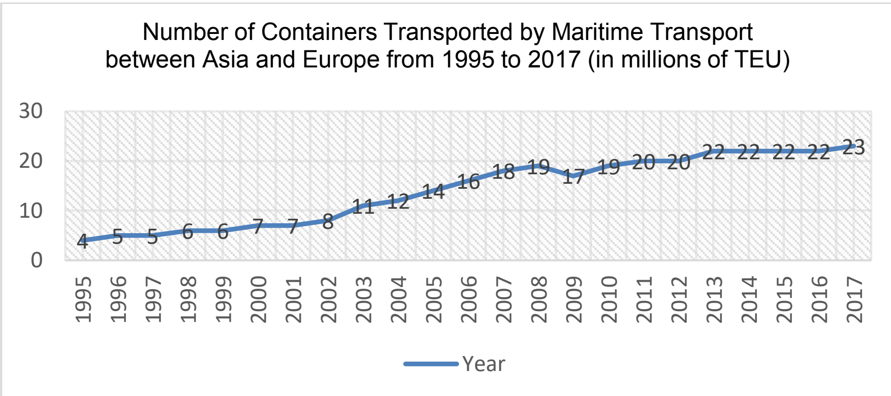

Fig. 1 Number of Containers Transported by Maritime Transport between Asia and Europe from 1995 to 2017 (Source: Authors using data from [3])

In a case of container transport to the Czech Republic, it is necessary to include into comparison a route from a European port to the Czech Republic using another mode of transport, namely road or rail mode, which enlarges time of transport and increases a price for transport. [7]

If we compile a table of WORLD TOP ports, ten of them are in China, but just three of them are in Europe (see Table 1). The size and utilization of Chinese ports is directly related to volume of exported goods to Europe and other continents.

Tab. 1 Ranking of the largest container ports in the world in 2016 (Source: Authors using data from [4])

Ranking	Port		2016	2015	2014	2013	2012
1	Shanghai, China	**Mill. TEU**	37.13	36.54	35.29	33.62	32.53
2	Singapore	**Mill. TEU**	30.90	30.92	33.87	32.60	31.65
3	Shenzhen, China	**Mill. TEU**	23.97	24.20	24.03	23.28	22.94
4	Ningbo-Zhoushan, China	**Mill. TEU**	21.60	20.63	19.45	17.33	16.83
5	Busan, South Korea	**Mill. TEU**	19.85	19.45	18.65	17.69	17.04
6	Hong Kong, S.A.R., China	**Mill. TEU**	19.81	20.07	22.23	22.35	23.12
7	Guangzhou Harbor, China	**Mill. TEU**	18.85	17.22	16.16	15.31	14.74
8	Qingdao, China	**Mill. TEU**	18.01	17.47	16.62	15.52	14.50
9	Jebel Ali, Dubai, U. A. Emirat.	**Mill. TEU**	15.73	15.60	15.25	13.64	13.30
10	Tianjin, China	**Mill. TEU**	14.49	14.11	14.05	13.01	12.30
11	Port Klang, Malaysia	**Mill. TEU**	13.20	11.89	10.95	10.35	10.00
12	Rotterdam, Netherlands	**Mill. TEU**	12.38	12.23	12.30	11.62	11.87
13	Kaohsiung, Taiwan, China	**Mill. TEU**	10.46	10.26	10.59	9.94	9.78
14	Antwerp, Belgium	**Mill. TEU**	10.04	9.65	8.98	8.59	8.64
15	Dalian, China	**Mill. TEU**	9.61	9.45	10.13	10.86	8.92
16	Xiamen, China	**Mill. TEU**	9.61	9.18	8.57	8.01	7.20
17	Hamburg, Germany	**Mill. TEU**	8.91	8.82	9.73	9.30	8.89

2.1 Perils

a. Security and Safety

Security

- Possibility of attack related to significant position in international trade and the value of transported goods
- Possibility of carrying containers with weapons, explosives and other dangerous objects
- Danger of transport of radioactive substances
- Smuggling people, drugs, chemicals, biological and other dangerous material [8]
- Possibility of attack by pirates (especially on South China Sea and Western Indian Ocean)

Safety

- Safety of cargo, crew, infrastructure and the environment
- Compliance with regulations and standards in shipbuilding, a safety test
- Minimizing risk of damage of a ship, damage to cargo, incorrect container fixing, loss of containers
- Stabilization of vessel

b. Reliability

Basic criteria, like delivery of goods to place of destination, delivery time, transport safety, a transport price and others, are applied.

Perils

- Human factor
- Technical condition of a ship
- Narrow throats (on busy routes and in ports)
- Climate conditions

c. Economic and Political Influences

Perils associated with economic impacts in particular are as follows:

- Increase or decrease of international trade
- Change of political situation in different parts of the world
- Manufacturing plants are moved inland in China and therefore, demand for rail transport is growing

d. Ecology

Maritime vessels use combustion engines burning diesel or heavy fuel oil. Low-quality fuel is used for marine engines in terms of environmental impact. As a result, high amount of emissions is deflated into air. Some states issued a low-emission zone along their coast, so cleaner fuel from additional tanks is burned in vicinity of harbours, but less quality and environmentally friendly fuel is burned on the open sea due to financial savings.

Another peril is probability of transferring biological material (animals, plants, bacteria etc.) from a source port to a port of destination or leak of fuel into a sea. [9]

3. TRANSPORT OF CONTAINERS BETWEEN CHINA AND THE CZECH REPUBLIC BY RAIL

Rail transport between China and Europe is possible with usage of Trans-Siberian Railway or using a route called “Silk Road”. Quantity of transported containers is constantly increasing. Around 2 000 TEU were transported in 2011, roughly 42 000 TEU were transported in 2016 and according to a forecast 100 000 TEU might be transported in 2020 [10].

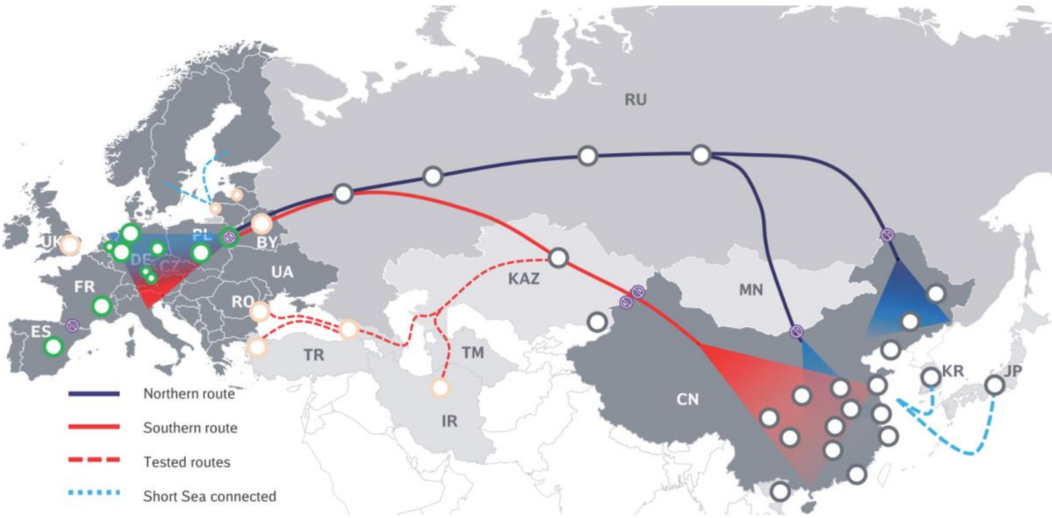

Fig. 2 Railway routes between China and Europe (blue – northern route, red – southern route) (Source: [5, 11])

3.1 Perils

a. Security and safety

Security

- Possibility of attack related to significant position in international trade and the value of transported goods
- Smuggling drugs
- Smuggling chemicals, biological and other dangerous material
- Smuggling people [11]

Safety

- Container damage during a transhipment
- Damage to goods, especially to perishable goods
- Technical condition of a railway line

b. Reliability

Basic criteria, like delivery of goods to place of destination, delivery time, transport safety, a transport price and other, are applied.

Perils:

- External influences (like weather)
- Transhipment when switching from one rail gauge to another rail gauge
- Narrow throats (on busy routes and in locations in repair)
- Danger of a traffic accident, a temporary closure of a route

b. Economic and Political Influences

Perils associated with economic impacts in particular are as follows:

- Increase or decrease of international trade
- Change of political situation in a state of departure or in a state of destination

c. Ecology

Rail transport is more environmentally friendly than road transport, but rail transport generates more transport externalities than maritime transport. Electric locomotives are more ecological than locomotives with combustion engine, but electric locomotives can't be used on every railway line, because not all of them are equipped for operation of electric locomotives.

However, negatives have to be taken into consideration of electric locomotives as well. Negatives are emissions and environmental burden in the place of electricity generation. Emission burden is higher in a case of usage of diesel engines.

4. COMPARISON

4.1 SWOT Analysis

A route from the Czech Republic to the People's Republic of China was chosen to compare container transport between maritime and rail transport.

SWOT analysis is proven method, which is used below in modified version (see Table 2 and Table 3).

Inner and auxiliary factors, namely "Strengths" and "Weaknesses", represent characteristics of the given modes of transport. The external and auxiliary factors, namely "Opportunities" and "Threats", represent perils and opportunities that these modes of transport may have in a future.

Tab. 2 SWOT analysis of maritime transport of containers (Source: Authors)

Strengths	Weaknesses
• Lower transport price • Higher offered capacity • Favourable for seaside regions • Transport of large quantities of goods	• Longer time of transport • Longer routes • Possibility of container damage or loss during a voyage • Need of transhipment on railways or roads • High CO_2 emissions and sulphur oxides
Opportunities	Threats
• Reduction of CO_2 emissions thanks to recovery of waste heat • Container checking to improve safety • Use of "Smart containers" • Use of modern satellite navigation • Increase of traffic efficiency in ports • Use of other ports	• Pirate attack • Terrorism • War conflict • Transport of dangerous substances and weapons • Congestion around large ports • Narrow throats • Unfavourable weather conditions

Tab. 3 SWOT analysis of rail transport of containers (Source: Authors)

Strengths	Weaknesses
• Shorter time of transport • Usually shorter route • Higher safety of transported goods • Possibility of direct transport from China to the Czech Republic by rail • Advantageous for Western and Middle China • Lower transport externalities produced by use of electric traction	• Higher transport price • Transport of smaller quantities of goods • Need of transhipping when changing a gauge • Need of transhipment on a road for last mile service • Poor state of infrastructure in transit countries
Opportunities	Threats
• Upgrading the Trans-Siberian Railway • Electrification of routes in transit countries • Use of locomotives equipped with a "last mile" module • Relocation of producing factories inland • Transport of material for producing factories eastwards (back loading) • Transport of products to the West • Increase frequency of train connections • Building "Silk Road"	• Termination of foreign trade support “One Belt, One Road” by Chinese government • Plunder of containers during a journey and during a transhipment • Uneven distribution of direction of container flows between China and Europe • Deterioration of economic cooperation between China and Russia, alternatively China and European states

4.2 Comparative model of container transport from China to the Czech Republic

It is important to compare price expediency of container transport between China and the Czech Republic using a comparative model of container transport between China and the Czech Republic.

Cities in the Chinese regions, from which containers are the most frequently transported into Europe or especially to the Czech Republic (see Table 4), were selected into the comparison. The selected cities are located on the east coast as well as inland in the People's Republic of China.

The most advantageous maritime and rail routes were determined in terms of pricing and time of transport from "Searates.com" application. Prices also include charges. The prices are “door-to-door”. The following calculation is based on available data and on average weight of 15 tonnes of goods per container. The calculation is related to 27th July 2017. [5] The maritime route goes from Chinese ports via Suez to Hamburg.

Tab. 4 Distances and prices of maritime transport between cities in the comparative model (Source: [5])

City of Origin	Destination City	Maritime Distance (km) to Port of Hamburg	Maritime Price per Container (USD)	
			20′	40′
Shanghai	Prague	20 576	3 343	4 564
Xian	Prague	23 634	4 239	5 649
Wuhan	Prague	21 573	3 525	4 446
Beijing	Prague	21 979	3 824	5 045
Urumqi	Prague	26 131	7 645	9 055

Road or rail transport is used for carriage from the inland to Chinese ports and for carriage from the port of Hamburg to Prague. [6] For transport from cities of Xian, Wuhan and Urumqi, inland river transport is partly used to maritime ports like Shanghai, Guangzhou and Tiajin.

The shortest distance from China to the Czech Republic is from coastal cities like Guangzhou and Shanghai. As the transport route continues further to the south, distances from cities in the south of the country, such as Wuhan, are shorter even though the cities are onshore. On the other hand, a maritime route from Beijing, which lies in the north of the country and which is relatively close to the coast, is longer.

The journey from cities like city of Urumqi, which are very far from the coast, is the longest one when using maritime way. This is caused by long distance from the cities to maritime ports. Such transports are relatively expensive and take long time.

Prices for maritime transports are on average from 3 000 USD/TEU to 4 000 USD/TEU. The lowest prices are reachable, when other mode of transport is used just little bit or not at all. Maritime transport is per kilometer significantly cheaper than rail transport or truck transport. Also inland river transport is relatively cheap. Anyway, transport of 40’ container is about 30% more expensive than transport of 20’ container. [5]

Rail transport is based on use of the southern route all along the route (see Table 5).

Tab. 5 Distances and prices of rail transport between cities in the comparative model (Source: [5])

City of Origin	Destination City	Distance by Rail (km)	Rail Price per Container (USD)	
			20′	40′
Shanghai	Prague	10 453	7 216	10 495
Xian	Prague	9 080	6 267	9 116
Wuhan	Prague	9 815	6 775	9 855
Beijing	Prague	9 317	6 432	9 355
Urumqi	Prague	6 558	4 527	6 584

The advantage of rail transport is possibility of stopping in more cities on a route, so larger number of cities can be connected.

Distances of railway routes have the opposite trend than distances of maritime routes, because distances to coastal cities are the longest for rail transport while cities like the city of Urumqi in northwest China is significantly closer than other cities in the middle or east of the country. The biggest distance is from Shanghai. The distance is more than 10,000 km long.

The price for rail transport is on average between 6 000 USD/TEU and 7 000 USD/TEU. Transport of 40’ container is about 40% more expensive than transport of 20’ container. [5]

Distance and price ratio of maritime transport compared to rail transport can be found in the following Table 6.

Tab. 6 Distance and price ratio of maritime transport to rail transport (Source: [5])

City of Origin	Destination City	Distance Ratio	Price Ratio	
			20′	40′
Shanghai	Prague	197 %	46 %	43 %
Xian	Prague	260 %	68 %	62 %
Wuhan	Prague	220 %	52 %	45 %
Beijing	Prague	236 %	59 %	54 %
Urumqi	Prague	398 %	169 %	138 %

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ANALYSIS OF DEFECTS DISTRIBUTION OF FLEET OF HYBRID BUSSES

Rafał BURDZIK[1], Robert JAWORSKI[2], Łukasz KONIECZNY[3]

Abstract

The paper presents analysis of defects distribution for the fleet of hybrid busses. The research was conducted in public transport company with the fleet of innovative milti-hybrid busses. The busses were eqipped with CNG diesel engine and electric engine. It was innovative construction based on CNG busses. The scope of research contained period of exploatation about 2 years.

Keywords

Hybrid bus, defect, fleet management

1 INTRODUCTION

Urban transport emits around 25% of CO_2 from total transport. More than 11,000 travels on the roads of Polish cities buses. Currently, the main source of the drive of public transport vehicles are self-ignition engines powered by diesel oil derived from crude oil processing [1]. Thus nowadays direction of development is focused on eco-friendly vehicles. An important direction for the development of the electric bus market is the creation of uniform interfaces available to all manufacturers. Agreement on this issue was signed by European electric bus manufacturers - Irizar, Solaris, VDL and Volvo along with suppliers of ABB, Heliox and Siemens charging systems [2]. One of the other solutions that limits CO_2 emissions to the atmosphere is the introduction of alternative compressed natural gas (CNG) as a fuel. Public transport vehicles are increasingly driven by CNG compressed engines stored up to 20 MPa stored in a vehicle in specially designed steel or lighter composite cylinders. The percent of gas-powered buses (LNG) is also growing. In these solutions, a hybrid drive is used with an opposite strategy to diversify the use of energy sources. The electric drive is used when starting off, while the rest of the road is overcome by means of an internal combustion engine.

The most ecological (zero-emission) vehicle used in public transport is an electric bus powered by high-powered lithium-ion batteries. There are three main methods of battery charging in electric buses: through the pantograph, induction loop and plug-in or battery charger. Due to the specific conditions of use of public transport vehicles, which are characterized by a high frequency of stops and starts and driving on short distances, often under congested traffic conditions, the principle of hybrid drives allows a significant reduction in fuel and energy consumption [3].

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2 HYBRID BUSSES

In a hybrid bus, the combustion engine operates under a lower load and is supported by an electric motor, which results in lower fuel consumption and the intensity of engine wear and lower operating costs.

Currently, many innovative solutions in the field of hybrid multirike vehicles can be found on the market [4,5]. An example is a multi-drive hybrid city bus that has 3 power sources: a ZS engine, a CNG installation and an electric motor. The construction is based on the concept of a series hybrid fueled with CNG fuel. The combustion engine has no connection to the propeller shaft, it is responsible only for the drive of the electric generator. In addition, installed supercapacitors accumulate surplus energy from recuperation. The principle of operation is as follows. During normal driving, the combustion engine acts as a generator that powers the electric motor. Thanks to that, the combustion engine most of the time works at a speed of approx. 1550 rpm, which ensures optimal consumption of CNG. Additionally, the recuperation mechanism was used as energy recovery during the braking process [6]. An electric motor acts like a generator and generates electricity that is stored in supercapacitors. When driving using energy stored in supercapacitors, the electric motor uses the energy stored in the capacitors. In addition, when stationary at stops, when the combustion engine is running at a speed of 550 rpm, additional electrical energy is generated and stored in capacitors (supercaps). The basic elements of the drive and power systems are shown in Fig. 1.

Fig. 1 Elements of a hybrid bus with drives: ZS-CNG-electric

3 RESEARCH AND ANALYSIS

The research was conducted in big public transport company in Poland. Due to trends, the company has extended its fleet with new hybrid busses [7-9]. The aim of the research was analysis of reliability and defect on early stage of operation for the vehicles until 30000 km mileage. As part of the research, a detailed analysis of emergency conditions occurring in hybrid buses in the initial period of their operation was made. Additionally, an analysis of repair activities carried out by the manufacturer's factory service as well as mechanics employed in the communication company was carried out. On the basis of the workshop records, the most frequently occurring symptoms of failure were identified as well as information on methods and methods of their removal were obtained.

As the results, the defect distribution matrixes have been obtained. Such collection of data enable to conduct many statistical analyses and to observe technical issues important for fleet management.

The example of collected report of defects for two exemplary busses have been depicted in table 1. For the analysis, the group of 15 articulated hybrid busses were observed. The defects distribution for this group of fleet have been depicted in figure 2.

Tab. 1 Hybrid busses defects reports

			It does not charge condensers	Disconnects the drive	The engine can not be started	During braking, the electric engine fault lamp lights up. "M" (yellow)	The "M" engine malfunction indicator is lit (red)	The fault lamp for the electric motor illuminates. "M" (yellow)	Displays the fault of the electric motor "M"	Displays the fault of the combustion engine	No power, driving with limited speed	Automatic shutdown of the internal combustion engine	Discharging super condensers too fast	Incomplete charging of super condensers	No charging or the possibility of discharging the condensers	Uneven operation of the internal combustion engine	E Auto Component Error Display (09)	The condenser control lights up	Gas leak from the heating installation	Disrupts gears while driving	Puncture on condensers	An unskilled computer	Fire in the engine compartment	Articulation failure	Failure of the wrist driver	Damaged attachment of the turbocharger	Cash register failure	Failure of monitoring
l.p.	bus number	date of defect	defect type - reported																									
1		2016-01-18																									1	
2		2016-03-03		1																								
3		2016-03-16																						1					
4		2016-07-22		1			1	1																				
5		2016-07-26																									1	
6		2016-08-02																									1	
7		2016-08-04						1																				
8		2016-08-05								1																		
9		2016-08-18		1																								
10		2016-09-02		1							1																	
11		2016-09-15							1																			
12		2016-09-27		1							1																	
13		2016-10-14		1																								
14	1	2016-10-29		1																								
15		2016-11-04			1																							
16		2016-11-06		1																								1
17		2016-11-07	1																									
18		2016-11-23	1	1	1			1																				
19		2016-12-16			1																							
20		2016-12-18		1																								
21		2016-12-20			1																							
22		2017-03-02												1														
23		2017-03-03		1																								
24		2017-03-26		1																								
25		2017-03-31										1																
26		2017-04-04		1																								
27		2017-04-06		1																								
28		2017-04-24											1	1														
Sum			2	14	4	0	1	3	1	1	2	1	1	2	0	0	0	0	0	0	0	0	1	0	0	0	3	1
1		2016-01-18																									1	
2		2016-01-25		1														1										
3		2016-03-02			1																							
4		2016-03-04		1					1																			
5		2016-03-10							1																			
6		2016-04-14			1																							
7		2016-04-29			1																							
8		2016-07-05					1																					
9	2	2016-07-06			1																							
10		2016-07-14		1										1														
11		2016-07-21		1										1														
12		2016-07-29		1			1	1																				
13		2016-08-01		1																								
14		2016-08-30		1																								
15		2016-09-09		1				1																1				
16		2016-09-19															1											
17		2016-09-24		1																								
Sum			0	9	4	0	2	2	2	0	0	0	0	2	0	0	1	1	0	0	0	0	0	1	0	0	1	0

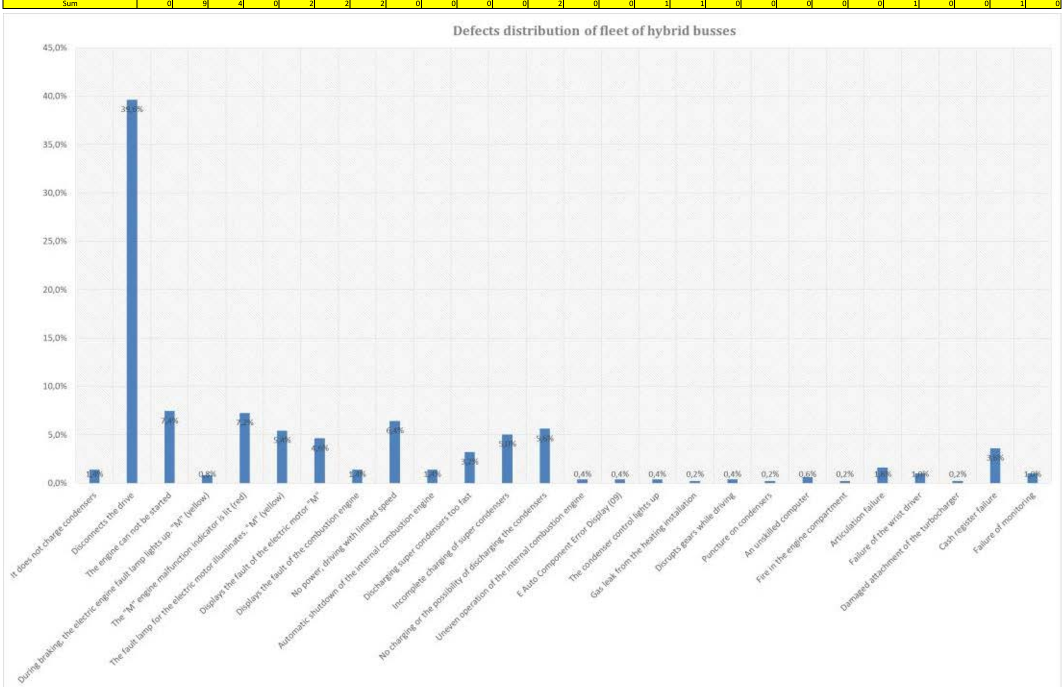

Fig. 2 Defects distribution of fleet of hybrid busses

4 CONCLUSION

The paper presents the preliminary research on fleet management issues of new hybrid busses in public transport company. Innovative technologies and new eco-friendly busses require new view in the reliability and maintenance issues for the fleet management. The concept of defects matrix as big data collection is simple method for data base analysis. Emergency state matrix prepared on the basis of the bus repair and maintenance records was developed. On its basis, the indicators of failure symptoms and indicators of failure removal methods presented in the following charts were determined.

On the basis of conducted analyzes carried out for the selected group of hybrid articulated busses, especially in the frequency of their occurrence, it can be noticed that failures revealed in particular construction and execution faults occurring at the stage of production of these vehicles resulting in shutting down vehicles as well as collision situations posing a direct threat to the safety of other vehicles and transported passengers.

◆◆

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USE OF BRAND MANAGEMENT FOR THE CZECH RAILWAYS LONG-DISTANCE TRAINS FROM THE MARKETING PERSPECTIVE

Jan CHOCHOLÁČ[1], Nina KUDLÁČKOVÁ[2], Roman HRUŠKA[3], Daniel SALAVA[4]

Abstract

Brand Management is a very important from the perspective of businesses because it helps businesses communicate with the target market. Brand management consists of tangible elements (product, design, packaging etc.) and intangible elements (customer experience and relationship with the brand). The Czech Railways company use brand management for specific long-distance train lines like for example “Metropolitan”, “Západní expres”, “Slovácký expres” or “Jižní expres”. The aim of the article is to analyse the use of Brand Management for long-distance train lines of Czech Railways and evaluate customer survey results.

Keywords

Brand Management, Czech Railways, Metropolitan, Západní expres, Slovácký expres, Jižní expres

1 INTRODUCTION

The problematics of Brand Management is a very important part of marketing. Brand Management, brand value, and consumer association associated with the brand can have a major impact on business economic results.

Historically, the entire railway network was operated by national carrier (ČD), former operator of Czech Railways. Since 2011, the market has been open to free competition. RegioJet entered the market in 2011, Leo Express entered the railway passenger market in 2012 and the last carrier was Arriva, which entered the railway passenger market in 2013.

Czech Railways started to use branding for selected long distance train lines (Ex3, Ex6, Ex7 and R18) from the timetable valid from 10 December 2017. One identical brand replaced the different names of the existing trains on each line. The aim of this article is to analyze the use of brand management for long-distance train lines of Czech Railways and evaluate customer survey results using primary marketing research.

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2 THEORETICAL BACKGROUND

One of the first marketing concepts was the concept based on the satisfaction of latent and expressed customer needs and it was customer-centric concept [1]. To implement this customer-centric concept within the companies was conceptualized a market-oriented strategy [2-6]. A few years later the contradictory but related brand orientation emerged which directly challenged a market-oriented strategy [1]. The first publication on brand orientation was publication by Mats Urde named Brand orientation – a strategy for survival in Journal of Consumer Marketing [7].

Urde defined brand orientation as *“an approach in which the processes of the organization revolves around the creation, development, and protection of brand identity in an ongoing interaction with target customers with the aim of achieving lasting competitive advantages in the form of brands”* [8]. Evans, Bridson and Rentschler defined brand orientation *“as the extent to which the organization embraces the brand at a cultural level and uses it as a compass or decision-making to guide four brand behaviors; distinctiveness, functionality, augmentation and symbolism”* [9]. Urde, Baumgarth and Merrilees emphasized its strategic importance and described it as “*a new approach to brands that focuses on brands as resources and strategic hubs”* and *“the continuous interaction between values and identity at three levels is a key proposition of brand orientation: the organization, the brand, and customer and non-customer stakeholders”* [10].

Brand management can also be defined as long-term effective brand management and related marketing decisions [11]. Management, building and image of the brand are the main factors of business success [12]. From the point of view of the business, brand management is absolutely crucial, as consumer responsiveness depends on brand value, brand associations, and all marketing activities implemented in brand management [11]. Brand management also exists to help customers simplify their lives by helping them navigate more quickly in their purchasing decisions [13]. Businesses often use brand spiraling, a way of using traditional media to promote and attract consumers to visit websites (television advertising, newspapers, magazines, billboards, etc.) where the main goal is raising brand awareness [12].

All long distance Czech Railways trains are run on regular routes and at regular intervals. All long distance lines have their numbers and are divided into international lines (E01 – E03), express lines (Ex1 – Ex4, Ex6 – Ex7) and fast trains lines (R5, R8 – R24, R26 – R27). The international lines routes are as follows: E01 (Hamburg – Berlin – Praha – Brno – Graz / Budapest), E02 (Praha – Olomouc – Vsetín / Ostrava – Žilina – Košice) and E03 (Praha / Wien – Ostrava – Warszawa). The express lines routes are as follows: Ex1 (Praha – Ostrava – Třinec / Opava), Ex2 (Praha – Olomouc – Vsetín), Ex3 (Děčín – Ústí nad Labem – Praha – Pardubice – Brno – Břeclav), Ex4 (Břeclav – Přerov – Bohumín), Ex6 (Praha – Plzeň – Cheb / Domažlice) and Ex7 (Praha – Tábor – Č. Budějovice – H. Dvořiště / Č. Krumlov). The fast trains lines routes are as follows: R5 (Praha – Ústí n. L. – Karlovy Vary – Cheb), R8 (Brno – Přerov – Ostrava – Bohumín), R9 (Praha – Havlíčkův Brod – Brno), R10 (Praha – Hradec Králové – Trutnov), R11 (Brno – Jihlava – České Budějovice – Plzeň), R12 (Brno – Olomouc – Šumperk / Jeseník), R13 (Brno – Břeclav – Přerov – Olomouc), R14 (Pardubice – Hradec Kr. – Turnov – Liberec), R15 (Ústí nad Labem – Česká Lípa – Liberec), R16 (Praha – Plzeň – Klatovy – Železná Ruda), R17 (Praha – Tábor – České Budějovice), R18 (Praha – Olomouc – Luhačovice / Veselí n.M. / Zlín), R19 (Praha – Česká Třebová – Brno), R20 (Praha – Ústí nad Labem – Děčín), R21 (Praha – Mladá Boleslav – Turnov – Tanvald), R22 (Kolín – Mladá Boleslav – Česká Lípa – Rumburk), R23 (Kolín – Všetaty – Ústí nad Labem), R24 (Praha – Kladno – Rakovník), R26 (Praha – Beroun – Písek – České Budějovice) and R27 (Ostrava – Krnov – Olomouc / Jeseník). [14]

The schematic overview of Czech Railways long-distance train lines is in the Fig. 1.

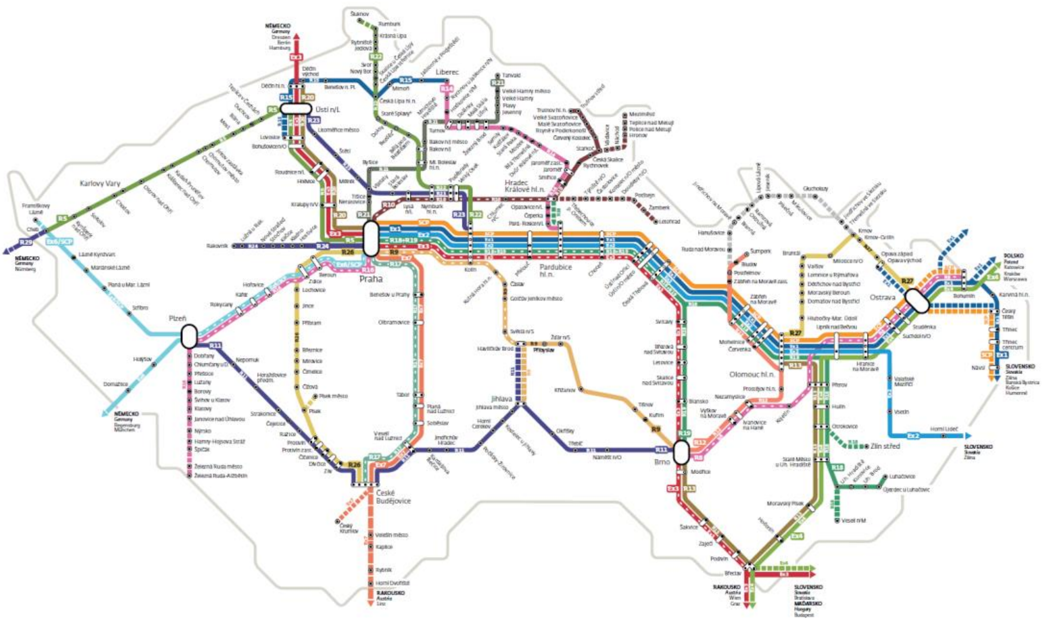

Fig. 1 The schematic of Czech Railways long-distance train lines [15]

This article is focused on these long-distance train lines: Ex3 (“Metropolitan” trains), Ex6 (“Západní expres” trains), R18 (“Slovácký expres” trains) and Ex7 (“Jižní expres” trains). The overview of “Metropolitan” trains is in the Tab. 1. Brand “Metropolitan” is used for trains connecting Budapest (Hungary) and Praha (Czech Republic) within the long-distance train line Ex3. Brand “Metropolitan” includes 12 EuroCity trains and 2 InterCity trains.

Tab. 1 The overview of “Metropolitan” trains [16-17]

Train category and number	Departure	Line	Arrival
EC 270	17:41	Budapest-Nyugati pu – Brno hl.n.	21:36
EC 271	06:22	Brno hl.n. – Budapest-Nyugati pu	10:19
EC 272	15:41	Budapest-Nyugati pu – Praha hl.n.	22:09
EC 273	05:51	Praha hl.n. – Budapest-Nyugati pu	12:19
EC 274	13:41	Budapest-Nyugati pu – Praha hl.n.	20:07
EC 275	07:51	Praha hl.n. – Budapest-Nyugati pu	14:19
EC 276	11:41	Budapest-Nyugati pu – Praha hl.n.	18:07
EC 277	09:51	Praha hl.n. – Budapest-Nyugati pu	16:19
EC 278	09:41	Budapest-Nyugati pu – Praha hl.n.	16:07
EC 279	11:51	Praha hl.n. – Budapest-Nyugati pu	18:19
EC 280	05:41	Budapest-Nyugati pu – Praha hl.n.	12:07
EC 281	15:51	Praha hl.n. – Budapest-Nyugati pu	22:19
IC 572	05:07	Břeclav – Praha hl.n.	08:07
IC 573	21:09	Praha hl.n. – Břeclav	00:35

The overview of “Západní expres” trains is in the Tab. 2. Brand “Západní expres” is used for trains connecting München (Germany) or Cheb (Czech Republic) and Praha (Czech Republic) within the long-distance train line Ex6. Brand “Západní expres” includes 30 Express trains.

Tab. 2 The overview of “Západní expres” trains [18-19]

Train category and number	Departure	Line	Arrival
Ex 350	17:33	Praha hl.n. – München Hbf	23:20
Ex 351	04:43	München Hbf – Praha hl.n.	10:31
Ex 352	15:33	Praha hl.n. – München Hbf	21:18
Ex 353	06:42	München Hbf – Praha hl.n.	12:31
Ex 354	13:33	Praha hl.n. – München Hbf	19:16
Ex 355	08:43	München Hbf – Praha hl.n.	14:31
Ex 356	11:33	Praha hl.n. – München Hbf	17:17
Ex 357	10:43	München Hbf – Praha hl.n.	16:31
Ex 358	09:33	Praha hl.n. – München Hbf	15:18
Ex 359	12:43	München Hbf – Praha hl.n.	18:31
Ex 360	07:33	Praha hl.n. – München Hbf	13:17
Ex 361	14:43	München Hbf – Praha hl.n.	20:31
Ex 362	05:33	Praha hl.n. – München Hbf	11:18
Ex 363	16:44	München Hbf – Praha hl.n.	22:31
Ex 550	20:33	Praha hl.n. – Cheb	23:27
Ex 551	04:32	Cheb – Praha hl.n.	07:31
Ex 552	19:33	Praha hl.n. – Plzeň hl.n.	20:58
Ex 553	07:01	Plzeň hl.n. – Praha hl.n.	08:31
Ex 554	16:33	Praha hl.n. – Cheb	19:27
Ex 555	08:33	Cheb – Praha hl.n.	11:31
Ex 556	14:33	Praha hl.n. – Cheb	17:27
Ex 557	10:33	Cheb – Praha hl.n.	13:31
Ex 558	12:33	Praha hl.n. – Cheb	15:27
Ex 559	12:33	Cheb – Praha hl.n.	15:31
Ex 560	08:33	Praha hl.n. – Cheb	11:27
Ex 561	16:33	Cheb – Praha hl.n.	19:31
Ex 562	06:33	Praha hl.n. – Cheb	09:27
Ex 563	18:33	Cheb – Praha hl.n.	21:31
Ex 564	06:05	Plzeň hl.n. – Cheb	07:29
Ex 565	19:35	Cheb – Plzeň hl.n.	20:55

The overview of “Slovácký expres” trains is in the Tab. 3. Brand “Slovácký expres” is used for trains connecting Praha and Luhačovice / Veselí nad Moravou / Zlín střed / Staré Město u Uherského Hradiště within the long-distance train line R18. Brand “Slovácký expres” includes 16 higher-quality fast trains.

Tab. 3 The overview of “Slovácký expres” trains [20-21]

Train category and number	Departure	Line	Arrival
Rx 880	18:20	Luhačovice – Olomouc hl.n.	20:00
Rx 881	06:00	Olomouc hl.n. – Luhačovice	07:45
Rx 882	16:31	Luhačovice – Praha-Smíchov	21:18
Rx 883	05:44	Hradec Králové hl.n. – Luhačovice	09:18
Rx 884	14:31	Luhačovice – Praha hl.n.	19:04
Rx 885	06:58	Praha hl.n. – Luhačovice	11:18
Rx 886	12:31	Luhačovice – Praha-Smíchov	17:18
Rx 887	08:58	Praha hl.n. – Luhačovice	13:18
Rx 888	10:31	Luhačovice – Praha-Smíchov	15:18
Rx 889	10:42	Praha-Smíchov – Luhačovice	15:18
Rx 890	09:44	Staré Město u Uh.Hrad. – Praha-Smíchov	13:18
Rx 891	12:38	Praha-Smíchov – Luhačovice	17:18
Rx 892	07:10	Veselí n.Moravou – Praha-Smíchov	11:18
Rx 893	14:42	Praha-Smíchov – Staré Město u Uh.Hrad.	18:14
Rx 895	16:42	Praha-Smíchov – Veselí n.Moravou	20:47
Rx 896	04:21	Staré Město u Uh.Hrad. – Praha hl.n.	07:36

The overview of “Jižní expres” train is in the Tab. 4. Brand “Jižní expres” is used for trains connecting Linz (Austria) and Praha (Czech Republic) within the long-distance train line Ex7. Brand “Jižní expres” includes 16 Express trains.

Tab. 4 The overview of “Jižní expres” trains [22-23]

Train category and number	Departure	Line	Arrival
Ex 530	16:53	České Budějovice – Praha hl.n.	18:57
Ex 531	07:48	Praha-Holešovice – Český Krumlov	10:55
Ex 532	14:07	Český Krumlov – Praha-Holešovice	17:08
Ex 533	14:48	Praha-Holešovice – České Budějovice	17:08
Ex 534	07:55	České Budějovice – Praha-Holešovice	10:08
Ex 535	16:01	Praha hl.n. – České Budějovice	18:03
Ex 538	06:55	České Budějovice – Praha-Holešovice	09:08
Ex 539	19:01	Praha hl.n. – České Budějovice	21:03
Ex 1540	08:00	Horní Dvořiště – Praha-Holešovice	11:08
Ex 1541	06:01	Praha hl.n. – Linz Hbf	10:07
Ex 1542	11:52	Linz Hbf – Praha-Holešovice	16:08
Ex 1543	09:48	Praha-Holešovice – Linz Hbf	14:07
Ex 1544	15:52	Linz Hbf – Praha hl.n.	19:57
Ex 1545	13:48	Praha-Holešovice – Linz Hbf	18:07
Ex 1546	20:00	Horní Dvořiště – Praha hl.n.	22:57
Ex 1547	17:48	Praha-Holešovice – Linz Hbf	22:07

3 METHODS AND DATA

The method of primary marketing research was chosen for analyse and evaluation of the use of brand management for long-distance train lines of Czech Railways. The primary marketing research was realized as electronic questioning combined structured personal questioning, while respondents were chosen in quotas in order to reach the representative sample.

Kozel et al. define the marketing research formula to set the right extend of selective sample. In this formula *n* is the minimum amount of respondents, *z* is the coefficient of reliability (when set as 1 the statement probability is at least 68.3 %, when set as 2 the probability of 95.4 % is ensured and when *z* set as 3 then the probability reaches at least 99.7 %); *p* and *q* are the amounts of respondents that are familiar with the issue (expressed in percent). When the values of *p* and *q* aren't known exactly the maximum product is used, i.e. $p = 0.5$ and $q = 0.5$; Δ is the set maximum acceptable incorrectness (5 % corresponds to $\Delta = 0.05$). [24]

$$n \geq \frac{z^2 \times p \times q}{\Delta^2} \tag{1}$$

$$n \geq \frac{2^2 \times 0.5 \times 0.5}{0.05^2} \geq 400 \tag{2}$$

After substitution in the equation no. 1 the minimum amount of respondents $n \geq 400$ (equation no. 2) is counted, with that amount the structured questioning sessions were realized. The calculation reflects the probability of statements of 95.4 % ($z = 2$) and the maximum acceptable incorrectness of 5 % ($\Delta = 0.05$). The marketing research was realized from 19th March 2018 until 13th April 2018, while all the included respondents shall meet the condition that they are Czech Railways travellers.

Respondents were asked the following questions for each of the four analyzed lines:

- Q1: Did you hear about trains of Czech Railways called “Metropolitan” / ”Západní expres” / “Slovácký expres” / “Jižní Expres”? Possible answers: yes / no.
- Q2: Can you assign a train called “Metropolitan” / “Západní expres” / “Slovácký expres” / “Jižní Expres” to a specific line? Possible answers: yes / no.
- Q3: Type one of the destination or transit stations of the train called “Metropolitan” / ”Západní expres” / “Slovácký expres” / “Jižní Expres”. An open question followed by checking the correctness of the response.
- Q4: Do you agree with the branding of individual lines, and so with a common name for each line? Possible answers: definitely yes / rather yes / rather no / definitely no.

4 RESULTS

The overview of results of questions Q1, Q2 and Q3 is presented in the Tab. 5.

Tab. 5 The overview of results [authors]

Brand	**Question 1 YES**	**Question 2 YES**	**Question 3 correct answer**
Metropolitan	264 (66.00 %)	228 (57.00 %)	202 (50.50 %)
Západní expres	217 (54.25 %)	175 (43.75 %)	121 (30.25 %)
Slovácký expres	179 (44.75 %)	125 (31.25 %)	65 (16.25 %)
Jižní expres	238 (59.50 %)	189 (47.25 %)	117 (29.25 %)

The results show that the most famous brand is "Metropolitan", which was heard by 264 respondents (159 men and 105 women). This may be due to the extensive marketing of the “Metropolitan” trains, where Czech Railways used TV, internet, newspaper, as well as outdoor advertising (backlight, citylight, led screens, rotunda, etc.). The “Metropolitan” trains within the Ex3 line are also passing through major cities (Praha, Pardubice, Brno, Břeclav, Bratislava and Budapest), where there is also a large passenger frequency. 238 respondents (59.50%), of whom 149 men and 89 women said they knew the “Jižní Expres”brand. The least known brand is “Slovácký expres”; only 179 respondents knew it (44.75%). This could be caused by tracing of this line. 57.00% of respondents were convinced that they knew a specific train line "Metropolitan", for ”Západní expres” it was 43.75%, for “Slovácký expres” it was 31.25% of respondents and for “Jižní Expres” it was 41.25%. However, respondents' answers to the third question have shown that only a small number of respondents are actually able to assign a particular route to the train.

It was confirmed again that the largest number of respondents was able to identify a destination or transit station for “Metropolitan” trains where the proportion of correct answers was 50.50%, which is 6.5 percentage points less than the respondents declared they knew. The smallest number of correct answers was for “Slovácký expres” trains, where only 16.25% of the respondents were able to identify the correct destination or transit station. 330 respondents agree with branding on individual lines (49.00% definitely yes and 33.50% rather yes). 50 (12.50%) of respondents rather disagree and 20 (5.00 %) of respondents certainly disagree.

5 CONCLUSION

As has already been said in the introduction, brand management issues are a very important area of marketing. Brand is a trademark that has a market name and a weight for customers, and for some types of businesses, it is essentially a brand of essential ownership. Whether it is a name, a term, a designation, a symbol, a design, or a combination of these factors, it always serves to identify products or services and is essential to distinguish own production from the production of competitors. Therefore, it is important to continuously examine how the brand is perceived and what attributes are associated with it and, if necessary, take action in the field of PR, promotion, advertising, etc., leading to correction and reinforcement of brand perception in a desirable way. Most successful companies sooner or later reach a stage where their products sell mainly brand. The main selling argument is not the quality, but the inertia of the brand. People tend to trust the brand regardless of the quality of the products or services. People tend to trust the brand regardless of the quality of the products or services, which may be of particular importance in the area of services. This was also the reason for the survey described above, as Czech Railways started to be the first in the transport market to use branding for selected long distance train lines from 2017 onwards. This means that one identical brand replaced the different names of the existing trains on each line. Research results show that this was a step in the right direction because customers perceive this change, especially when it is associated with extensive marketing communications, as in the case of the “Metropolitan” brand, which was heard by 264 respondents.

The survey also revealed that 330 respondents agreed on the branding of individual lines and this step can therefore be recommended not only in other business areas of Czech Railways but also to other companies operating in the field of public passenger transport.

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TRENDS IN SUSTAINABLE DEVELOPMENT IN THE POSTAL SECTOR

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Abstract
The each major postal system is characterized by a strong infrastructure and appropriate human, technical and technological resources. The activities of these systems are economically demanding and have a negative impact on the environment, which represents some of the most delicate problems of sustainable development. This paper presents the basic principles and proposals for the improvement of sustainable development capabilities in the postal systems.

Keywords
postal system, sustainable development, improvement, reception, transport, delivery

1 INTRODUCTION

The postal system at the global level includes individual systems, composed of a large number of postal companies. Every postal company, whether it is a private or public postal operator (PPO), is based on a branched network throughout the territory where it provides services. This territory may include a part of a district or a specific city, the whole territory of a city, a state or a region. However, if we consider the postal system as unique or global, we can conclude that almost every inhabited territory on the planet is covered by the services of at least one operator. Accordingly, it can be concluded that the global postal system, dimensionally one of the largest business systems that exist.

Postal system includes a highly developed distributive network, whose basic characteristics are the great number of postal items, plenty of business and customers' subjects and developed infrastructure. The functioning of such a system has an important effect on the environment [1].

Universal Postal Union (UPU), which enacts some regulations, decisions and strategies in functioning of postal activity, has the key role in the business of postal companies at a global level. UPU initiated the Program of environmental protection in 1994, founding the Working group for environmental issues. At the same time, the Project group for sustainable development was founded (the Sustainable Development Project Group) with the aim to enable support to the operators in their efforts to integrate sustainable development into their business [2]. Three main dimensions of sustainable development are the following:

- Economic,
- Ecological and
- Social

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In order to achieve the goal of sustainability, it is necessary to act through all of these three dimensions. Postal operators should satisfy the needs of the population, their needs through the economic profit, but also to accomplish the principles of environmental protection.

In October 2012, on the 25th UPU Congress in Doha, Postal Strategy was adopted for the period 2013- 2016, which defines as one of the four aims the promotion of sustainable development of the postal sector [3]. Based on this strategy and the earlier efforts, many postal operators started to apply the global mission of sustainable development through various tendencies and sustainability policy. At the last (26th) UPU Congress in Istanbul (2016), there was also discussion about sustainable development. It was suggested that the member countries and/or their designated operators shall adopt and implement a proactive sustainable development strategy focusing on environmental, social and economic action at all levels of postal operations and promote sustainable development awareness. The following aspects of environmental protection are listed [4]:

- Designated operators should make their products and services as environment friendly as possible within the limits imposed by technologies and resources;
- The consumption of materials and energy should be optimized and be the minimum consistent with the efficient conduct of operations;
- Materials used should comply with non-pollution or non-toxic standards established by the relevant national and international agencies;
- Designated operators should promote the recycling of paper and other materials. They should also promote the use of recycled materials.

It is clear that in order to achieve the sustainability of the global postal system, it is necessary to implement appropriate activities within individual postal systems. The subject of paper is to examine the basic indicators of sustainable development in the postal system. The goal of the paper is to define activities and solutions that should contribute to the improvement of the postal system in the field of sustainability.

2 SUSTAINABLE DEVELOPMENT TRENDS IN THE POSTAL SYSTEM

Despite different development levels of postal operators and systems, a trend applied for all, refers to the approach to the concept of sustainable development. Under authority of Universal Postal Union and according to the strategy from Doha, that has been adopted, postal operators are concentrated to this concept step by step. Economic dimension of sustainable development has been distinguished as alarming dimension.

More than 600 000 posts in the world form a postal system, which becomes the largest global and distributive network on the planet. More than 1 500 000 vehicles, a large number of motorcycles and airplanes are being used daily to accomplish postal service. Production, technical and technological systems and employees require the energy consumption and other kind of energy every day such as water, paper etc., which have a negative impact on ecology. To reduce this negative impact, it is necessary all the actors to take part in it. Also, it is essential that all companies and organizations accomplish their aims and business policy according to the environmental protection and negative emissions reduction [5, 1]. In 2008, the postal operators received the first questionnaire from Universal Postal Union for greenhouse gas emissions. The goal of this questionnaire, which consists of three parts, is to determine the fuel consumption on an annual basis, as well as the number of passed kilometres for each vehicle and the amount of fuel and electric energy for lighting, heating, microclimate maintenance and other daily consumption. Considering the low level of replies in the first year (mainly because it’s not impossible to gather data), the questionnaire was carried out again in 2009. The standard protocol, that refers to the emissions reduction and environmental protection, is based on the internationally accepted resources in this field, such as GHG (Greenhouse Gas) protocol WRI/WBCSD (World Resources

Institute and World Business Council for Sustainable Development), International Energy Agency, Global Reporting Initiative (GRI) and ISO 14000 standard. The purpose of that document is to identify all emission resources that are coming from the postal activities [6, 1].

Despite the fact that the problem of the sustainability of the postal system was mentioned in the years preceding the 25th UPU Congress in Doha, the guidelines adopted at this Congress are the main trigger for the implementation of sustainable development activities in the postal system. Four programs are defined:

1. Improve remuneration systems between designated postal operators - Fair and appropriate remuneration systems among designated operators, in line with market needs and conditions, form the basis of a well-functioning and sustainable international postal network. Remuneration systems that benefit some designated operators but penalize others are not sustainable in the long term. If left unchecked, they jeopardize the sustainability of a universal network. Action is required to harmonize and improve the different remuneration systems for the various postal products (e.g. letters, packets, parcels, EMS).
2. Strengthen the UPU's capacity to respond appropriately to changing needs in the market - Adapt UPU structures, as well as national regulatory frameworks, to the changing needs of the markets. There are two aspects to the objective: first, to make sure that the UPU and its structure remain relevant for its member countries at a time when governments tend to consider postal services no more important than any other commercial activity; and second, to facilitate the broad exchange of views and best practices with respect to postal market developments.
3. Stimulate the inclusion of all segments of the population through greater and/or targeted access to postal services - The postal network is an asset that can be leveraged to increase financial and social inclusion. This programme seeks to use the postal network to advocate and foster financial inclusion, as well as the provision of basic government and communications services to people in remote areas.
4. Promote environmental awareness and social responsibility - Put a framework in place to allow the postal sector to develop in a sustainable way. The UPU has expanded its environmental activities by promoting best practices and measuring the impact of the postal sector on the environment. In this area, synergies with other organizations should be encouraged. At the same time, in cooperation with other United Nations organizations and within the framework of the UN Millennium Development Goals, the UPU has used the postal network to help raise awareness of key social issues, such as the fight against HIV/AIDS. These kinds of activities should feature prominently on the UPU's sustainable development agenda. Finally, the UPU should continue to promote social dialogue and decent working conditions within the postal sector.

Defined programs and adopted guidelines are still the mechanisms and tendencies that postal operators are striving for. 26th UPU Congress in Istanbul (2016), there was also discussion about sustainable development. One of the three main goals of the adopted strategy is - Ensure sustainable and modern products. One of the curiosities was that it is the 26th Universal Postal Congress made strides in sustainability as the first "paper smart Congress", meaning the majority of documents have been presented to delegates in electronic format.

2.1 Sustainable development in the process of postal services providing

Postal service accomplishing means the reception of items and their sorting, transport and delivery to the recipient. These are basic parts of sub-systems in the postal service providing. In the complex process of distribution where a customer is the main actor, from reception to the delivery, it is necessary to manage the items, information and people's flow at the same time, requiring on this way operator has new equipment and organization [7].

Reception of postal items and sustainable development

Reception of postal items is being accomplished in the units of postal network via postal clerks on the terrain via couriers or via postal mail boxes. The units of postal network enable the possibility of postal items reception on their post office counters. The reception is carried out by postal clerk, using the necessary equipment. Reception of items via couriers refers mainly to the express services.

Post office counters in the units of postal network are workplaces, which contain certain equipment, necessary for the clerk's work. Equipment means computer terminal, precise electronic scales, franking machines and the other extra equipment.

Reception of items via courier implies that a sender will contact the call centre, then this application will be forwarded to the courier, that goes to the address and accomplishes the reception of postal items. It is essential to pay attention to the processes, which are on the border with economic profitability and affect the environment. Driving to the reception address and later transport of postal items are basic influential factors.

Postal mail boxes are set on certain locations in certain areas, manly of narrow city districts. The organization of visiting these locations and collection of items by a postal employee is not enough developed, i.e. the emptying of mail boxes is not often. This kind of reception of postal items is not enough developed in the real system. In ideal case, the presence of mail box increases significantly availability to the postal system. There's no need for clients to use transport means to the mail box, because the locations are various. Therefore, it contributes notably to the costs reduction and environmental protection [1].

Table 1 shows the appropriate impacts on sustainable development in the reception segment as well as the proposed activities and the aim of their realization.

Tab. 1 Sustainable development on the reception of postal items

Impacts	The way of acting	Aim
Unused powerful, outdated and energy ineffective computer configuration	Introduction of new technologies, e.g. hardware and software virtualization	Increase of system's use, reduction of required resources and systems for their feed, development of green IT
Outdated systems for franking and unreliable scales	Purchase of new efficient franking machines and introduction of new more qualified electronic scales	Increase of energy efficiency, noisy reduction, increase of efficiency of counter's place
Inappropriate territorial organization and schedule of couriers	Constant tracking and analysis of customers' requirements	Establishment of the appropriate territorial organization and schedule of couriers, which should prevent preventive delays in receiving items, but also to efficiently perform the service with certain savings.
Inefficient routes to which couriers transport items	Application of appropriate tools and algorithms for finding the best route	Defining the best (the most efficient, the cheapest ...) route, which will be the most environmentally and cost-effective

Sorting of postal items and sustainable development

Sorting of postal items represents the process of items classification based on the addresses, by destination. The classification is the complex logistic process, which generates maintenance costs, electricity consumption, etc. Overload mechanization and systems for items classification have the biggest potential for improvement according to the sustainable development in this part of postal service providing.

Table 2 shows the appropriate impacts on sustainable development in the sorting segment as well as the proposed activities and the aim of their realization [1].

Tab. 2 Sustainable development on the sorting of postal items

Impacts	The way of acting	Aim
System of main transport flow	Use of the most modern means, low energy consumers, tracking flow of items and its analysis	Use of energy efficient and economically profitable systems and system of increased productivity according to the right dimensioning
Outdated systems	Tracking and efficiency analysis of outdated systems, delay in the use of self-sustaining systems, such as gravity means and ejection from the use of ineffective	Reduction of energy consumption and negative impact on the environment with the delay level of system efficiency
Capacity dimensioning	Tracking of the items transfer and analysis of their flow	Right dimensioning of system for classification

Transport of postal items and sustainable development

For purposes of postal items transport, the means of road traffic, air traffic and ship transport are being used. Various factors have an impact on sustainable development of this sector: different characteristics of transportation mode, regulatory and legislative bodies, providers of services, financial systems, technologies of land use and behavior of people, which take part on all levels and all segments of system. Transport is in rapid growth, and accordingly to that, it represents the sector with the fastest growth of environment pollution [8]. Road transport is one of the greatest pollutants of air, water and ground, noisy etc. [1]. Satisfaction of the sustainable development in road traffic can be achieved on many ways [8]. Two ways that are often applied are the following: combined ground transportation and the use of alternative fuels in road traffic. Combined ground transportation is being used in the postal traffic, which includes road and railway traffic. Combined transport is the solution that has all advantages of transport modes, which take part in it. On the other hand, there is a need all deficiencies should be minimized. Also, sometimes, because of the geographical limits, it is not possible to accomplish direct transport, but the combined transport is being used. The sector of road traffic cannot be replaced, but its economic and ecological impact is not on good level. The basic cause, for mentioned bad impacts, is the fact that is expensive and “dirty” fuel that is used. In road transport of postal items, diesel and petrol are mostly being used as fuel. The use of alternative fuels is necessary and it reduces negative impact on environment. Table 3 shows the appropriate impacts on sustainable development in the transport segment as well as the proposed activities and the aim of their realization [1].

Tab. 3 Sustainable development on the transport of postal items

Impacts	The way of acting	Aim
Energy efficiency	Combination of road and railway traffic, wherever it is possible and deadlines permits	Railway traffic is more energetically more efficient, with its role it increases the total energy efficiency of system.
Mobility	Combination of road and railway traffic, wherever it is possible and deadlines permits	Road traffic has notably better mobility, with its role, it increases the total system mobility
Costs		Including the savings of both systems, total costs are being reduced
Negative impact on environment	The use of renewable resources to the level of their regeneration and use of non-renewable resources to the level of possibility of renewable substitute development	Reduction of negative impact on environment

The basic principles of sustainable development in part of postal items delivery, we can consolidate through the perception of sustainable development parameters of some activities in segment of items reception and transport. New trends in the postal items delivery, which will be discussed below, can contribute to sustainable development in this segment, but also at the level of the entire postal system.

3 NEW TRENDS IN THE POSTAL ITEMS DELIVERY AND SUSTAINABLE DEVELOPMENT

Delivery of the postal items represents the last and one of the most important activities in the process of their distribution to the users. Modernizing the delivery system is an essential step to effectively respond to user requests and possible unforeseen situations, which can be a disruptive factor. Due to the numerous possibilities it offers, the application of new technologies for this purpose is a convenient solution. In the field of organization and technological development of items and packages, the most up-to-date tendencies relate to the development of systems for the use of unmanned aircraft - drones and autonomous vehicles. The application of these systems should have a positive impact on sustainable development.

3.1 Delivery by drone

Drone is a type of unmanned aircraft. The most common and traditional use of drones is for military purposes, but more and more are being tested for their use in various special services (police, fire-fighters, health care ...) and civil sectors (various forms of delivery, agriculture ...). Drones consist of a large number of technologically advanced components, which enable them to operate efficiently and reliably. In addition to physical parts, software support, which is a connection between the parts, the drone and the control centre, is also very important, and together with the sensors and between the drones and the environment [9].

Based on the technology they use in flying, the drones are divided into two basic types:

- Independent aircraft - drone flying autonomously according to pre-defined and stored data;
- Remote control drone - The flight is controlled via a remote control, operated by a pilot (operator, navigator ...).

The basic advantages of drones in the field of delivery of packages relate to their speed, the ability to access difficult terrain and remote locations, overcoming obstacles and potential traffic congestion, positive environmental impacts, etc. In addition to numerous advantages, there are numerous limitations. First of all, the underdeveloped and defined legislation, low transport capacity, the possibility of errors due to incorrect GPS data.

Amazon and DHL are companies that are among the first to test the delivery by drone and work on their development. One very positive argument to consider is that drones can increase the delivery time available. Based on the tests carried out, by Amazon (the territory of Chattanooga, Tennessee), there have been some indications of the functioning of the drones in the delivery system. First of all, the cost of the package delivered to the drone, depending on certain details, is about $ 0.07, while the cost of the courier per package is about $ 1.2. Significantly lower costs of delivering packages are noticeable, than by courier. Due to the expected market expansion in the future, this cost will be further reduced. On the other hand, there are additional costs that are not introduced into the analysis, and they relate to investments in the drone stations [10].

The drive that the drones use is based on an electric battery. For this reason, their positive impact on the preservation of the environment is extremely important. Positive economic performance, as well as ecological characteristics, represent the basic potential of drones to contribute to the sustainable development of the postal system through the delivery system of items. The positive impact on the sustainable development of the postal system is reflected in the following:

- Lower costs - better economic performance;
- The use of environmentally cleaner drives - minimum emissions of harmful gases;
- Indirect reduction of harmful emissions due to reduction of number of delivery vehicles;
- It indirectly affects the reduction of congestion in traffic;
- The ability to access difficult terrain and remote locations;
- Expanding territorial accessibility, which is of great importance for users.

3.2 Delivery by autonomous vehicles

After the introduction of automatic dispatch processing machines, the automation of other parts of the chain of postal items was started. At this point, various pilot projects for the use of autonomous vehicles are being implemented worldwide as solutions for automated delivery or collection of shipments. The first delivery by autonomous truck took place on October 25, 2016 between Fort Collins and Colorado Springs [11].

The potential application of autonomous vehicles in the postal sector is divided into two main categories: delivery to the end user - last mile delivery and line transport of items. Five suitable technologies are identified [12]:

1. An autonomous vehicle operated by a delivery agent - is a semi-autonomous vehicle in which the delivery agent is located, who can manage or perform the tasks of preparing or optimizing the delivery route while the vehicle carries a greater part of the responsibility for driving. Certainly, upon arrival at the desired address, the delivery agent realizes the delivery;
2. An autonomous vehicle parked independently - the activity of finding parking spaces by the delivery agent can negatively affect the efficiency of the delivery process. A vehicle that only locates parking eliminates this problem. After the delivery agent turns on the parking assistant and leaves the vehicle, the vehicle only finds the closest available parking space. After the delivery has been completed, the delivery agent finds the location where the vehicle is located via GPS coordinates.
3. An autonomous vehicle tracking delivery agent - This approach is based on the concept that the vehicle is accompanied by a delivery agent who moves on foot so that the items is always nearby (no loss of time to go to the parked vehicle). This reduces the fatigue of the delivery agent and diminishes the possibility of his injury.

4. An autonomous vehicle that complements the quantity of items on delivery - it implies that at some point in the delivery process the vehicle goes only to the postal network unit on the supplement of the items, and then returns again on the route to the delivery point.
5. Mobile packing box - the vehicle contains partitions that act as mailboxes for themselves. Charged with items, the vehicle would go on delivery, and users could access through the code or bar code to the appropriate partition and take over the items.

Due to the electric drive of the vehicle, their positive impact on the environment is remarkable. It would also indirectly affect the reduction of the number of vehicles that are significant polluters of the environment. Economic indicators are not very accurate, but the fact that further development of technology will influence the increase in the economic availability of these systems.

Depending on which concept is being applied, the positive impact on the sustainable development of the postal system is reflected in the following:

- The use of environmentally cleaner drives - minimum emissions of harmful gases;
- Indirect reduction of harmful emissions due to reduction of number of delivery vehicles;
- It indirectly affects the reduction of congestion in traffic;
- Reducing the possibility of injury of the delivery agent;
- More efficient use of the cargo space - saving time, reducing the number of departures on delivery…

Based on the above mentioned characteristics and possible impacts, it is concluded that the implementation of these innovative systems can lead to the improvement of the sustainable development of the postal service. Also, attention should be paid to different variants of combined delivery.

4 CONCLUSION

The impact of postal operators on the parameters of sustainable development is reflected through the all segments, which are necessary for functioning of the postal system. It is of global importance that postal companies take the initiative that leads to sustainable business as soon as possible. This requires raising awareness first of management, and then indirectly to all employees in the system. Aspirations and activities in the process of promoting sustainable development are part of the strategies adopted at the congresses of the Universal Postal Union. Some of the most important approaches are the application of different business concepts and solutions, such as combined transport, the use of alternative and renewable fuels, the improvement of economic accessibility, etc. New technologies and innovative systems for performing appropriate activities in the process of shipments of items, such as the use of drones and autonomous vehicles for delivery, show great potential for the improvement of sustainable development through all its dimensions. In the future, the issue of sustainability of business systems will be increasingly sensitive. Postal companies, which together constitute a logistic system of enormous proportions, have the responsibility to act in accordance with the adopted strategies. In this way, it will give a good example of successful and responsible business for smaller business systems.

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FACULTY OF TRANSPORT ENGINEERING 25 YEARS

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PROMOTION OF SAFETY CULTURE WITHIN SERBIAN REGULATORY FRAMEWORK

Marija Glogovac[1], Olja Čokorilo[2]

Abstract

The paper explains the concept of Safety Culture as the most important condition of successful functioning of an organization, since the Safety Management System cannot be effective without a positive Safety Culture. The five main components of Safety Culture are described: Reporting Culture, Just Culture, Flexible Culture, Learning Culture and Informed Culture. The emphasis is on the concept of Just Culture, because the information that are obtained by reporting occurrences and motivating employees to do so, are much more useful for safety improvement than punishment of employees, which leads to information concealment and hence to endangering the safety. Finally, the paper provides important issues of the promotion of safety culture within Serbian regulatory framework.

Keywords

Safety, Culture, Accident, Occurrences, Safety Management System

1 INTRODUCTION

Although the air traffic has become increasingly safer over the past twenty years, accidents still occur. Therefore, it is necessary to establish an adequate Safety Management System with the aim of continuous improvement of safety by identifying hazards, collecting and analysing data and continuously assessing safety risks. The most important precondition for a successful and effective Safety Management System (SMS) implementation is a positive Safety Culture [1].

Safety in aviation is a state in which the risk of endangering the lives and health of people and causing damage to property are reduced and maintained at an acceptable level through constant hazard identification and risk control. In order to understand the concept of safety it's necessary to consider three different periods of air traffic safety [2]:

- The technical era - from the early 1900s until the late 1960s. In that period, aviation could be described as an unreliable system, since aviation accidents were considerably more frequent than today. Safety deficiencies were related to technical factors and technological failures.
- The human factors era - from the early 1970s until the mid-1990s. Aviation became considerably safer in that period. The focus was on the influence of human factors on the frequency of the accidents. New technologies and regulations were applied.
- The organization era - from the mid-1990s to the present day. Aviation has become the safest transport mode. Organizational factors were considered as a combination of human and technical factors.

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According to the ICAO Standards and Recommended Practices (SARPs) that are defined in Annex 19 [1], Member States have an obligation to establish a State Safety Programme (SSP) with the aim to achieve an Acceptable Level of Safety Performance in civil aviation. SSP is an integrated set of regulations and activities aimed at improving safety. The implementation of SSP must be commensurate with the size and complexity of the State's aviation system and may require coordination among multiples authorities responsible for individual element functions in the State.

As a part of their State Safety Programme, States shall require that service providers implement a Safety Management System (SMS) acceptable to the State. SMS should as minimum include:

- a process for identification actual and potential hazards and risk assessment,
- a process for development and implementation actions that are necessary for maintaining an acceptable level of safety,
- a provision for continuing monitoring and regular assessment of the safety performance.

The main components of SSP and SMS are shown in Table 1.

Tab. 1

SSP components	SMS components
• State safety police and objectives	• Safety police and objectives
• State safety risk management	• Safety risk management
• State safety assurance	• Safety assurance
• State safety promotion	• Safety promotion (Safety Culture)

2 SAFETY CULTURE

Some authors provided detailed research to assess employees' perceptions of safety management and safety culture in the aviation industry [3]. Others provide summarization of the numerous reports and studies that have been conducted to define the influence of safety culture on aviation safety and other complex industries [4].

Culture can be defined as a system of values, ways of behaviour and belief, which is characteristic of a certain social community, group or organization. The three most important cultural components are: organizational, professional and national cultures, as it is shown in Fig 1. These components have relevance to safety management initiatives, because they are determinants of organisational performance.

Organizational culture is an essential part of every organization. It can be defined as a system of values, beliefs, assumptions and norms of behaviour that are common for members of certain organization. Organizational culture affects the following:

- Interaction between the members of the organization,
- Interaction between industry and regulatory authority,
- The acceptance and utilization of a certain technologies,
- The degree of information sharing between employees,
- The creation of an environment in which personnel are efficient, competent, loyal to the organization and ready for teamwork.

The most effective way to promote safe operations in organization is to ensure that it is developed the way of thinking in which all staff feel responsible for their actions and consider the impact of safety on everything they do.

Professional culture defines the characteristics of a particular professional group. It is a product of education, training and work in a particular work environment. From a safety management perspective, professional culture affects the ability of a professional group to distinguish between safety performance issues and industrial issues.

National culture defines the characteristics of particular nation. People of different nationalities are different, so the teamwork in mix national cultures environment can lead to misunderstandings. For example, the concept of safety risk differs between different national cultures. When applying SSP managers should assess and consider the differences in the national cultures of personnel.

Fig. 1 Community Cultures

Safety Culture is a product of the combined effects of Organisational Culture, Professional Culture and National Culture. It can be positive, negative or neutral [5].

2.1 Pillars of Safety Culture

According to James Reason [6, 7] there are five main components od Safety Culture (Fig.2):

- Reporting Culture is a culture in which people are encouraged to report their errors and nermisses. Open reporting is very important to any SMS.
- Just Culture refers to the encouragement and motivation of employees to provide information that have or may have an impact on safety, without fear of being treated unfairly and/or that they will be subjected to restrictive measures, but with a clear distinction between acceptable and unacceptable behaviour. Only a small proportion of unsafe human acts are intentional (criminal activities, sabotage, reckless non-compliance, etc.)
- Flexible Culture refers to organization's preparedness for reconfiguration in the face of high tempo operations of certain kind of danger.
- Learning Culture means that the organization is ready and able to learn from mistakes and to implement major reforms.
- Informed Culture means that people in the organization have current knowledge of factors that affect the safety of the system as a whole.

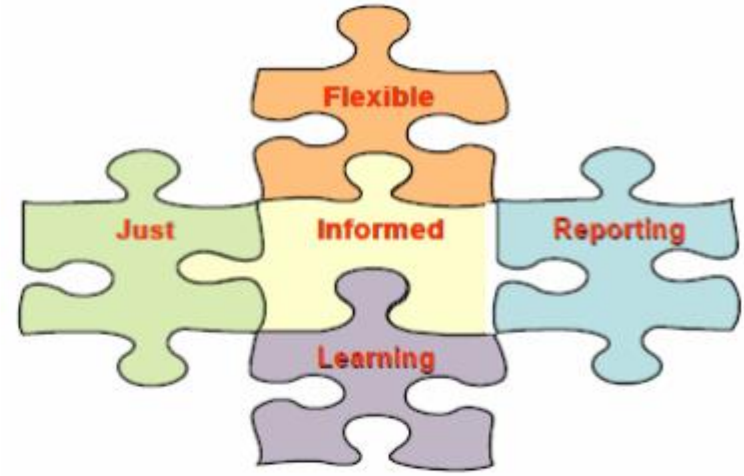

Fig. 2 Pillars of Safety Culture

2.2 Just Culture

According to Heinrich Pyramid [7], each accident is caused by a huge number of unreported occurrences. Based on Figure 3, for every 300 unreported occurrences one accident occurs. Minimising the number of unreported occurrences will lead to a reduction of number of incidents and major accidents. Therefore, it is necessary to motivate and encourage employees to report all occurrences, unsafe situation, omissions and deficiencies, without fear of being sanctioned, with the aim to improve safety through experience and lessons learnt, which means establishment of Just Culture.

Fig. 3 Heinrich Pyramid [7]

By monitoring the number of particular occurrences, which are important from the aspect of safety, it is possible to precisely determine the level of safety in certain segments of air traffic. These occurrences are: accidents, serious incidents and major incidents.

Figure 4 shows the number of ATM caused accidents, ATM caused serious incidents and ATM caused major incidents for FIR Belgrade for the period 2014-2016. It can be concluded that an increase of air traffic for three years is not significant (Figure 5). The number of accidents, serious incidents and major incidents is almost the same for considered years. There are no significant changes recorded.

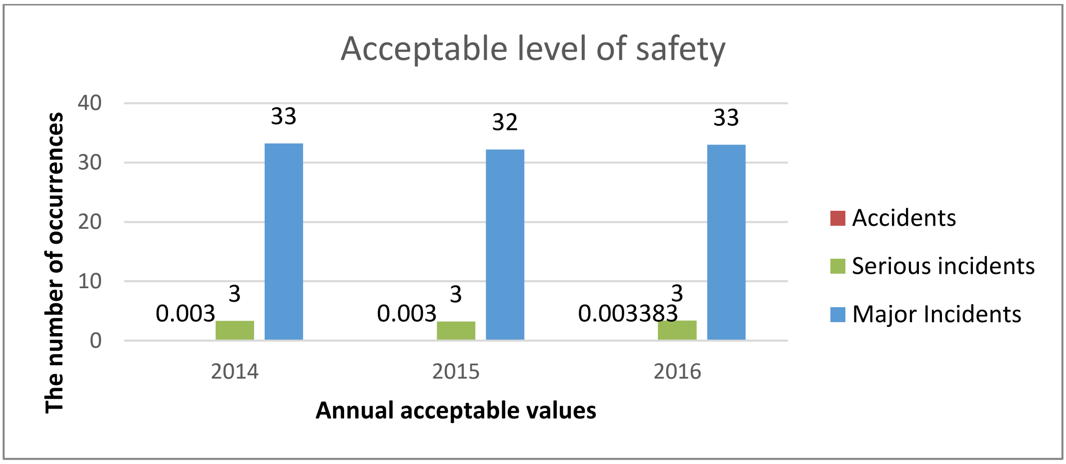

Fig. 4 Acceptable level of safety

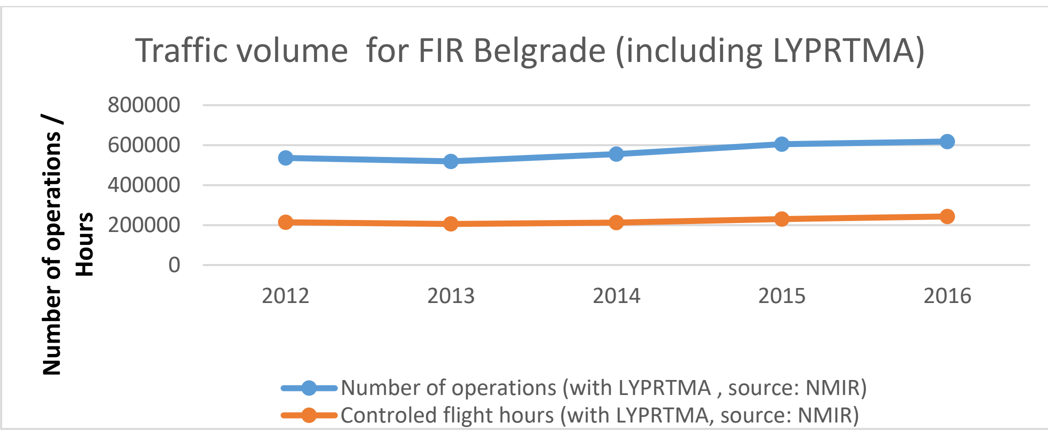

Fig. 5 Traffic volume for FIR Belgrade

2.3 Safety awareness within Civil Aviation Directorate of the Republic of Serbia

Management of CAD is a team of experienced professionals in aviation that are aware of their role in aviation and air traffic safety as NSA. In daily communication with staff management, they stipulate their safety awareness and actively promote Just Culture concept. There are six pre-requisites for Just Culture [8, 9]:

- **Motivation and promotion** – Staff should be motivated to provide essential safety-related information.
- **Ease of reporting** – Reporting occurrences shall be made as easy as possible for staff.
- **Acknowledgement** – Reporters like to have information about their report, such as whether their report was received, what will happen to it, what to expect and when.
- **Independence** – A certain degree of independence must be assigned to managers of reporting system.
- **Feedback** – Feedback to reporters and other stakeholders is essential for functioning of the system.
- **Trust –** An atmosphere of trust should exist between reporters and managers of the reporting system.

All staff in ATM/CNS/PEL departments are persons of high degree of knowledge, skills, professional experience and personal and professional integrity. There is a procedure for continuous training of staff and annual plan of training, which assure a learning culture within departments. After completion of individual training, new knowledge is shared with other colleagues in formal manner, which is an environment of learning culture in CAD.

Regarding the informed culture, when is necessary, CAD is organizing meetings, workshop, presentations, for CAD staff, other NSA staff, ANSP staff and other representatives of industry.

With the aim of continuous assurance and improvement of safety culture within CAD, department (ATM/CNS/PEL) managers together with head of division and director of CAD are periodically performing review of:

- Audit activities,
- Inspections activities,
- Occurrence investigation and analysing activities,
- Training activities,
- Activities regarding participation in internal work groups and teams and international cooperation with other NSA and ANSP,
- Overall results of planned activities,
- Plans for following periods.

3 CONCLUSION

Air traffic is constantly increasing, and that also increases the number of potential hazards that can endanger its safety. In order to reduce safety risk in aviation or maintain it at an acceptable level, it is necessary to establish Safety Management System. Safety management is a constant process aimed at continuous detection of hazards and risk management. Perfect SMS does not exist, because it is impossible to foresee all possible interactions between people and technologies.

For successful work of one organization, it is necessary that there is an atmosphere of trust in which people are aware of the risk and hazards induced by their activities, and are encouraged to provide essential safety-related information, but still to understand where the line is drawn between acceptable and unacceptable behaviour. Any human or organizational errors must first be considered as an opportunity to improve operations through experience, feedback and lessons learnt.

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EVALUATION OF TRAIN TIMETABLE USING INDICATORS

Karel Greiner[1]

Abstract
The article describes one of the evaluation tools of an application used for ordering train paths by railway undertakings in the Czech Republic. The tool allows calculating many indicators for the needs of freight and passenger transport. The calculation can be performed for selected lines, areas, tractions and periods. The areas can be standard (the Czech Republic and its regions) as well as user-defined (an arbitrary set of transport points and sections). After the calculation is done, selected paths of trains can be excluded or additionally included, which results in an immediate recalculation of the results.

Keywords
timetable, train, transport indicator, information system

1 INTRODUCTION

The annual train timetable in the Czech Republic is designed using the KANGO and KASO information system [1]. One of its components is the KANGO-Vlak and KASO-Vlak application [2] (hereinafter KANGO-Vlak), which primarily serves to acquire train paths required by a railway undertaking from an infrastructure manager.

The KANGO-Vlak program also provides several analytical tools. One of them is a module to calculate transport indicators, which is the content of this article.

2 SELECTING AND FILTERING TRAINS

Indicators are calculated for selected trains. Selection of trains can be done manually in the list of trains or automatically according to specified criteria. The tool to select trains offers a large number of criteria covering most of the train data, such as the interval of train numbers, a calendar, an engine of the train, and others. The user may specify any combination of the offered criteria. A train is chosen if it meets all the entered criteria. The tool also offers an option to maintain the current selection of trains. This allows adding more trains matching the criteria to the current set of selected trains (selected manually or using the tool to select trains).

In addition to the tool to select trains, the application provides a tool to filter trains, which offers the same criteria as in selecting trains. After they are entered in the list of trains, only such trains are displayed that meet all specified criteria. It is an active filter that is automatically performed with any change received from the application server. The filtered list can be created from selected trains.

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3 USER AREAS

Calculation of the indicators can be done not only for the standard areas (the Czech Republic and its regions), but also for the user areas. User area is an arbitrary set of transport points and sections. An area may contain a name and comment.

To prevent anyone from modifying or deleting a given area, the user may lock it. In this case, it can be modified or deleted only by the user who locked it or the administrator. Other users may view it and use it.

Transport points of the user area can be of the following types:

- Normal – common points of the area.
- Facultative – a train that runs within the area through the facultative points, facultative stopping points, and facultative sections:
  - and goes on through points or segments not belonging to the area is not included in the area,
  - and does not run through other points and segments not belonging to the area is included the area.
- Normal stopping – if a train runs through normal stopping points, it has to stop in all these points in order to be included in the area.
- Facultative stopping – if a train goes through the facultative stopping points, it has to stop in all these points in order to be included in the area. Furthermore, if the train goes only through the facultative points, facultative stopping points and facultative sections:
  - then goes on through points or segments not belonging to the area, it is not included in the area,
  - does not go through other points and segments not belonging to the area, it is included in the area.

A train stopping point means the starting and destination point and also a track point where the train stops.

User area transport sections can be of the following types:

- Normal – common sections of the area.
- Facultative – see facultative points.
- Prohibited – a train that goes through some of the prohibited sections is not included in the area.

Facultative points, facultative sections and prohibited sections are used mainly in defining tracks of a book timetable, where there are points and segments that are part of several tracks.

Fig. 1 shows two fictitious lines: A – E and A – G. Track A – E represents a user-defined area. It contains the points A and B and the section between them, which are part of both lines. In order to avoid including the trains running along A – E track were not included in the A – G track, the points A, B and the section between them are marked as facultative. Endpoints of the track A – E must be marked as facultative because they are also part of other tracks. If there was a train that would only go from point A to point B or vice versa, it would be included in the track A – E.

Stopping points have been introduced to define the book timetable lines, which form a subset of a longer line and do not include trains that pass through certain points of this line.

Transport points and sections can be added/removed to/from the area in the dialog box, in a tabular or graphical form in the window of the railway network.

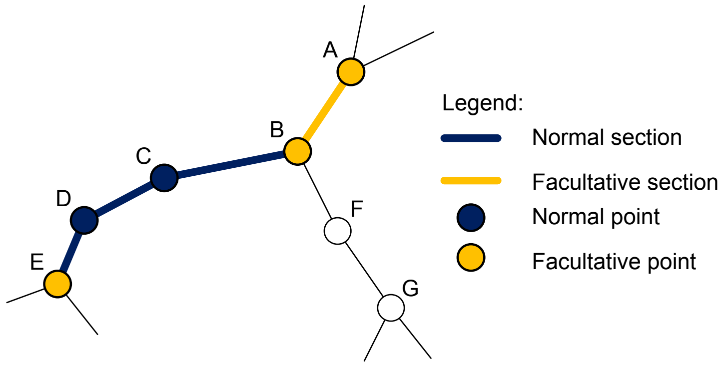


Fig. 1 User area of fictitious line A – E

An uninhibited section can be included in the area only partly. The portion of the inclusion of a section in the area can be defined by a coefficient, e.g. 0.25 of the length of the section. This functionality is used in calculating transport indicators for a track section, whose borderline can be within of the transport section.

4 CALCULATING INDICATORS

Indicators are calculated for selected areas, tractions and the specified period within the validity of the annual timetable. The selected indicators are calculated for each combination of the selected areas and tractions separately.

The areas include the following:

- the Czech Republic,
- regions of the Czech Republic,
- user areas.

The traction is determined by the decisive engine in the given section of the path of the train. On the train, engines are entered with a section, validity calendar and functions on the train (train, pusher etc.). The decisive engine is the engine with the train function.

The calculation can be done for the following tractions:

- electric locomotives,
- electric units,
- electric – electric locomotives and multiple units,
- diesel locomotives,
- railcars,
- motorized – diesel locomotives and railcars,
- all – regardless of traction.

For a given area and traction, only such sections are taken into account (further on referred to as the compliant sections) that meet all the following conditions:

- the section belongs to the relevant area,
- in the section, the decisive engine of the relevant traction is indicated on the train,
- the train runs in the section in the specified period,
- in the section, some of the selected transport types of trains is indicated on the train (such as passenger, InterCity),
- in the section, a selected general note is indicated on the train,
- in the section, the selected party to have ordered the train (Ministry of Transport, the regional authority or municipality) is indicated on the train,

- in the section, the selected integrated transport system is indicated on the train.

General notes are notes that appear in the timetable for passengers, for example, "seat reservation can be bought for marked passenger cars".

Transport types, general notes, ordering parties and integrated transport systems are entered on the train similarly to engines, i.e. with a section and validity calendar.

These conditions must be met also in terms of calendars. For a given traction and train path section, *A* set of days is calculated resulting from intersection of these sets:

- a set of all days in the specified period,
- union of sets of calendar days of the decisive engines of the given traction,
- union of sets of calendar days of selected transport types of trains,
- a set of calendar days of selected general notes,
- a set of calendar days of the party to have ordered the train,
- a set of calendar days of selected integrated transport system.

If set *A* is empty, the given section of the train is excluded from the calculation for the given area and traction.

Some indicators are calculated with data of the parameters of the train. The parameters of the train include weight, length, number of cars, rolling resistance, maximum speed, etc. On the train, they are entered with the section and the validity calendar.

The following examples of calendars make use of the numbers 1 to 7 representing the day of the week Monday to Sunday in the given period. The term the number of days the train runs, which is also used, means the number of days of the set *A* in the given compliant section.

The module offers calculation of the following indicators.

Total number of trains – the number of trains running at least in one compliant section multiplied by the number of days the trains run. For example, the train runs in the first compliant section on 1–4 and in the second compliant section on 4–6. The value of days 1–6 is added to the indicator for this train.

Daily number of trains – the number of trains running at least sometime in one compliant section. If the train runs at least sometime in one compliant segment, the value 1 is added to the indicator for this train.

Reduced number of trains – the number of trains calculated as a quotient of the indicator "total number of trains" and the number of days of the specified period.

Total train kilometres – the sum of multiples of lengths of compliant sections and the number of days the trains run. For example, a train in the first compliant section 10 km long runs in 1–4 and in the second compliant section 20 km long it runs in 4–6. The value

$$10a + 20b \tag{1}$$

is added to the indicator for this train where *a* is the number of days 1–4 and *b* is the number of days 4–6.

Daily train km – the sum of the lengths of the compliant sections of the trains.

Reduced train kilometres – the quotient of the indicator "total train kilometres" and the number of days of the specified period.

Total gross ton kilometres – the sum of the multiples of the weights of the parameters of the trains, the lengths of the compliant sections and the number of days the trains run. If there are multiple variants of parameters of trains in a section on the train, the weight of the train is calculated by the weighted average with regard to the number of days of the validity of individual variants of the parameters of the trains.

Daily gross ton kilometres – the sum of the multiples of the weights of the parameters of the trains and the lengths of the compliant sections. If there are multiple variants of the parameters of the trains in a section on the train, the weight of the train is calculated by the weighted average with regard to the number of days of the individual variants of the parameters of the trains run.

Reduced gross ton kilometres – the quotient of the indicator "total gross ton kilometres" and the number of days of the specified period.

Average weight of the train – the quotient of the indicator "total gross ton kilometres" and "total train kilometres".

Total, daily and reduced vehicle kilometres – are calculated the same way as the gross ton kilometres, except that instead of the weight of the parameters of the trains is used the number of cars.

Total, daily and reduced axle kilometres – are calculated the same way as the gross ton kilometres, except that instead of the weight of the parameters of the trains is used the number of axles.

Travel speed – the quotient of daily train km and total travel time of individual trains in compliant sections including the actual travel time and the duration of stay at intermediate transport points of the path of the train.

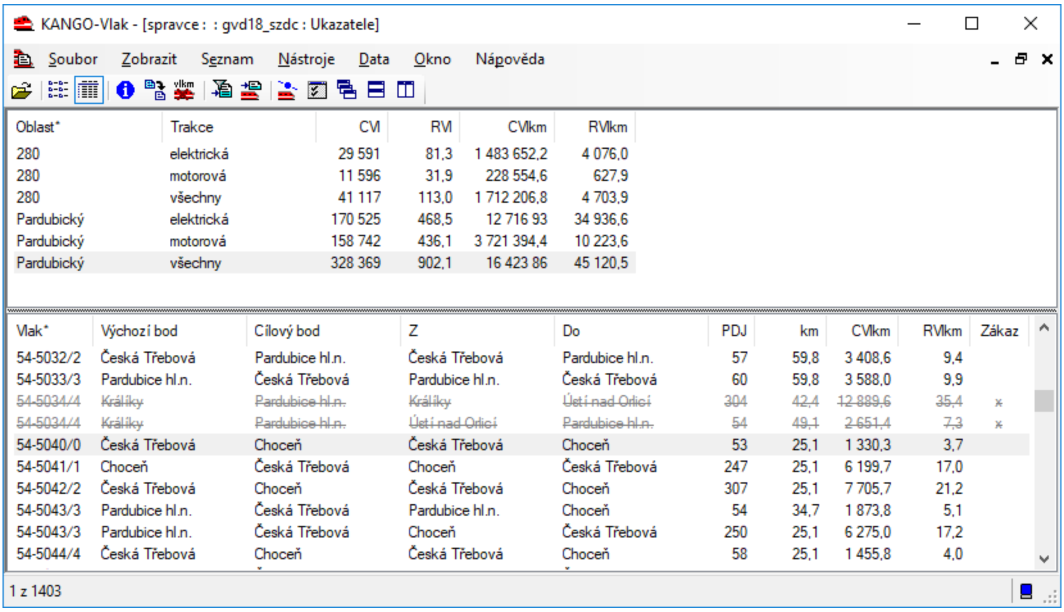
Sectional speed – the quotient of daily train km and total travel time of individual trains in compliant sections including the actual travel time and the duration of stay at intermediate points of the path of the train where a departure or intermediate technical inspection is not performed and neither is customs clearance and passport control.

Technical speed – the quotient of daily train km and the sum of journey time of individual trains in compliant sections not including the stay in the intermediate transport points of the path of the train.

During the calculation of indicators, completion and accuracy is checked of the information needed for the selected indicators. The calculation will take place even if errors have been found in some sections or points of train paths. These sections and points are not, however, included in the calculation. The errors detected are recorded in a protocol file.

The result is a window containing a list of indicators calculated for the selected area and tractions and, if need be, a list of trains, from which the indicators for each area and traction have been calculated. Fig. 2 shows an example of such a window containing the indicator of the reduced and total number of trains (CVl and RVl columns), total and reduced train km (CVlkm and RVlkm columns) in two regions and on one track of the book timetable for passengers for the entire 2017/2018 season of the timetable. The bottom of the window contains a list of trains for the selected line at the top of the window. For each train is given its starting point and destination, path section, which belong to the area and traction and partial values of the calculated indicators (PDJ column represents the number of the days the train runs). The train or the section of its path can be excluded from the calculation, which will automatically recalculate the total values of the indicators. The excluded trains are shown in the Figure with a crossed grey lettering.

The list of indicators, including the list of trains, can be saved to a text file and subsequently loaded into a spreadsheet or word processor for further processing.



Oblast*	Trakce	CVl	RVl	CVlkm	RVlkm
280	elektrická	29 591	81,3	1 483 652,2	4 076,0
280	motorová	11 596	31,9	228 554,6	627,9
280	všechny	41 117	113,0	1 712 206,8	4 703,9
Pardubický	elektrická	170 525	468,5	12 716 93	34 936,6
Pardubický	motorová	158 742	436,1	3 721 394,4	10 223,6
Pardubický	všechny	328 369	902,1	16 423 86	45 120,5

Vlak*	Výchozí bod	Cílový bod	Z	Do	PDJ	km	CVlkm	RVlkm	Zákaz
54-5032/2	Česká Třebová	Pardubice hl.n.	Česká Třebová	Pardubice hl.n.	57	59,8	3 408,6	9,4	
54-5033/3	Pardubice hl.n.	Česká Třebová	Pardubice hl.n.	Česká Třebová	60	59,8	3 588,0	9,9	
~~54-5034/4~~	~~Králíky~~	~~Pardubice hl.n.~~	~~Králíky~~	~~Ústí nad Orlicí~~	~~304~~	~~42,4~~	~~12 889,6~~	~~35,4~~	x
~~54-5034/4~~	~~Králíky~~	~~Pardubice hl.n.~~	~~Ústí nad Orlicí~~	~~Pardubice hl.n.~~	~~54~~	~~49,1~~	~~2 651,4~~	~~7,3~~	x
54-5040/0	Česká Třebová	Choceň	Česká Třebová	Choceň	53	25,1	1 330,3	3,7	
54-5041/1	Choceň	Česká Třebová	Choceň	Česká Třebová	247	25,1	6 199,7	17,0	
54-5042/2	Česká Třebová	Choceň	Česká Třebová	Choceň	307	25,1	7 705,7	21,2	
54-5043/3	Pardubice hl.n.	Česká Třebová	Pardubice hl.n.	Choceň	54	34,7	1 873,8	5,1	
54-5043/3	Pardubice hl.n.	Česká Třebová	Choceň	Česká Třebová	250	25,1	6 275,0	17,2	
54-5044/4	Česká Třebová	Choceň	Česká Třebová	Choceň	58	25,1	1 455,8	4,0	

Fig. 2 Window of the calculated indicators

5 CONCLUSION

The application KANGO-Vlak along with other applications of the KANGO and KASO systems were deployed in routine operation at the end of 2010. Their introduction resulted in improving and accelerating the work on the design of the annual timetable.

The module of calculation of the indicators provides a basic set of indicators for planning and evaluating a designed timetable. The calculation can be influenced by set of the parameters.

Indicators are calculated for selected trains and or geographical areas. Selection of trains is possible effectuate manually in the trains list or automatically according to pre-set criterions. The area can be predefined (Czech Republic and its regions) or defined by user. User area represents arbitrary set of transport points and sections of required type (e.g. stopping point, prohibited section). Type of transport point and section determines including/excluding of the train path in the appropriate area.

◆◆

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S-CODE: SWITCHES AND CROSSINGS OPTIMAL DESIGN AND EVALUATION

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Abstract
The S-CODE project is addressed all of the aims and objectives detailed in topic Research into new radical ways of changing trains between tracks – and work towards the developments required to realise Next Generation Switches and Crossings, as detailed in the Shift2Rail Multi-Annual Action Plan. The overall aim of the S-CODE project is to investigate, develop, validate and initially integrate radically new concepts for switches and crossings that have the potential to lead to increases in capacity, reliability and safety while reducing investment and operating costs. The project has identified radically different technology concepts that can be integrated together to achieve significantly improved performance for Switches and Crossings based around new operating concepts. Within this project the research team of University of Pardubice Faculty of Transport Engineering deals with optimisation of wheel-rail interface in Switches and Crossings and using of novel material for Switches and Crossings components. This paper contents particular results of both mentioned fields.

Keywords
paragraph, page, heading, footer

1 INTRODUCTION

The S-CODE project is running alongside sister projects - the ongoing IN2RAIL lighthouse project and the Shift2Rail joint undertaking Research into enhance track and switch and crossing system “IN2TRACK”. Outputs from these two projects is feeding into the S-CODE project, in order to develop a solution of technology readiness level 4 (TRL4) that can be later developed into Technology Demonstrator – Next Generation Switches and Crossings (S&C).

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2 OBJECTIVES

In order to develop the project, the consortium decomposed the high level aims documented in the project call and the technical ambition for technology demonstrator detailed in the Multi-Annual Action Plan, to identify the key objectives that helps to provide radically new ways of changing trains between track in order to improve capacity, reliability and safety, while reducing investment costs and life-cycle costs [1]:

- **Objective 1:** Identify existing best practice in switch and crossing innovation and fuse this with technological advances from other sectors to develop new approaches for switch and crossing operations, that draw on new concepts for drives, control, monitoring, logistics and installation that will allow the investment costs associated with S&C to be retained (or reduced) whilst significantly improving performance;
- **Objective 2:** Develop a modular switch and crossing architecture that allows subsystems to be easily changed or upgraded such that the gains in S&C system performance available from the adoption of new concepts can be realised progressively without the need for complete system renewal, thus allowing benefits to be attained more rapidly;
- **Objective 3:** Realise resilience-based design methodologies, maintenance free and degradation free systems and self-adjusting technologies that will allow complete **self-inspection** and **self-correcting and healing** functionality through the development of an S&C immune system, contributing towards a **50% improvement in the reliability and availability of switches**;
- **Objective 4:** Develop concepts that utilise new materials and construction techniques, together with an optimised wheel-rail interface to realise a **new movement principle** which has the potential to contribute to a **reduction in the life cycle cost of switches by up to 30%**;
- **Objective 5:** Significantly increase the allowable running speed of trains while also dramatically decreasing the switching time in order to contribute to a **capacity improvement of up to 100%**;
- **Objective 6:** Ensure that an integrated system, including a **fail-safe locking mechanism** design is arrived at that mitigates all risks associated with technical failure, human error and influencing external factors, that may result in incidents occurring, thus ensuring that the number and magnitude of incidents is reduced and the safety of passengers and the work force is retained at the highest level;
- **Objective 7:** To validate the new concepts developed in the project in a laboratory (TRL4) to allow assessment of the performance of the innovations;
- **Objective 8:** To provide hard evidence (calculations and simulations, experimental results, and economic, risk, reliability and LCC analysis) that supports the performance improvements made against Objectives 1 to 6;
- **Objective 9:** To integrate the identified, developed and validated concepts to produce a solution(s) that can be taken forward to **realise the Technology Demonstrator Next Generation S&C**.

The key outcomes and innovations of the S-CODE project will be [1]:

- The development and prototyping of a modular whole system switch and crossing architecture that allows subsystems to be changed over the life of the S&C. This will enable innovations to be added as they become available. The architecture and subsystems will be modelled to allow rapid development of further capabilities.
- The design and prototyping of Next Generation Design components that can be incorporated into the architecture, using new materials and technologies to create a variety of permanent way subsystems.

- The design and prototyping of a Next Generation Control subsystem that can be incorporated into the architecture, which will include an ‘immune system’ capable of self- adjustment, self-correction, self-repair and self-heal.
- The design and prototyping of Next Generation Kinematic subsystem that can be incorporated into the architecture, that includes new actuation and locking philosophies that make use of concepts such as redundancy and ‘limp-home’ through the use of novel actuators and mechatronic systems.
- Analysis will be undertaken to quantify the value of these innovations from the perspective of reliability, life-cycle cost, and higher speed switches/train throughput.

The S-CODE project aims to address the three specific technical challenges in topic "Research into new radical ways of changing trains between tracks in order to improve the overall performance of switches and crossings". Furthermore, the S-CODE project has been developed and conceptualised taking into account the needs of the Shift2Rail Multi-Annual Action Plan Next Generation S&C demonstrator.

Specifically, the S-CODE project:

- Identifies, develop and validate new concepts for next generation control – including a modular architecture, plug’n’play control, monitoring, sensor and data systems;
- Identifies, develop and validate new concepts for next generation design – including materials, component reduction, switching function, installation and logistics;
- Identifies, develop and validate new concepts for next generation kinematics – including actuation systems, mechatronic solutions, fault tolerance and S&C ‘immune system’;
- Uses the modular architecture to integrate the design concepts to develop alternative holistic solutions suitable for different scenarios that are can be selected and developed in later stages of the Shift2Rail programme (see fig. 1).

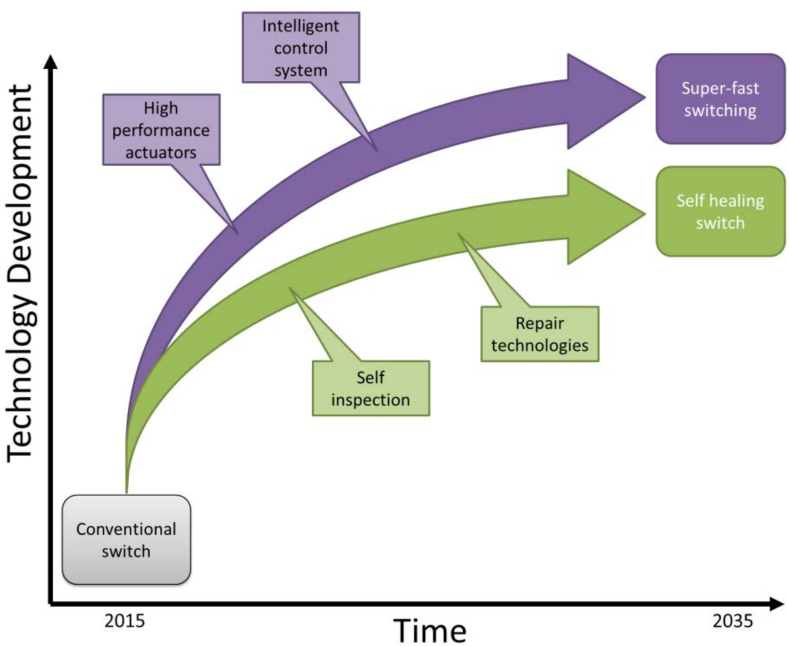

Fig. 1 The progressive and modular integration of different design concepts to realise Next Generation S&C for use in different scenarios [1]

3 METHODOLOGY OF SOLUTION S-CODE PROJECT

The S-CODE project will be divided into three phases [1]:

- Phase 1: Requirements and initial design
- Phase 2: Technical development
- Phase 3: Demonstration and evaluation

3.1 Requirements and initial design

This phase of the project mainly addresses **Objectives 1 and 2** by eliciting the key industrial and technical requirements, as well as identifying existing best practice and technologies from other domains that can be exploited to help achieve significant improvements in S&C design. An architecture for modular design is developed that enables different subsystems to be interchanged during the life of an S&C installation. This allows the subsystems to be developed with some level of independence (different manufacturers, different timescale for upgrade/renewal). This phase of the project also considers the design philosophy and develops initial high level conceptual designs for new S&C through the use of horizon scanning techniques, such as back-casting.

- **WP1 – Best practice, elicitation of requirements and horizon scanning**
- **WP2 – Overall system architecture and initial high level design**

3.2 Technical development

This phase of the project addresses **Objectives 3 to 6**, and concentrates on the detailed technical design of the three main subsystems (control, design, kinematic actuation). The overall aim of this phase of work is to develop fault tolerant, low-LCC, low-carbon, low-maintenance turnout components and subsystems, through the use of novel materials, processes, electronics, signal processing and mechatronic design concepts as identified in Phase 1. A number of different design concepts is developed for each subsystem, with the most promising designs being taken forward for detailed development.

- **WP3 – Next generation control: monitoring and sensing systems**
- **WP4 – Next generation design: materials and components**
- **WP5 – Next generation kinematic systems: actuators and mechatronics**

3.3 Demonstration and evaluation

This phase of the project addresses **Objectives 7 to 9**, and concentrates on the evaluation and validation of the three main subsystems. Initially design concepts are validated separately through laboratory hardware-in-the-loop testing. Later, the design concepts are integrated using the modular architecture to produce a candidate solution for development at higher technology readiness levels through the remainder of the Shift2Rail programme.

- **WP6 – System integration and concept validation**
- **WP7 – Evaluation, impact and future developments**

3.4 Work packages interaction

The work packages has been interacting, as shown in fig. 2. In Phase 1, best practice assessment, requirements elicitation, horizon scanning, architecture development and high level design has been undertaken [1]. This produces high level concepts that can be developed into full designs (marked a to d) in Phase 2. In Phase 3, the most promising design concepts from Phase 2 has been taking forward for validation (e.g. WP5 – design a). The validation process enables evaluation and assessment to be undertaken and final solutions to be integrated (e.g. WP3 – design a, with WP4 – design a, and WP5 – design d).

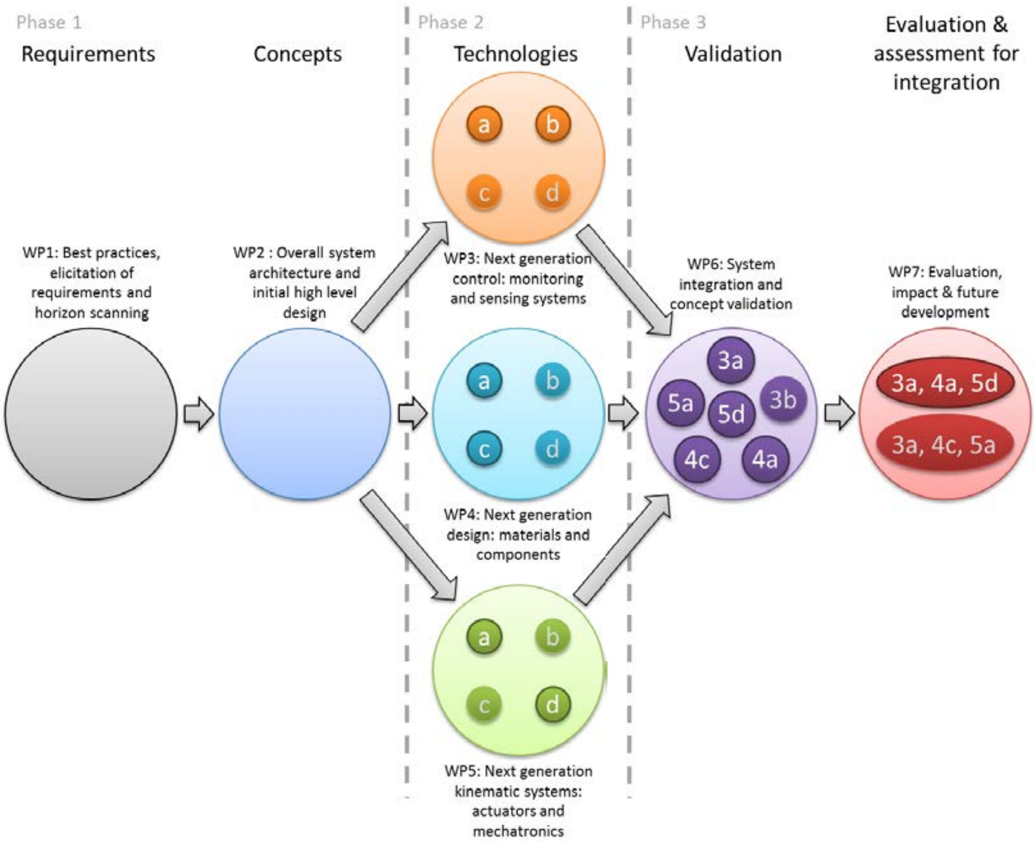

Fig. 2 S-CODE work package interaction [1]

4 AMBITION

The key innovations of the project are the following [1]:

4.1 Innovation 1: Modular S&C Architecture

The development of a plug'n'play architecture for S&C allows different components and subsystems to be replaced, renewed and updated over different timeframes. This allows:

- S&C to be configured for different locations, that have particular requirements;
- different manufacturers to develop different subsystems;
- allow future innovations to be made in each of the subsystem areas.

4.2 Innovation 2: Next Generation S&C Control

In the area of next generation S&C control, the key innovation lies in the use of embedded electronics and sensors to provide significantly improved control, monitoring, inspection and safety functionalities. This significant improves reliability, and reduce life cycle costs.

4.3 Innovation 3: Next Generation S&C Design

Next generation S&C design utilises novel materials that have been designed specifically for application in S&C. This enables the switching and locking function to be radically changed, which improves reliability and reduces switching time (capacity). New materials and optimal design also improves the wheel/rail interaction, which reduces (eliminates with lighter vehicles) degradation of the running rails and support components. Installation and logistics is considered at the design stage, allowing these tasks to be carried out more quickly, and with a reduced need for people to be on the track. BIM is used to integrate the next generation of S&C design, to both help integrate different solutions and to speed-up approvals and standardisation.

4.4 Innovation 4: Next Generation S&C Kinematic Systems

Next generation S&C kinematic systems make use of mechatronic systems and fault tolerance – approaches commonly found in other safety critical industries (e.g. aerospace). Such approaches need to be adopted cost effectively, and without increasing the complexity of the S&C mechanism. With improved actuation, many benefits can be realised including improved reliability, improved availability, improved switching time (capacity).

4.5 Technology Readiness Level (TRL)

Fig. 3 shows the rise in technology readiness level in each of the mentioned areas through the course of the project [1].

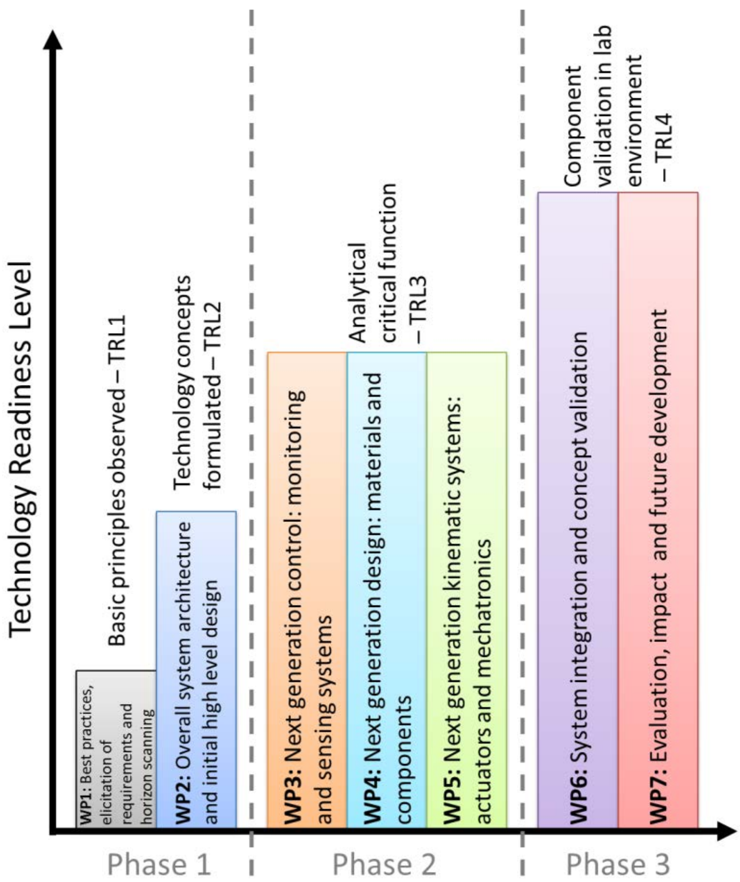

Fig. 3 Technology Readiness Level improvements through the S-CODE project [1]

5 WORK PLAN — WORK PACKAGES, DELIVERABLES

Fig. 4 shows the structure of the work packages that have been developed using a systems engineering process to deliver the S-CODE project [1]. Phase 1 of the project (WP1 - Best practices, elicitation of requirements and horizon scanning, and WP2 - Overall system architecture and initial high level design) is used to decompose the high level objectives, and to develop initial radical design concepts. Phase 2 of the project (WP3 - Next generation control: monitoring and sensing systems, WP4 - Next generation design: materials and components, and WP5 - Next Generation kinematic systems: actuators and mechatronics) focuses on the key detailed technical work, while Phase 3 (WP6 - System integration and concept validation, and WP7 - Evaluation, impact and future development) concentrates on system integration, and preparation for realisation of Next Generation S&C demonstrator.

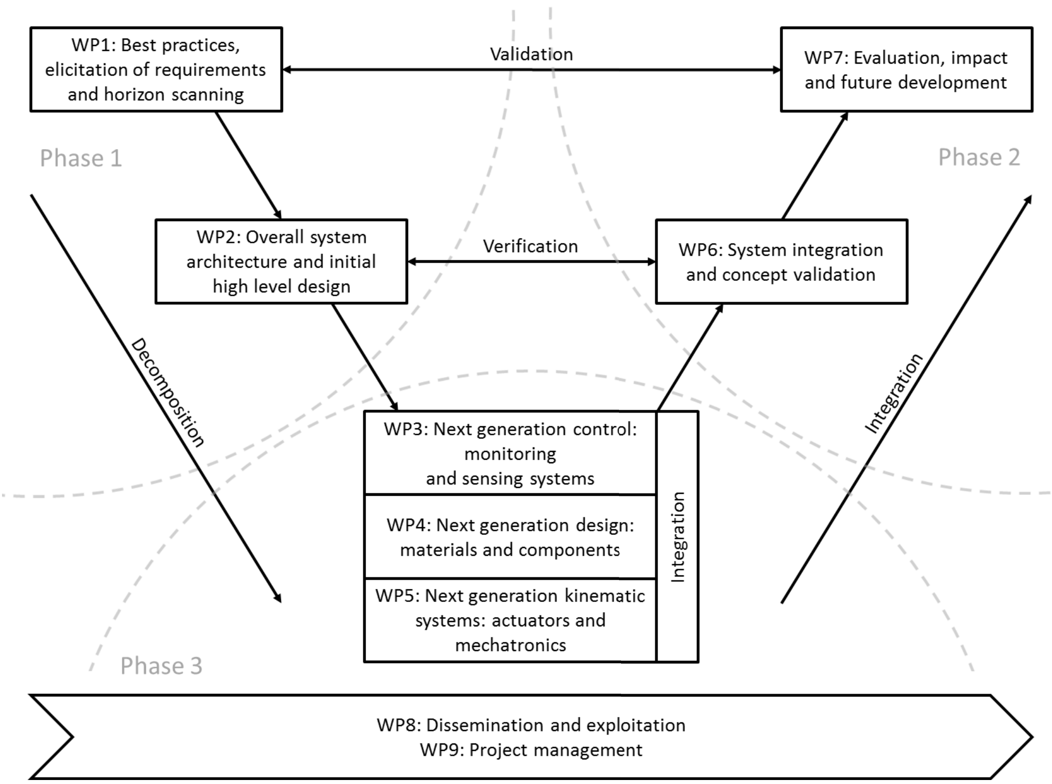

Fig. 4 S-CODE work package structure [1]

6 RESEARCH ACTIVITIES OF UNIVERSITY PARDUBICE, FACULTY OF TRANSPORT ENGINEERING WITHIN S-CODE PROJECT

The research teams of University of Pardubice, Faculty of Transport Engineering deals with 3 activities in WP3 and WP4 of Phase 2 (Technical Development) of the S-CODE project. These activities are described in the following subchapters.

6.1 Intelligent self-diagnostic monitoring development

It is one task of WP3 in order to develop approaches for intelligent self-diagnostic monitoring – the first step of developing the S&C immune system. Self-diagnostic monitoring is a precursor to full fault tolerant control. Self-diagnostic monitoring includes functions (and hence algorithms) for self-inspection, fault detection, fault diagnosis and fault prognosis. A variety of algorithmic techniques are implemented for this purpose, including conventional model-based diagnosis, artificial intelligent neural network fault classifiers, quantitative and qualitative reasoning, etc. [1]

For WP3, there are several work streams that is together delivering a unified monitoring and sensing system. The areas of responsibility for sensing are split into:

- Autonomous inspection to inform autonomous repair using lasers, video and other NDT techniques.
- Embedded passive dynamic effect monitoring using accelerometers and other relevant sensors.
- On-train monitoring and correlating the data with the passive dynamic effect monitoring.
- Fault tolerant control of the S&C.
- Embedded monitoring of the actuation system.

These sensor systems must be able to communicate so that the data can be sent wherever it is required. A communications protocol is developing for the In2track project and will be used by all the partners to ensure interoperability and modularity. The data will all then be collected and processed to provide diagnostics and prognostic analytics.

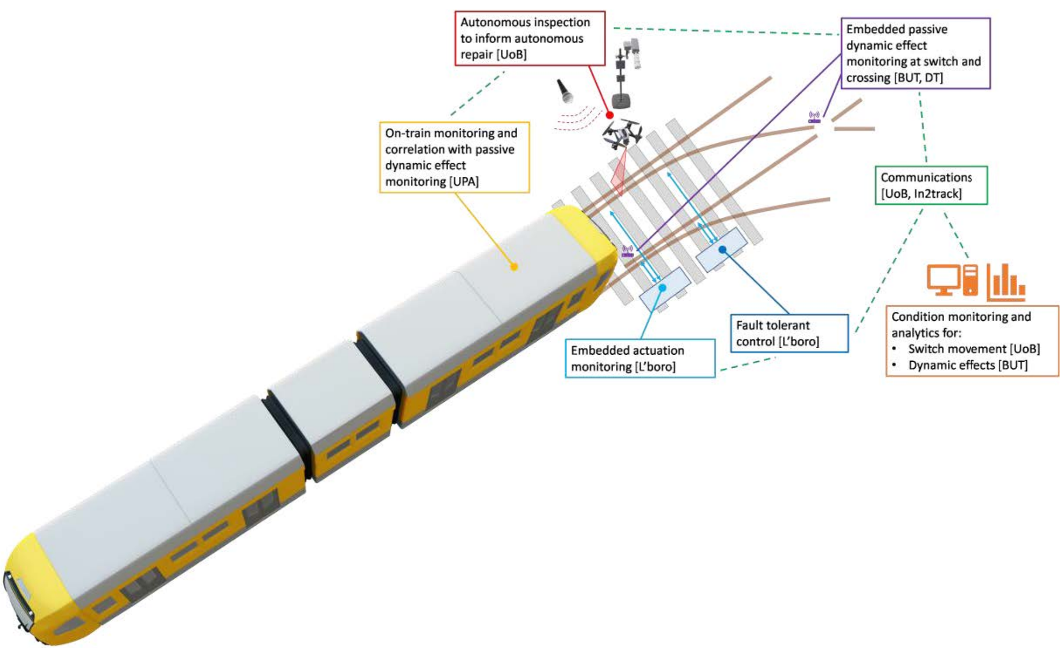

Fig. 5 S-Code WP3 workstreams [2]

The intelligent self-diagnostic monitoring system is now developing base on experimental experiences of all included project partners. The research activities of University of Pardubice, Faculty of Transport Engineering are concerned to S&C diagnostic system located on the vehicle. The experience also enables to participate in identification of vehicles at the S&C stationary diagnostic system and intelligent evaluation techniques based on neural network.

S&C are problematic points in the track. Dynamic response corresponding maintenance costs are higher than at common track. To prevent the failure or destroying some mechanical parts it is necessary to have the information not only about actual state of specific S&C parts but support effectivity of the preventive maintenance by regular long-term monitoring/measurement of S&C.

Very useful measuring instrument to get the data for following diagnostic evaluation is usage of instrumented rail vehicle.

Measuring technics is normally installed on special measuring cars (DB, OEBB) or whole units (ADIF, SNCF, DB, JAPAN, Network Rail) today, because special measuring technics needs the special handling, professional staff and it is very expensive. The advantage of special vehicle from the point of view of the long term measurement is that the special measuring cars/units have relative same behaviour in time (comparable results for all S&C, negligible influence of vehicle parameter changes) and any deviations in vehicle parameters as well as in measuring technics could be checked and removed (technics recalibration) before each measuring run.

Anyway, there are some tests with monitoring of S&C through common trains equipped with basic measuring technics too. This approach could enable to monitor of chosen track section in relatively short time intervals (in some cases more time a day), but presumes low price, low power consumption, compact autonomous measuring technics (best as wireless) and cooperation with operators/owner of the vehicles. The possibility of wide spreading of such instrumented vehicles on common trains with sending the processed and evaluated qualitative information of S&C state to the vehicle operator (vehicle diagnostics through the vehicle response measured by same sensors as the track and S&C) as well as to the track operator (S&C diagnostics) could be a close future.

Suitable sensor technics for on train monitoring of S&C:

- Optical sensors for measurement of the track geometry in S&C (lateral and vertical rail and track alignment, track gauge, cant), measured and processed according existing standards. Sensor technology as well as data processing is in common use today. Measurement is necessary for knowledge about the deviations of the track geometry (significant influence in dynamic interaction vehicle-S&C) under some load and other conditions like rest of measured quantities.
- Mechanical sensors:
  - Acceleration on axle boxes (lateral for monitoring of the contact geometry wheelset/track – signal filtering till app. 50 Hz, vertical for diagnostics of wing rail and crossing nose wear and ballast and substructure characteristics – signal filtering till app. 1000 Hz). Frequency range depends on track construction and dynamic behaviour of S&C with ballast and subsoil. Sensor technology is in common use today. Future development is in the special software for data evaluation, which will be able to describe separately state of substructure, ballast and rails in S&C through some qualitative markers from measured signal (decomposition of influences of specific construction parts on wheel/rail dynamics). Different methods (statistical, non-statistical) and approaches (analysis in time as well as frequency domain, neural networks) should be used. Precise positioning of signals to S&C parts has to be solved too.
  - Acceleration on bogie frames and carbody (lateral and vertical) describing running safety, running comfort and track loading according common used standards like EN14363 (normalized methodology of the measurement and standard evaluation during vehicle running tests, signal filtering till 20 Hz). Sensor technology is in common use today. Future development is in the special software for data evaluation, which will able to describe separately state of substructure, ballast and rails in S&C through some qualitative markers from measured signal (decomposition of influences of specific construction parts on vehicle/track dynamics). Different normalized and non-normalized methods (statistical, non-statistical) and approaches (analysis in time as well as frequency domain, neural networks) should be used. Precise positioning of signals to S&C parts has to be solved too.

- Optical scanners for rail wear. Technology used for track diagnostics today. In S&C higher sampling frequency to get information about shape of toe/stock rail and wing rail/crossing nose and precise positioning of signals to S&C parts is required.
- Microphones on vehicles. Additional information to previous measurement. Correlation has to be checked.

Sensor technologies (piezo, MEMS, laser and profile scanners) for S&C diagnostics measurement are known and commonly used today. The future development is in low price (but still precise enough), low power consumption, compact sensors (best as wireless) and autonomous DAQ modules with online processing.

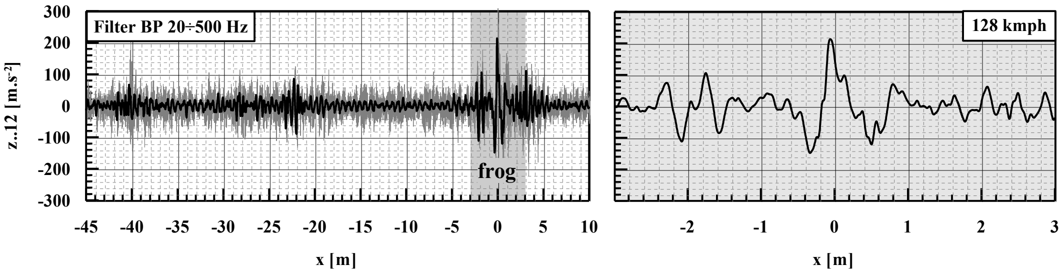

Fig. 6 Typical acceleration course measured on the axle box in the course of passing over a whole turnout (left); filtered acceleration signal corresponding to passing over the frog area (right) (experimental measurement) [2]

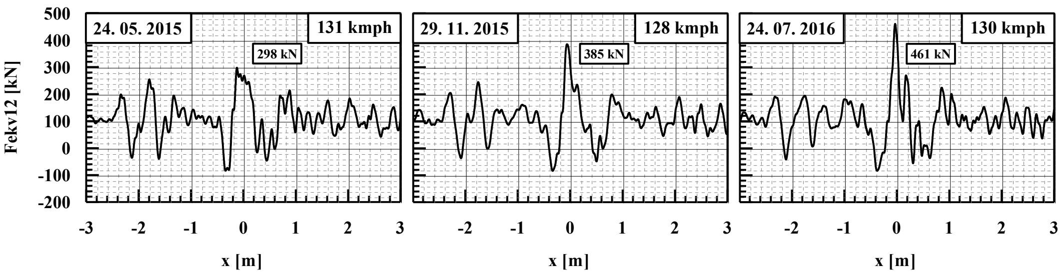

Fig. 7 Courses of the equivalent loading of the same turnout during its one year operation (experimental measurement) [2]

Software tools are still in development. Methods enabling quality description of the state of specific parts of S&C is the future. Correlation as well as validation of developed software needs to realize a lot of measurement, information about the intervention in S&C during measuring time period (tamping, welding,…) and information about vehicle state. Computational simulations could help with sensitivity analysis between vehicle parameters, S&C state and measured signals. Neural networks as well as controlled preventive maintenance need the information about limit state of each S&C part during the operation or failure behaviour for debugging and "learning" of algorithms.

S&C self-diagnostic system based on dynamic effects measurement consists of

- automatic measuring of vibrations using accelerometers,
- meassured data preproccessing and collecting,
- online evaluation.

All evaluated parameters inputs into the neural network and then faults/degradation at an early staged captured. Identification of the type of fault and fault locations for repairs, trigger autonomous maintenance is necessary.

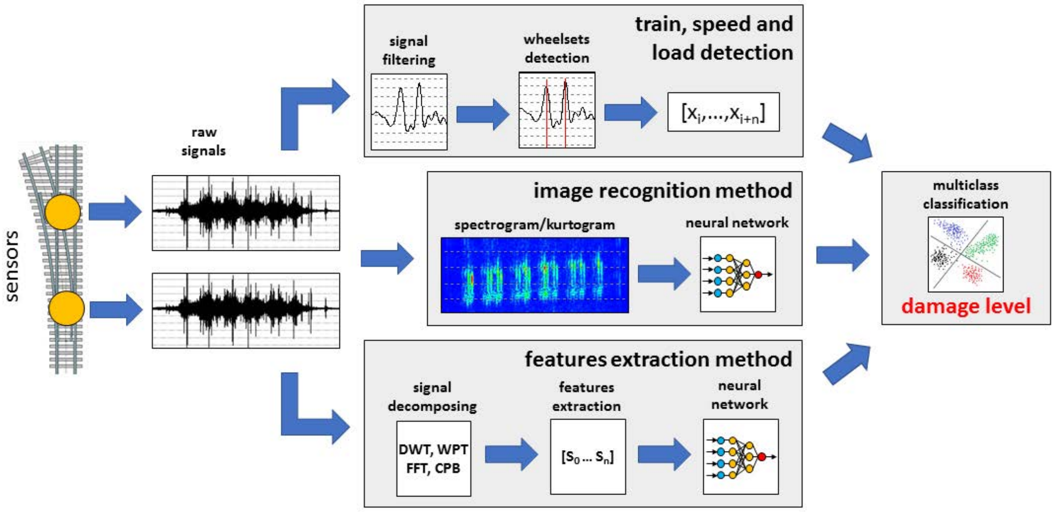

Fig. 8 Example of S&C self-diagnostic system evaluation [2]

6.2 Using novel material and additive manufacturing solutions for reduced complexity and fewer components in the switching mechanism

It is one task of WP4 in order to investigate the technologies for reducing complexity, resulting in fewer components, while also reducing or retaining the same level of carbon emission, noise radiation and cost. Designs are established that make use of novel components to safely enable radically new mechanisms for switching a wheelset from one track to another. The task considers the innovative and constitutive properties of novel materials such as self-healing composites, low-wear low-friction surfaces, durable spring steels, impact- and wear- resistant nose design, geo-polymer and other synthetic materials for the development of new switch and crossing components. The output of this task will be a new design for the switching function that reduces complexity while improving performance. Based on the new design, consideration will also be given to the need for new or improved design guidelines for switch and crossing components, subsystems and systems in terms of safety compliance and reliable implementation across Europe [1].

Within this task of WP4, one part of research team of University of Pardubice, Faculty of Transport Engineering deals with development of contact layer using highly resistible steel. The current research reveals the distinctive restriction of standard pearlitic steels in sense of limited toughness and high temper sensitivity. Also commonly used high alloyed austenitic steel, with superior strength / plasticity ratio, has substantial disadvantages. Despite the intensive twining hardening capacity, this steel requires dynamic pre-hardening in advance the operational loading to suppress intensive wearing in these applications. Hence the multi-phase surface layer, created by diffusion-less phases combined with carbon enriched residual austenite, presents the prospective way to fulfil contradicting requirements for mechanical behaviour of materials in rail-wheel contact, especially for highly dynamic loaded parts of S&C.

The suggested concept is based on usage of the novel steel; diffusionless transformation have been applied to develop steel with microstructure consisting of a mixture of bainitic ferrite, retained austenite, and some martensite. This steel with improved rolling contact resistance and increased wear resistance compared to standard pearlitic steel is considered for the contact layer of the high loaded parts of S&C.

The chemical composition of the steel, mainly the limited carbon content guarantees the enhanced thermal stability. Good weldability is based on the same principle. It means mainly the resistance to unacceptable phase transformation due to slip in rail-wheel contact, followed by intensive heating and fast cooling. The tendency to immediate brittle phase on contact surface, followed by spalling is suppressed as opposed to the standard pearlitic steels.

On the other hand, the surface microcracks creation, caused by depletion of plasticity, is natural response to contact fatigue loading. In this sense, to increase the operational safety in rolling contact means to modify the natural micro-cracks propagation. To avoid the cross-sectional damage, the driving of the cracks propagation will be based on local deformation at a crack tip. Improvement of crack resistance can be achieved by the hardness scattering, i.e. by distribution of hard and soft phases in the microstructure. Thus, the concept is based on intentional structural heterogeneities creation (see fig. 9) creating the obstacles for critical crack propagation. The thinner residual layer and the more intense plane strain stage suppression results in the higher energy consumption during destruction.

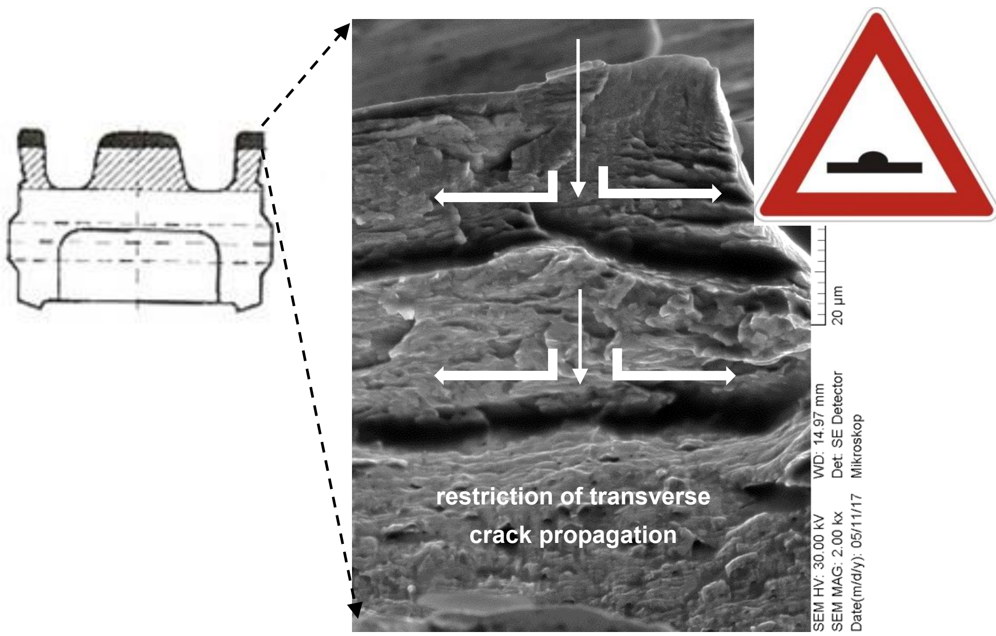

Fig. 9 Crack propagation obstacles in surface layer [3]

Besides the advantages of primary created microstructure, two subsequent structural transformation of steel is estimated:

- processes due to additional heat and pressure while connecting the surface layer to the rest of crossing profiles,
- diffusionless transformation in surface layer during dynamic loading.

Consequently, the final wear is decreased while fatigue resistance will be substantially enhanced against operational loading.

Contrary to some additive technology, the primary deformation state of cladded surface can be preserved. Required ratio of the hardness and the other mechanical parameters between S&C and wheels should be controlled.

To find out the sensitivity to mentioned processes, the material for surface layer needs to be prepared in different stages of primary deformation state. Based on this concept the comprehensive analyses of novel steel will enable to find the prospective technology solution. To evaluate the response to different heat/pressure ratio, the adjusted flash butt welding technique will be employed to prepare experimental heterogeneous joints.

The experimental testing of rolling-contact response will enable to evaluate the improvement of the operational lifetime and safety. Special test rig (see fig. 10) will be used for simulation of operational loading at defined loading parameters (contact pressure, longitudinal slip, etc.). Precise history of material response, mainly degradation processes need to be recorded and compared to standard pearlitic steel.

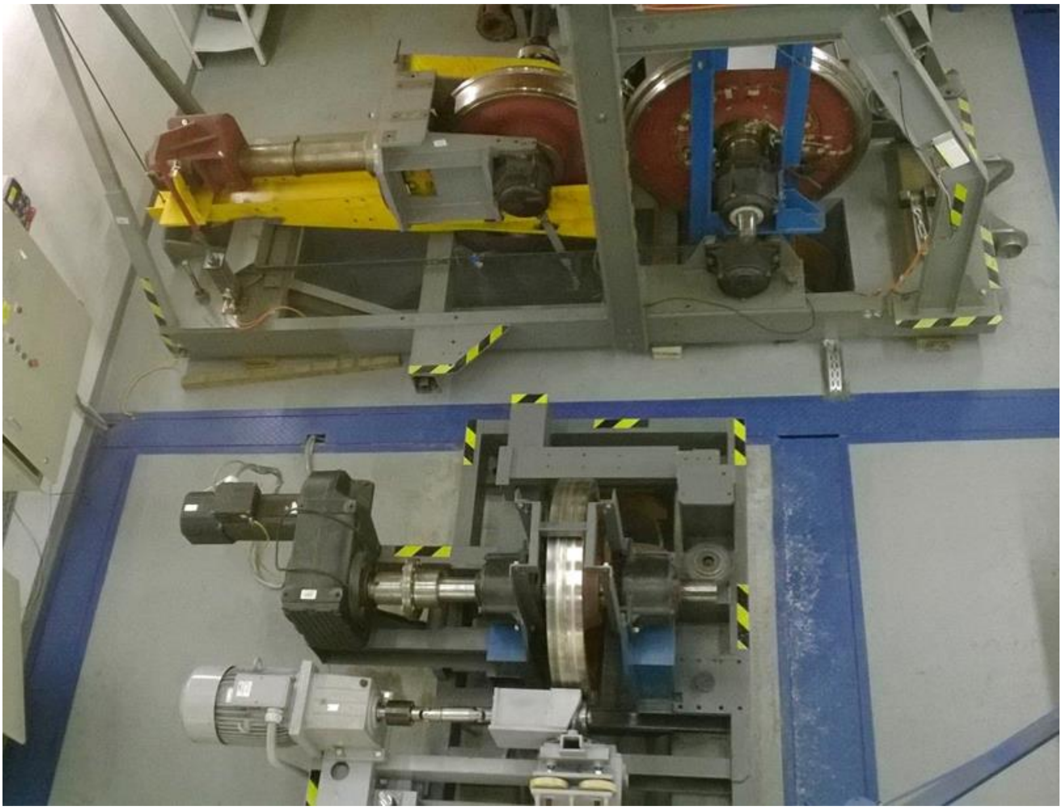

Fig. 10 Rolling – contact testing rig [3]

6.3 Wheel rail interface design and optimisation

It is one task of WP4, which makes use of standard wheel/rail interface models held by the industry partners, as the advanced switch and crossing interaction model that has been developed over a number of years, and used and verified for use on mainline (normal and tilting trains), metros and trams in a number of countries through Europe. This task utilizes previous data collected through measurement campaigns undertaken to assess the dynamic effects of vehicles passing through S&C, and the subsequent analysis of rail and wheel profile evolution, wear, contact geometry and the development of optimised wheel profiles. This task extends this work to simulate and assess rail and wheel profile wear and contact geometry for the new switch and crossing concepts, and then carry out optimisation of both wheel and rail profiles to allow trains to travel at higher speeds through switches and crossing [1]. All parts of this task are covered by research University of Pardubice, Faculty of Transport Engineering.

Actually, the new wheel-rail interface model is developing. The innovation of the current model is based on different rail profiles of one rail during passing of the vehicle over whole switch. The input data consists of 3D model of the turnout which can be obtained from the 3D modelling software (in case of new turnout) or from the 3D scanner (in case of turnout in operational state). In both cases, the 3D geometry of the turnout is obtained which presents the primary data of the turnout geometry. For the wheelset-track contact-geometry assessment, the rail cross sections are necessary to use. Input 3D geometry model can be in both mentioned cases used for creation of cross sections in appropriate longitudinal step (see fig. 11).

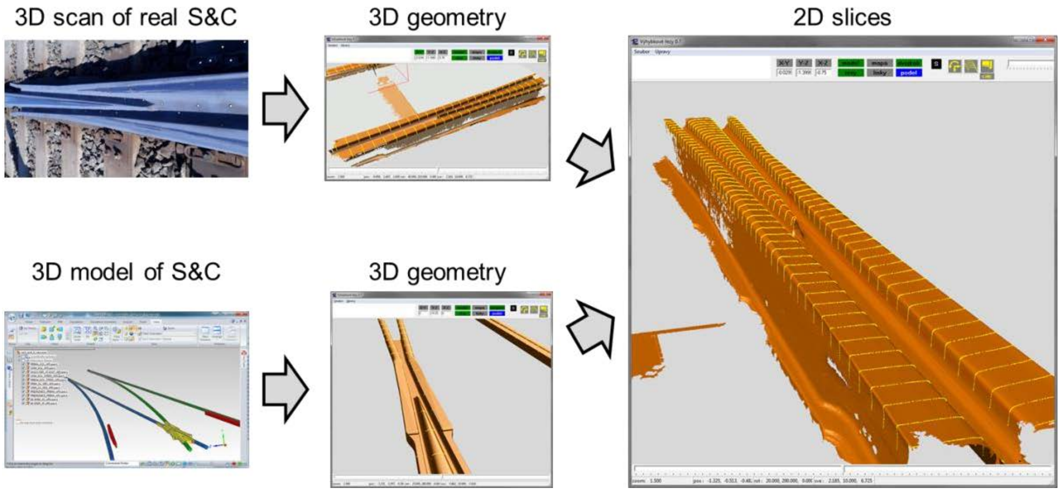

Fig. 11 Using of 3D geometry obtained from two different systems for rail cross section creation [4]

The new approach to wheelset-track contact geometry assessment is based on analysis of contact points in critical parts of the turnout where wheel changes its contact between two rails (stock rail – tongue in switch area and wing rail – frog nose in frog area). For this analysis, the range of rail cross sections in appropriate step is necessary to evaluate. Therefore, the new wheel-rail interface model includes cross section of both rails with possible contact together (see fig. 12).

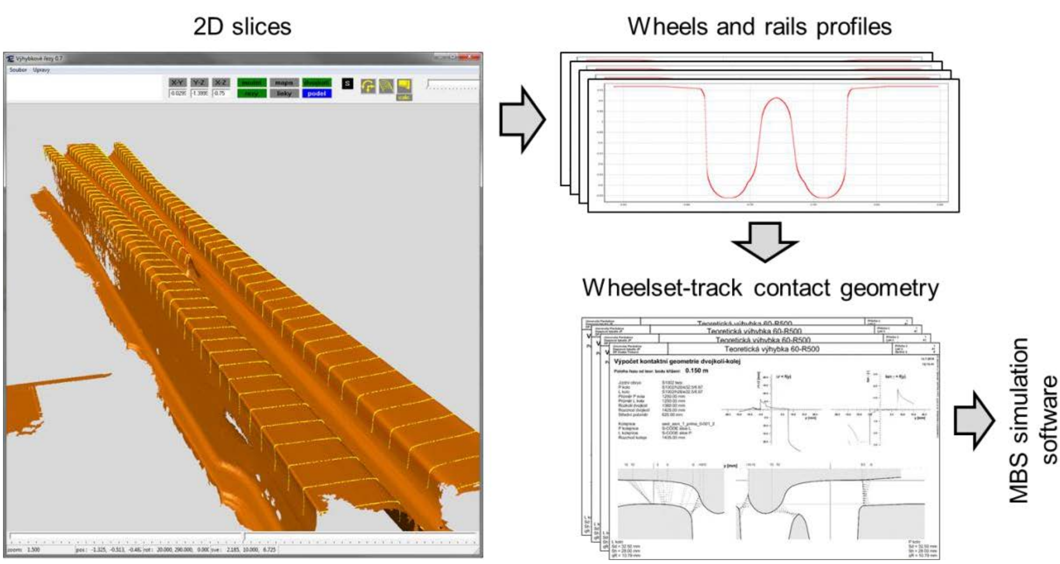

Fig. 12 Wheelset-track contact geometry assessment [4]

Parameters of wheelset-track contact geometry are one of the important input data to multibody simulation software SJKV (see fig. 13) of vehicle running behaviour evaluation, which presents the result effect of interaction between turnout and vehicle.

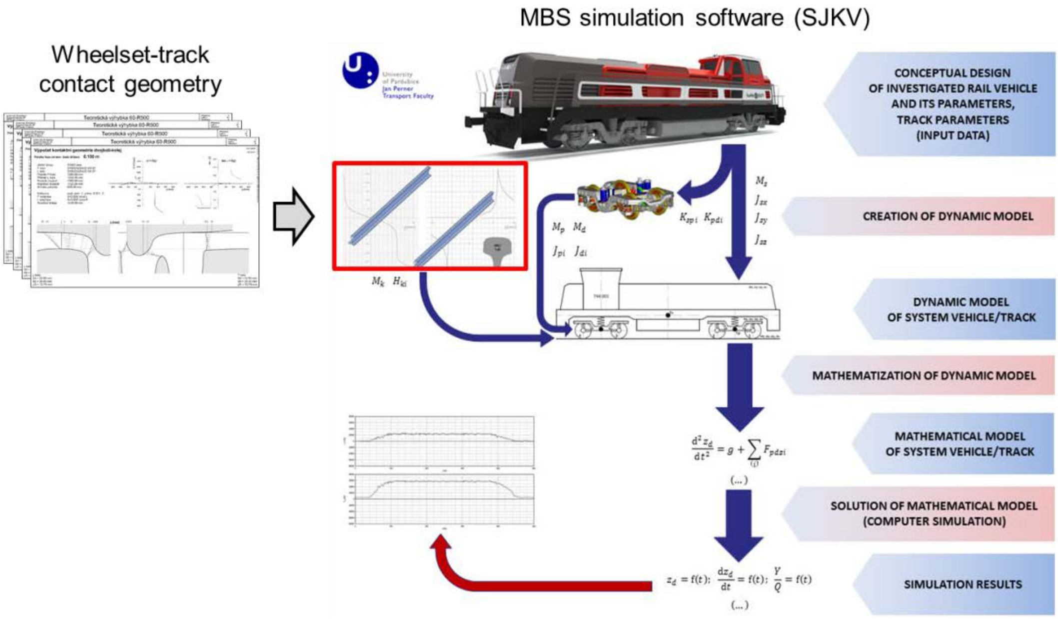

Fig. 13 System of vehicle running behaviour evaluation with help of multibody simulation [4]

7 CONCLUSION

The S-CODE project has determined many challenges in development of S&C design and other resulting consequences. Some ideas, which are developing within this project, have visionary form and it is obvious that they can be applied only for radically new railway system in future. But the project also provides possibilities for developing radical new technologies which can be tested actually only as a laboratory specimen, but these technologies have potential to real application at the current railway in near future. The heterogeneous contact layer described in chapter 6.2 can be included into the range of this type of typical technologies. Development of an intelligent self-diagnostic system is actually common part of important production lines maintenance. The present technical level enables to use these technologies also for S&C maintenance technology and application of these monitoring systems is also possible in near future. Finally, improvement of wheel-rail contact model presents also very important progression in development of S&C wheelset-track contact analysis. A track and a vehicle presents a connected system and we cannot regard their parameters separately. The improved wheel-rail contact model, which has been actually developing, will be able to apply to any radically new S&C structures developed by other partners of S-CODE project.

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NEW POSSIBILITIES FOR PROVIDING SERVICES BY POSTAL OPERATORS THROUGH INFORMATION-COMMUNICATION TECHNOLOGY

Iveta KREMENOVA[1], Juraj FABUS[2]

Abstract

In the article, we focused on the business of postal operators in our country and abroad. Based on the results of secondary research about service providing by national postal operators in our country and abroad, we can say that postal services are constantly evolving and modernizing. When comparing the services of the four national postal operators: Slovak Post a.s., Czech Post s.p., Deutsche Post AG and Swiss Post Ltd, we have found that competition in the field is high and therefore every one of them is trying to innovate its services. The Deutsche Post and Swiss Post are mainly focused on information-communication services. The Slovak Post and Czech Post do not use all the opportunities offered by ICT. The article deals not only with the analysis of the services provided by selected postal operators in the Czech Republic and abroad, but also, in particular, with drafts for new services using ICT. This article discusses the use of new ways of delivering shipments.

Keywords
Postal operators, technologies, drones, delivery, new services

1 INTRODUCTION

In the article, we focused on the business of postal operators in our country and abroad. We try to get closer to services provided through information and communication technologies, services of selected national postal operators, such as Slovak Post, and Czech Post, Deutsche Post and Swiss Post. The aim of the article is to bring our draft for a new business area for the postal operator Slovak Post Office.

The implementation of new electronic services in the portfolio of services is an opportunity for postal undertakings. According to UPU, electronic mail services can be divided into:

- ePost services,
- eFinance services,
- eCommerce services,
- eGovernment services.

ePost represents services that are subject to extensive development, especially in developed countries. Includes mailboxes, online direct mail and public internet at post offices, robotics, and more. ePost are postal services provided to customers using ICT.

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eFinance includes services such as online payment, e-invoicing, electronic transactions and more. With e-finance, you can manage your finances yourself anytime and anywhere. Whether you're using a computer, tablet or smartphone, a wide range of functions are available for online account management.

eCommerce is a service that sells philatelic or postal products, but includes on-line subscriptions to various magazines and e-shopping.

eGovernment is an electronic form of public administration through ICT. These include services that are strategically important. These include, for example, digital identity or electronic payments within the pension system. Is the use of electronic communications devices, computers and the Internet to provide public services to citizens and other persons in a country or region.

Given the growing needs of customers, postal businesses should provide new electronic services. At present, it is important for postal service providers to adapt to new trends, enabling them to move forward in the field. [4, 6, 7] We have selected ePost services through ICT for our draft.

2 RESULTS OF SECONDARY RESEARCH

The subject of our secondary research is the four national postal operators, namely Slovak Post a.s., Czech Post s.p., Swiss Post Ltd and Deutsche Post AG. [2, 3] The objects of the survey is the services and technologies of selected postal operators. Our research is focused on services provided through information and communication technologies. The results of our secondary research are shown in the following table 1. [5]

Tab. 1 Results of secondary research

Services and technology	National postal operators			
	Slovak Post	Czech Post	Deutsche Post	Swiss Post
Mobile app - postcard	✓	✓	✓	✓
eGovernment, state services	✓	✓	✓	✓
Mobile operator at the post office	✓	-	-	-
PostShop	✓	✓	✓	✓
Robot POSTBOT	-	-	✓	-
e-health	✓	-	-	✓
A small robot for delivery of packages	-	-	✓	✓
eSIPO	✓	✓	✓	✓
Drones	-	-	✓	✓

Source: [5]

Note on the e-Health service provided at Slovak Post - a healthcare professional can apply for the issue of an electronic card at the IOMO workplace. The completed application as well as the contract for issuing the electronic license will be sent by Slovak Post to the National Health

Information Centre. When processing a request, the health professional must be provided with a proof of identity and a registration number. [1]

2.1 Results of comparison of ways of delivering through ICT

The following table 2. shows the results of the secondary analysis for the area of technologies that support delivery through the use of ICT.

Tab. 2 Technologies of national postal operators

Technologies	National postal operators			
	Slovak Post	Czech Post	Deutsche Post	Swiss Post
Small robots for delivering packages	-	-	✓	✓
Robots POSTBOT	-	-	✓	-
Drones	-	-	✓	✓

Source: Authors

Based on a comparison of selected postal technology, we found that Deutsche Post AG offers the most service in the field of modern delivery of packages and packages. Another national postal operator that provides innovative delivery methods is Swiss Post Ltd.

Deutsche Post AG and Swiss Post Ltd are striving to continuously upgrade their services and are therefore delivering new technologies such as drone and small robots designed to deliver packages. Deutsche Post AG also offers a robot delivery service called POSTBOT [2, 3]. Slovak Post and Czech Post do not provide any of the above-mentioned modern technologies.

2.2 Results of the comparison of eGovernment - state services to the post office

The comparison of national postal operators that provide eGovernment service can be found in the following table 3.

Tab. 3 State services at the national post office

Services	National postal operators			
	Slovak Post	Czech Post	Deutsche Post	Swiss Post
State services	✓	✓	✓	✓

Source: Author

Based on results of the comparison we found that all of the selected national postal undertakings provide state services directly on post office.

3 DESIGN OF NEW BUSINESS AREAS FOR THE POSTER OPERATOR

Based on research results we also prepared the following drafts for Slovak Post:

- Drones delivery,

• Serving through small robots,
• posting using POSTBOT postage robots.

Establishment of new business areas for the national postal operator Slovak Post would extend the current delivery options in a conventional way. In the next part of the article we will approach the first draft.

3.1 Droning delivery

As part of the draft of the drones for Slovak Post is necessary to amend the legislation on the use of drone in Slovakia, as the use of drones for delivery of consignments is currently prohibited.

Slovak Post postman in Zilina 03 currently delivery parcels and parcels to three city districts, namely Budatin, Zadubnie and Zastranie. Delivery of drones directly to customers of Slovak Post would be realized in the city district of Zilina - Zastranie. Modern drone would deliver shipment from the Slovak Post Žilina - Budatin directly to the Zilina - Zastranie district, which would make it easier for the postal courier, as the city part is at higher altitudes and the bus service is not available at regular intervals. Drones would only deliver packages and lighter packages, up to a weight of 3 kilograms.

3.2 Route of delivery and design of a drone delivery solution

The route for delivering shipments and packages via the drone is displayed on the following figure 1.

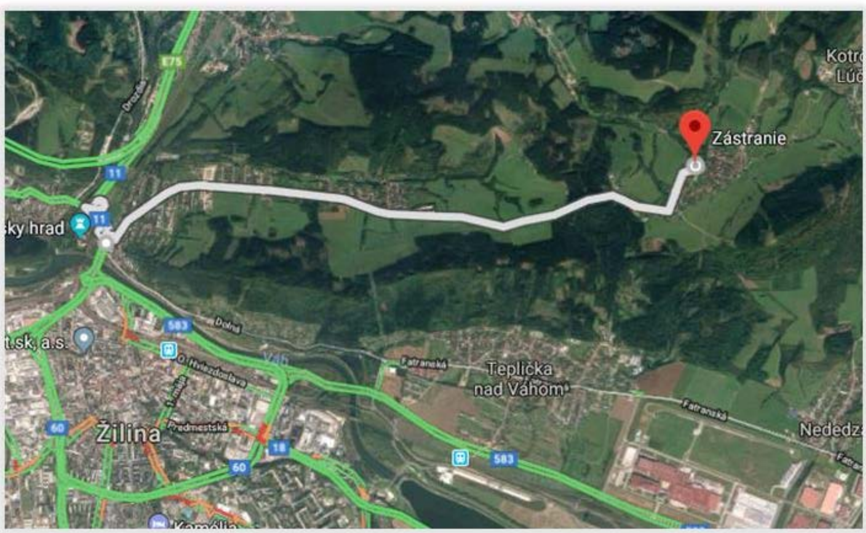

Fig. 1 Route delivery via drone. (Source: https://www.google.sk/maps/. [Online].)

The Budatin - Zastranie route is 7.8 km long, which is about 12 minutes by car and the walk takes approximately 2.5 hours. From a safety point of view, a modern drone would deliver non-residential consignments from a safety point of view through the mountain range. At both ends of the route would be drone ports - landing stations designed for receiving and dispatching parcels and parcels.

In the area of the Slovak Post 03 would be built by droneport, designed for take-off and landing of the drone. A specialist employee would inform the customer by telephone about the arrival of his mail, agreeing on the exact time of delivery by drone to the city of Zastranie. After placing the shipment on the drone, the customer will be informed of the departure from the mailing area, delivery will take approximately 3 minutes. The recipient would wait for a drone placed below the local hill Stranik to get the shipment and then confirm the delivery. After taking the shipment to the relevant customers, the drone would return to the landing area - a droneport located in the Slovak Post area 03 Zilina along the programmed route. The cost of delivery by unmanned aircraft would be 3 Euros.

Customers of Slovak Post 03 Žilina could also send shipments and lighter packages from the city district Zastranie via the drones. The customer would informed the Slovak Post by phone in the case they want to use the service. They would agree on the exact time of the shipment during the call. Drone would be sent by a specialized employee to the landing area - the droneport in Zastranie, where the sender of the consignment would be waiting. After insertion of the consignment into the storage space, drone would be directed to a landing surface - a droneport located in the premises of the Slovak Post. Post office employee would take over the consignment and then send it to the appropriate address.

The following figure 2. shows the draft of delivering shipments and packages via a drone.

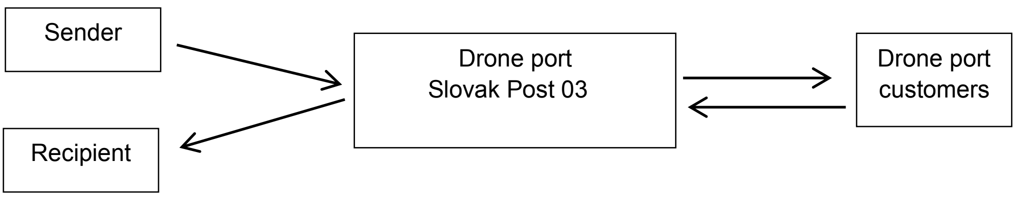

Fig. 2 Draft of drone delivery solution (Source: *Author*)

Deliveries would be delivered on a pre-programmed route via a four-propeller Quadcopter droning, which would represent a delivery time of approximately 3 minutes.

The more the drones have propellers, the stability is the greater. The smaller the number of propellers, the easier and faster it is. For this very reason, we chose the pilotless four-prop aircraft. See Fig. 3.

Fig. 3 Drone for Slovak Post (Source: *http://www.hybrid.cz/oficialne-nemecka-posta-zacala-pouzivat-drony)*

The pilotless airplane would include a camera, a GPS and an electronically installed parachute that would be triggered in the event of a breakdown during a flight. In case of a possible fall, insurance would also be appropriate. With respect to population size of Zastranie, we propose to purchase one drones for delivering. Slovak Post would be able to cooperate with Micronrones. [2]

A very important part of the draft is a recommendation to modify the legislation because the delivering by drones in Slovakia is not allowed. By decree 1/2015 issued August 19, the Traffic Administration determined the conditions under which we can use the drones.

4 CONCLUSION

Based on the results of our comparison, three drafts were made; delivering by drones, small robot delivery and POSTBOT delivery. In the article, we focused only on first draft because of scope of the article. By introducing new delivery technologies, the postal operator will improve its market position and streamline current delivery methods. A new way of delivering via a drones would not replace regular delivery, but would modernize it, making it easier for postal service providers. Once the legislation has been amended, this mode of delivery would have been a major advancement and modernization. Amazon's secret R&D project aimed at delivering packages to your doorstep by "octocopter" mini-drones with a mere 30-minute delivery time. [8, 9]

This research has been supported by the University of Zilina in the scope of VEGA project, 1/0725/17 | 13 | Research on the life cycle of a startup company as a basis for the business model of network start-up company and Project CIS by Ministry of Educations SR.

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EVALUATION OF TRAVEL COMFORT OF PASSENGERS – RELATIONSHIP BETWEEN VEHICLE AND ENVIRONMENT

Lukáš MÁLEK[1]

Abstract

The aim of this paper is to present in more detail a part of the passengers' travel comfort evaluation method in a rolling stocks design. This paper deals only with an interaction between a VEHICLE and an ENVIRONMENT. Introduced part of the method is focused on a mathematical model design of acting environmental factors on the vehicle and their random behaviour. The selected environmental factors are noise, vibrations, light and heat. Definition of sources of the selected factors are designed, their manners of a propagation in a surrounding (energetic path tracing) and statistical complex evaluation of final intensity of the selected factors in a random critical point of the vehicle interior as well. The mathematical model design is a simulation of the vehicles interior, which is possible to parametrically impact by geometrical and material indexes of the vehicle design.

Keywords

passengers, travel comfort, design, interaction, mathematical model, noise, vibrations, light, heat, random behaviour, complex evaluation, intensity, vehicles interior, simulation, geometrical and material indexes

1 INTRODUCTION

The introduction of this paper is a reaction on the sustainable mobility topic in railway transportation. A service life of a rolling stock is designed on a base of a definition its service, usually it is cca from 30 till 40 years. During this time, a vehicle has to be sustainable and reliable and has to meet the needs of an operator and an end customer, alias passenger. By renovation and reconstruction, use of the old vehicle is possible to prolong its service life according to constructions´ options of the vehicle, valid regulations and needs of an operator.

Sustainable mobility is settled not only from an economic-political aspects and charges of traction energy. A huge part also is an attractive and effective mobility. On the one side a development of the vehicle is bound up with the specification of technical interoperability (TSI), whose aims are:

- safety,
- reliability,
- health protection,
- protection of mother nature and
- technical compability.

On the second side is required to regard with the sustainable mobility also from travel comfort point of view, because it is not defined in TSI. Is important to motivation of the end customers, passengers, to the utilization of public transport and by this fulfill the sense of the sustainable

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mobility. This is the possible way how to achieve energy savings and to reduce global and local exhalations in our surrounding as well.

The vehicle, which fulfills TSI, doesn´t need to be explicitly comfortable and a travel culture doesn´t need to be attractive. In order to be the vehicle correctly and appropriately designed is required to have a strategy in a system integration of components and to think of needs of a future transport, because this is socially necessary and useful.

From the end customer point of view are engended different groups of passengers by owing to offers of hi-speed, commuter, light and urban transport. These target audiences are variously exposed to travel process with culturally-traditional subtext[2].

From the vehicle design point of view there is a portfolio of offered products - rolling stocks. These products are mostly developed on a basis of platforms that are adapted according to individual needs of operators. Methods used for the vehicle development are grounded on available standards, TSI and UIC, legislations and customer requirements.

This study frame takes in a tracing of the base four factors that define a travel comfort quality and methods used for comfort evaluation of passengers in order to the vehicle design. The factors:

- noise,
- vibrations and accelerations,
- illumination and
- heat

are evaluated by specific methods from point of view of:

- audiometry,
- accelerometry,
- photometry and
- thermometry.

General design of mathematical model is constructed of four base parts:

- collectivization of information and integration of input parameters [5],
- simulation of the vehicle interior,
- comfort evaluation of the vehicle interior and
- setting of system reliability.

Completely the model is calculated by input parameters:

- the vehicle design parameters (material indexes, geometric indexes),
- the environment paramters (climatic indexes, ride indexes, information indexes) and
- the human parameters (ergonomic indexes, hygienic indexes).

The aim of this paper is a design of a principal of the part of mathematical model - simulation of the vehicle interior.

Behaviour of the traced factors in critical point is evaluated on energetic level, because the energy is their common denominator. Intensity and form of the energy are evaluated between their sources and critical point -> observer. Necessary element is an exposition of the energy. A time variable is a dimension of continuum and is required for dynamic analyses.

2 PHILOSOPHICAL DESCRIPTION OF PROBLEM

From the macroscopic point of view is a main idea based on a system balance between a human, a vehicle and an environment [1]. Geometrically is possible to present the system balance on the figure below. Well known variables are the subsystems itself:

- the environment ***E***,
- the vehicle ***V*** and

[2] Culturally-traditional subtext means national diversity of population, urbanism, folclor, ecology, hygiene etc.

- the human ***H***.

Unknown variables of the system balance are penetrations between the subsystems:

- between the environment and the vehicle ***E-V***,
- between the vehicle and the human ***V-H***,
- between the human and the environment ***H-E*** and
- between the environment, the vehicle and the human ***P = E-V-H***.

Relationships of the penetrations of two adjacent subsystems are independent variables; the penetration of all three subsystems is dependent variable.

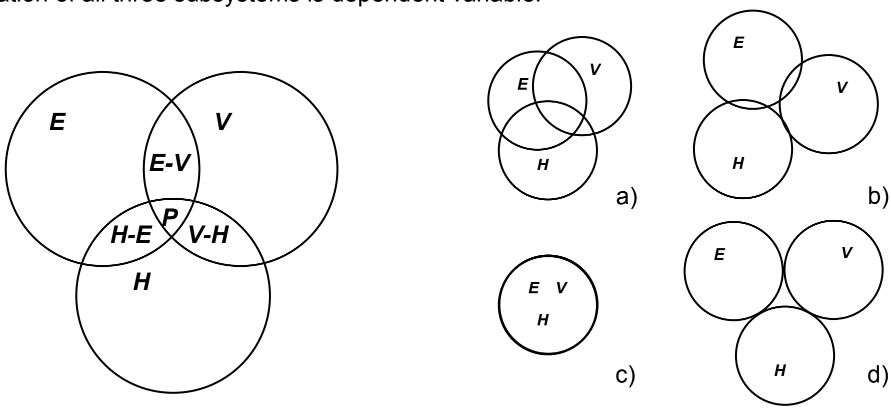

Fig. 2 System balance

E....................... Environment subsystem
V....................... Vehicle subsystem
H....................... Human subsystem
E-V, V-H, H-E.... Subsystem penetration
P = E-V-H.......... System penetration

As is shown on the figure above, is possible to predict examples of typical configurations of the system balance:

a) system compatibility is dominant from the environment point of view,
b) system compatibility is dominant from the environment point of view and the compatibility between the human and the vehicle is zero,
c) system stability and
d) system instability.

Relationship ***E-V*** expresses an interaction between the vehicle and the environment, where is the train operated. The interior environment is affected by the vehicle design itself.

The vehicle design is in the mathematical model presented like a boundary area between exterior and interior environment and is paramterized by own material and geometric indexes.

The reliability of the vehicle subsystem is given by relationship between the suitable critical components and the all layout components. That means the relationship between the suitable geometric/material paramaters of the vehicle and complete vehicle parameters package.

$$R_V = \frac{suitable\ critical\ components}{all\ layout\ critical\ components} \leq 1 \tag{1}$$

Similar situation is for reliability of the environment subsystem. The relationship between suitable parameters and all layout environmental parameters leads to percentage of success - reliability of the environment.

$$R_E = \frac{suitable\ environmental\ parameters}{all\ layout\ environmental\ parameters} \leq 1 \tag{2}$$

Known reliability of the vehicle and the environment is a good step to calculate the reliability of interaction of both subsystems, as is shown on the figure below and formula (3).

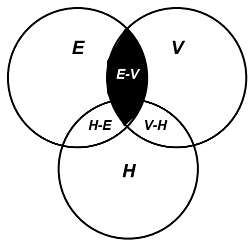

Fig. 3 Interaction between environment subsystem and vehicle subsystem

$$R_{E-V} = R_E \cdot R_V \leq 1 \tag{3}$$

How is possible to identify suitable parameters? For that is required to create a mathematical model of continuum, what describes the energy behaviour of traced factors. The behaviour of these factors is controled by the environmental and the vehicle parameters and affects the energy intensity and form from its source to the end point – observer.

3 DESIGN OF SYSTEM SIMULATION

By simulation of the interior vehicle environment is possible to achieve the relationship ***E-V*** according to relevant traced factors. Because the simulation is based on energetic description of these factors and approximates to their real behaviours is required to define:

- necessary conditions (energy conservation law),
- initial conditions (sources and environment) and
- boundary conditions (vehicle design).

3.1 Energy conservation law condition

By usage of 3D CAD systems is possible to simulate approximately the real 3D space. This space is defined by formula (4).

$$\Omega \subset \mathbb{R}^3 \tag{4}$$

By this way is possible to percept the vehicle subsystem ***V*** like geometry of boundary area ***dΩ*** of two different enviroments ($\boldsymbol{\Omega} = \boldsymbol{\Omega_e} + \boldsymbol{\Omega_i}$). The design of mathematical model of the interior vehicle description is based on the energy balance and complies with energy conservation law [2].

Stationary description of both environments in random place of the vehicle $\boldsymbol{X_e}$ and $\boldsymbol{X_i}$ and in time $\boldsymbol{t}$ is defined

$$u_e = u(\boldsymbol{X_e}, t),\ \ \boldsymbol{X_e} \in \Omega_\mathrm{e}, t \in \langle 0, T) \subset \langle 0, +\infty), \tag{5}$$

$$u_i = u(\boldsymbol{X_i}, t),\ \ \boldsymbol{X_i} \in \Omega_\mathrm{i}, t \in \langle 0, T) \subset \langle 0, +\infty). \tag{6}$$

Transfer of mechanical energy and radiation energy in the macroscopic scale is evaluated like a waving and is possible to consider in both cases general vector functions of the energy flow

$$\phi_{energy} = \phi(\boldsymbol{X}, t), \quad \boldsymbol{X} \in \Omega, t \in \langle 0, T) \subset \langle 0, +\infty). \tag{7}$$

Distribution density of sources in random place of vehicle ***X*** and time ***t*** is expressed

$$f_{sources} = f(\boldsymbol{X}, t), \quad \boldsymbol{X} \in \Omega, t \in \langle 0, T) \subset \langle 0, +\infty). \tag{8}$$

Construction of vehicle inclose the interior balance subarea

$$U(\Omega_i, t) = \int_{\Omega_{vehicle}} u_i(\boldsymbol{X_i}, t) d\boldsymbol{X_i}. \tag{9}$$

Energy flow transmitted in normal vector direction of vehicle boundary area is represented like surface integral of flow function

$$\phi_{energy}(\partial\Omega_i, t) = \int_{\partial\Omega_i} \phi(\boldsymbol{X}, t) \cdot \boldsymbol{n}(\boldsymbol{X}) dS. \tag{10}$$

For dynamic description is possible to express the evolution conservation law by step by step formatting in local differential form

$$\frac{\partial}{\partial t} u_i(\boldsymbol{X_i}, t) + \mathrm{div}\phi_{energy}(\boldsymbol{X_i}, t) = f_{sources}(\boldsymbol{X_i}, t). \tag{11}$$

Important is, that sources distribution function can be affected by interior and exterior stat of the vehicle

$$f_{sources} = f\big(\boldsymbol{X}, t, u_i(\boldsymbol{X_i}, t), u_e(\boldsymbol{X_e}, t)\big), \quad \boldsymbol{X}, \boldsymbol{X_i}, \boldsymbol{X_e} \in \Omega, \qquad t \in \langle 0, T) \subset \langle 0, +\infty). \tag{12}$$

3.2 Description of traced factors sources

Sources of energetic traced factors are defined into three groups:

- ambient sources,
- diffused sources and
- sharp sources.

Ambient sources are flat character, where a direction of emitted intensity is sagittal to plane element, for example: heat sources.

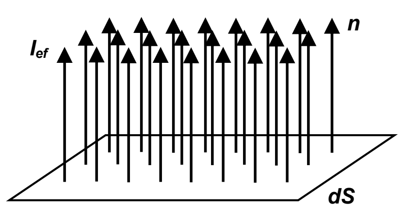

Fig. 3 Ambient source

Diffuse sources are point character, where a direction of emitted intensity is given by vector of emission and its space angle, for example: sound sources.

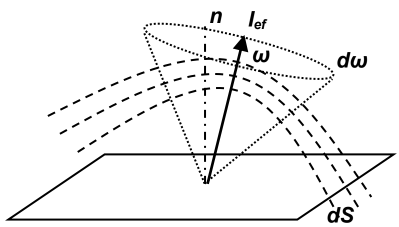

Fig. 4 Difuse source

Sharp sources are point character, where a direction of emitted intensity is given only by vector of emission, for example: light spot sources.

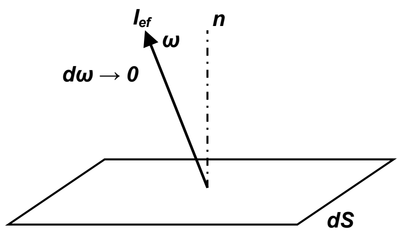

Fig. 5 Sharp source

The source description is one of the ***E*** and ***V*** subsystem parameter, because it has an influence on the energy propagation.

3.3 Description of energy behaviour in space

Energy powers related to the plane element are traced intensities on the boundary area of different environment. The energy expanding in the space has never expire, only can be reflected, absorbed, transformed or transmitted (emitted). These processes are called energy losses or gains.

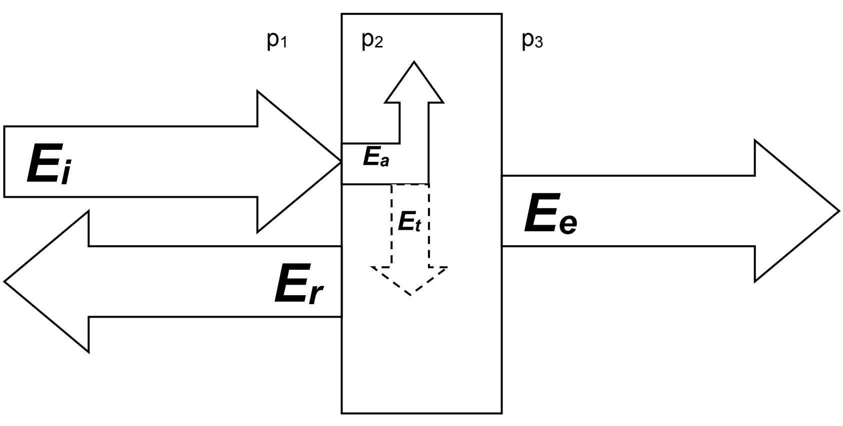

Fig. 6 Energy behaviour in space (schema)

E_i – Energy impacted
E_r – Energy reflected
E_a – Energy absorbed
E_t – Energy trasformed
E_e – Energy emmited
p_i – *where i=1,2 and 3 are different stationary environment*

Complete energy balance on an interaction interface is

$$\mathrm{E_i = E_r + E_e + E_a + E_t}. \quad (13)$$

Energy power is defined like an amount of work performed per time unit

$$P_{ef} = \frac{\partial A_{ef}}{\partial t}\ [W]. \quad (14)$$

For energetic description is better to use an intensity of traced factors. The intensity is the energy power related to the plane element ***dS***. Than is possible to express the intensity

$$\mathrm{I_{ef}} = \frac{\partial P_{ef}}{\partial S}\left[{}^{W}/_{m^2}\right]. \quad (15)$$

Following formulas express the effective intensities by specific effective variables for traced factors (sound, vibration and acceleration, illumination and heat)

$$I_{1/ef} = p_{ef} \cdot v_{ef} \cdot \cos(\varphi) \cdot \cos(\theta)\ \left[{}^{W}/_{m^2}\right], \quad (16)$$

$$I_{2/ef} = \frac{m \cdot a_{ef} \cdot v_{ef}}{S} \cdot \cos(\gamma)\ \left[{}^{W}/_{m^2}\right], \quad (17)$$

$$I_{3/ef} = \frac{\eta \cdot \phi_{ef}}{S}\ [lx], \quad (18)$$

$$I_{4a/ef} = \frac{\lambda \cdot T_{ef}}{d}\ \left[{}^{W}/_{m^2}\right], \quad (19)$$

$$I_{4b/ef} = \alpha \cdot T_{ef}\ \left[{}^{W}/_{m^2}\right], \quad (20)$$

$$I_{4c/ef} = \varepsilon \cdot \sigma \cdot {T_{ef}}^4\ \left[{}^{W}/_{m^2}\right]. \quad (21)$$

Now it is known how the factors expanding through the environment. The effective variables depend on the parameters of the environment. That means, that the ***E*** subsystem parameters like a humidity, an air speed, a day/night mode, a concentration of particles etc., can affect these effective variables.

How does it work on the boundary area of the vehicle ***δΩ***? In elementary scope is the energy transmission in the place ***X*** and direction ***ω*** from the normal vector ***n*** of the plane element ***dS*** shown in the figure below.

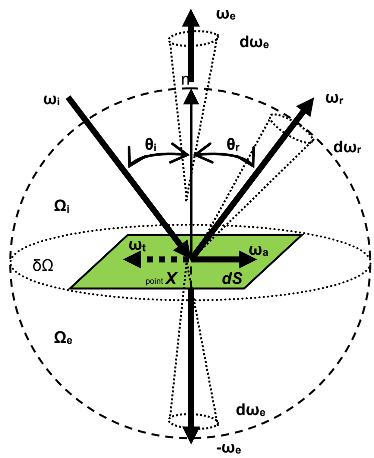

Fig. 7 Energy behaviour on boundary segment dS

Incoming intensity $\boldsymbol{\omega_i}$ impacts the plane element ***dS*** under the vector angle $\boldsymbol{\theta_i}$ and in ideal case the intensity $\boldsymbol{\omega_r}$ is reflected again under the same angle $\boldsymbol{\theta_r}$ into the surrounding. Outgoing intensity also depends on the space angle $\boldsymbol{d\omega_r}$, which is defined by ambient, diffuse or sharp character of the boundary area element.

These boundary area character is described by the vehicle ***V*** subsystem parameters like a material absorbtion, reflection, transformation and emission are. Also the energy behaviour on the boundary area depends on its position in 3D space and its global orientation of normal vector ***n***.

Intensity transmission related to the space angle is possible to express in following

$$I_i(X;\omega_i) = \frac{\partial^2 \mathrm{P}_i(X;\omega_i)}{\partial S \partial \omega_i cos\theta_i} = \frac{\partial I_i(X;\omega_i)}{\partial \omega_i cos\theta_\mathrm{i}} \left[{}^{W}\!/_{m^2 sr}\right], \tag{22}$$

$$I_r(X;\omega_r) = \frac{\partial^2 \mathrm{P}_r(X;\omega_r)}{\partial S \partial \omega_r cos\theta_r} = \frac{\partial I_r(X;\omega_r)}{\partial \omega_r cos\theta_\mathrm{r}} \left[{}^{W}\!/_{m^2 sr}\right], \tag{23}$$

$$I_e(X;\omega_e) = \frac{\partial^2 \mathrm{P}_e(X;\omega_e)}{\partial S \partial \omega_e cos\theta_e} = \frac{\partial I_e(X;\omega_e)}{\partial \omega_e cos\theta_\mathrm{e}} \left[{}^{W}\!/_{m^2 sr}\right], \tag{24}$$

$$I_a(X;\omega_a) = \frac{\partial^2 \mathrm{P}_a(X;\omega_a)}{\partial S \partial \omega_a cos\frac{\pi}{2}} = \frac{\partial I_a(X;\omega_a)}{\partial \omega_a cos\frac{\pi}{2}} \left[{}^{W}\!/_{m^2 sr}\right], \tag{25}$$

$$I_t(X;\omega_t) = \frac{\partial^2 \mathrm{P}_t(X;\omega_t)}{\partial S \partial \omega_t cos\frac{\pi}{2}} = \frac{\partial I_t(X;\omega_t)}{\partial \omega_t cos\frac{\pi}{2}} \left[{}^{W}\!/_{m^2 sr}\right]. \tag{26}$$

Power densities in investigated place ***X*** – integration:

$$I_i(X) = \int_{\Omega^+} I_i(X;\omega_i) cos\theta_\mathrm{i} d\omega_i. \tag{27}$$

$$I_r(X) = \int_{\Omega^+} I_r(X;\omega_r) cos\theta_\mathrm{r} d\omega_r. \tag{28}$$

$$I_{e+}(X) = \int_{\Omega^+} I_{e+}(X;\omega_{e+}) cos\theta_{e+} d\omega_{e+}. \tag{29}$$

$$I_{e-}(X) = -\int_{\Omega^-} I_{e-}(X;\omega_{e-}) cos\theta_{e-} d\omega_{e-}. \tag{30}$$

$$I_a(X) = \int_{\Omega} I_a(X;\omega_a) cos\frac{\pi}{2} d\omega_a. \tag{31}$$

$$I_t(X) = \int_{\Omega} I_t(X;\omega_t) cos\frac{\pi}{2} d\omega_t. \tag{32}$$

According to this is possible to define distribution functions:

$$\varrho_r(\omega_i \longrightarrow \omega_r) = \frac{I_r(\omega_r)}{I_i(\omega_i) \cdot \cos\theta_i \cdot d\omega_i} \leq 1\ [sr^{-1}], \tag{33}$$

$$\varrho_{e+}(\omega_i \longrightarrow \omega_{e+}) = \frac{I_{e+}(\omega_{e+})}{I_i(\omega_i) \cdot \cos\theta_i \cdot d\omega_i} \leq 1\ [sr^{-1}], \tag{34}$$

$$\varrho_{e-}(\omega_i \longrightarrow \omega_{e-}) = \frac{I_{e-}(\omega_{e-})}{I_i(\omega_i) \cdot \cos\theta_i \cdot d\omega_i} \leq 1\ [sr^{-1}], \tag{35}$$

$$\varrho_a(\omega_i \longrightarrow \omega_a) = \frac{I_a(\omega_a)}{I_i(\omega_i) \cdot \cos\theta_i \cdot d\omega_i} \leq 1\ [sr^{-1}], \tag{36}$$

$$\varrho_t(\omega_i \longrightarrow \omega_t) = \frac{I_t(\omega_t)}{I_i(\omega_i) \cdot \cos\theta_i \cdot d\omega_i} \leq 1\ [sr^{-1}]. \tag{37}$$

Completely is possible to describe the energy conservation law:

$$\varrho_r + \varrho_{e+} + \varrho_{e-} + \varrho_a + \varrho_t = 1. \tag{38}$$

Formulas above are the general expression of energy behaviour on the boundary area, equivalent of the vehicle design. For each traced factor is possible to define ***V*** subsystem parameters that are for each factors specific, but in the consequence they have same effect in energy behaviour.

For sound propagation, there are sound reduction indexes, sound absorbtion indexes, sound reflection indexes, densities of material, spectral filtering indexes etc.

For vibration, there are damping indexes, elasticity indexes, plasticity indexes etc.

For illumination, there are transparency indexes, reflextion indexes, color indexes etc.

For heat, there are conductivity indexes, emission indexes, tansfer indexes etc.

3.4 Energetic path tracing of factors

Main problem is that at this moment current methods used for passenger comfort evaluation are very different. These methods use different units; different evaluation and they are focused on mean value for the whole vehicle. This mean value is usually defined by standard or specification.

The design of the simulation model comes in with complex evaluation. It simulates the vehicle in environment conditions and calculates final intensity of each factor in critical point. The final intensity is not only the direct intensity from source to the critical point. The model also includes reflected, absorbed and transmissed energy of factors from in interaction with the vehicle.

In this case is selected a method of energy path tracing that is inspired by rendering equation used in rendering of 3D scenes [3]. Generally is possible to describe the sources, boundary areas and observeres at mathematical way

$$f_{sources} = f_f(\boldsymbol{X}, t),\ \ \boldsymbol{X} \in \Omega, \qquad t \in \langle 0, T) \subset \langle 0, +\infty), \qquad f \in \mathbb{N}, \tag{39}$$

$$u_e = u(\boldsymbol{X_e}, t),\ \ \boldsymbol{X_e} \in \Omega_\mathrm{e}, \qquad t \in \langle 0, T) \subset \langle 0, +\infty), \tag{40}$$

$$u_i = u(\boldsymbol{X_i}, t),\ \ \boldsymbol{X_i} \in \Omega_\mathrm{i},\ \ t \in \langle 0, T) \subset \langle 0, +\infty), \tag{41}$$

$$\partial\Omega_{vehicle} = \sum_{v=1}^{n} \partial\Omega_v\,, \qquad v \in \mathbb{N}, \tag{42}$$

$$\mathrm{O}_{passengers} = \sum_{p=1}^{n} \mathrm{O}_p\,, \qquad p \in \mathbb{N}. \tag{43}$$

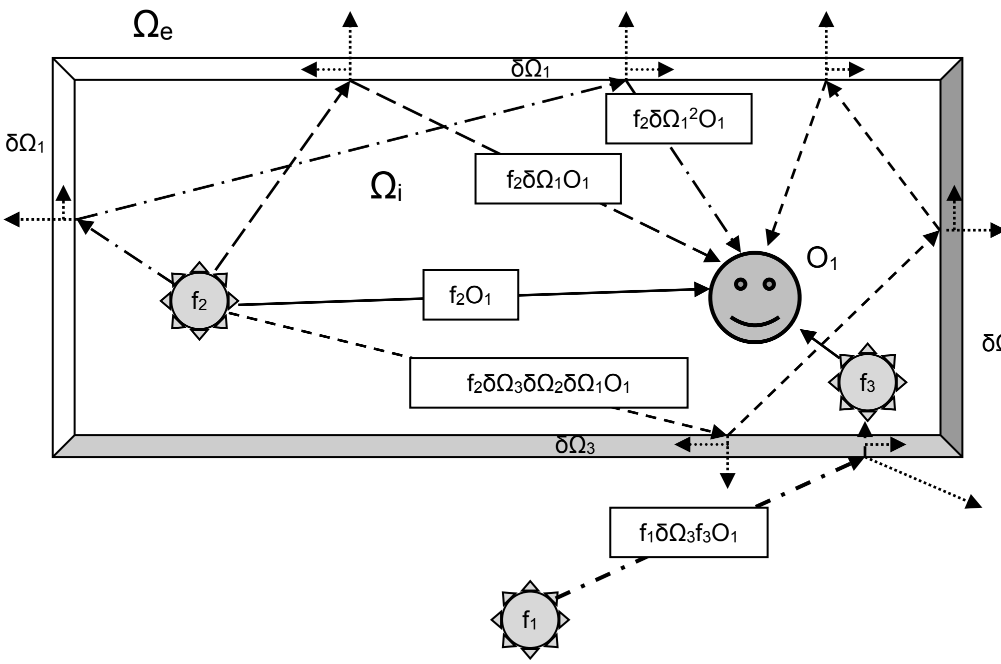

Fig. 8 Path tracing of energy from sources to observer

As is shown in the example in the figure above, there is the whole traced space $\boldsymbol{\Omega}$. By the boundary area $\boldsymbol{\delta\Omega_{vehicle}}$ is the space splitted into the exterior $\boldsymbol{\Omega_e}$ and interior $\boldsymbol{\Omega_i}$ space of the vehicle. In the space $\boldsymbol{\Omega_e}$ there is the source $\boldsymbol{f_1}$ and in the space $\boldsymbol{\Omega_i}$ there are sources $\boldsymbol{f_2}$ and $\boldsymbol{f_3}$ and the observer $\boldsymbol{O_1}$. The boundary area is possible to split into particular boundary areas with different parameter $\boldsymbol{\delta\Omega_1}$, $\boldsymbol{\delta\Omega_2}$ and $\boldsymbol{\delta\Omega_3}$.

The design of the mathematical model is calculating all possible ways of interactions between the sources and observer. That means that effective traced factor is interacting with all relevant

E subsystem parameters together with all relevant ***V*** subsystem parameters. This fact has an effect on the final energy that comes to the observer and describes the relationship ***E-V*** of subsystems.

3.5 Simplification of design of mathematical model

Because of huge count of possible paths is the design of the mathematical model very complex for analytic solution. In this case is necessary to consider some simplifications and select stochastic methods and approaches as followings:

- reverse path tracing from the observer in direction to defined source, as is shown in the figure below – it leads to a filtering of not required paths,

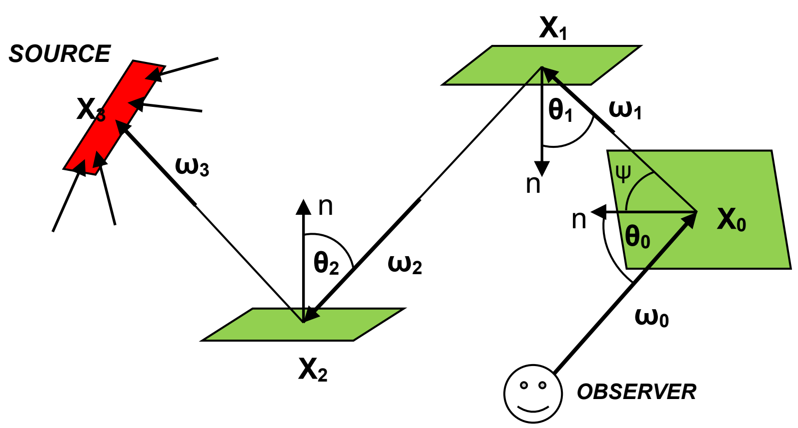

Fig. 9 Reverse path tracing

- simplification of vehicle body structure - setting of functional assemblies,
- selection of a calculation method - statistic evaluation of pseudo-random processes, as is ilustrated in the figure below.

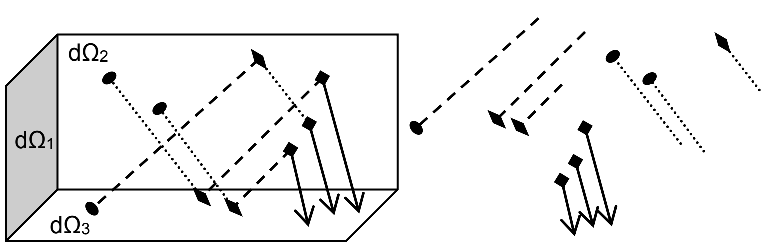

Fig. 4 Statistical evaluation of parallel energetic paths

Using by Monte Carlo method is possible to process in statistical way the intensity data of the parallel paths and their estimation is possible to describe in probability steps expressed by formula (X):

$$\langle I\rangle_{OBSERVER} = \frac{I_i(X_0,\omega_0)\cdot\cos\psi}{p_0(X_0,\omega_0)}\cdot\sum_{l=0}^{k}\left[\prod_{m=1}^{l}\frac{\varrho_r(X_{m-1},\omega_m\longrightarrow\omega_{m-1})\cdot\cos\theta_{m-1}}{P_m\cdot p_m(\omega_m)}\right]\cdot I_{e+}(X_l,\omega_l). \tag{44}$$

$\boldsymbol{P_m}$................. probability of next step $\boldsymbol{m}$

$\boldsymbol{p_m(\omega_m)}$.......... probability density for incoming direction $\boldsymbol{\omega_m}$

Mathematical description of the integral of the energetic path from the observer to the source is completed by geometric factor that is connected with the vehicle geometry and by visible factor that defines direct path between the observer and the source:

$$\begin{aligned} I(\boldsymbol{X_0},\boldsymbol{\omega_0}) = I_{e+}(\boldsymbol{X_0},\boldsymbol{\omega_0}) + \int_{\partial\Omega} & I_{e+}(\boldsymbol{X_1} \rightarrow \boldsymbol{X_0}) \cdot \varrho_r(\boldsymbol{X_1} \rightarrow \boldsymbol{X_0} \rightarrow \boldsymbol{\omega_0}) \\ & \cdot Gf(\boldsymbol{X_0} \rightarrow \boldsymbol{X_1}) \cdot Vf(\boldsymbol{X_0} \rightarrow \boldsymbol{X_1}) dS_{X_1} \\ & + \iint_{\partial\Omega} I_{e+}(\boldsymbol{X_2} \rightarrow \boldsymbol{X_1}) \\ & \cdot [\varrho_r(\boldsymbol{X_2} \rightarrow \boldsymbol{X_1} \rightarrow \boldsymbol{X_0}) \cdot Gf(\boldsymbol{X_1} \rightarrow \boldsymbol{X_2}) \\ & \cdot Vf(\boldsymbol{X_1} \rightarrow \boldsymbol{X_2})] \\ & \cdot [\varrho_r(\boldsymbol{X_1} \rightarrow \boldsymbol{X_0} \rightarrow \boldsymbol{\omega_0}) \cdot Gf(\boldsymbol{X_0} \rightarrow \boldsymbol{X_1}) \\ & \cdot Vf(\boldsymbol{X_0} \rightarrow \boldsymbol{X_1})] dS_{X_1}\, dS_{X_2} \\ & + \iiint_{\partial\Omega} I_{e+}(\boldsymbol{X_3} \rightarrow \boldsymbol{X_2}) \ldots dS_{X_1} dS_{X_2} dS_{X_3}\,. \end{aligned} \tag{45}$$

Gf.... geometric factor
Vf.... visible factor

3.6 Implementation of vehicle parameters to simulation

The formula (45) is a mathematical expression and is too complicated. The formula of the energetic path is possible to express in operators form as is shown in formula (46). Generally is possible to describe the energetic path as follows:

$$I = \sum_{s=0}^{n} T^s \cdot I_{e+} + T^{n+1} \cdot I. \tag{46}$$

I......final intensity of the traced factor in the critical point,
$\boldsymbol{I_{e+}}$...source behaviour,
T.... integral, alias transport, operator determines the direction and character of the propagated intensity.

The path is possible to express like a Neumann progression:

$$I = I_{e+} + T \cdot I_{e+} + T^2 \cdot I_{e+} + T^3 \cdot I_{e+} + \cdots, \tag{47}$$

By recursive application of the transport operators ***T*** is achieved the recursive energetic path tracing from the observer to the source:

$$I = I_{e+} + T(I_{e+} + T(I_{e+} + T(I_{e+} + \cdots. \tag{48}$$

Integral, alias transport, operator ***T*** is splitted into an ambient (***A***), diffuse (***D***) and sharp (***S***) component in the proportion to perform the realistic simulation in the best way.

$$T = (A) + (D) + (S) \tag{49}$$

The components is possible to write out according to Phong model [4] in following way:

$$(A) = I \cdot C_a, \qquad C_a \in (0,1), \tag{50}$$

where C_a is the material index, zero value of which means, that the ambient component is not valid.

$$(D) = I \cdot C_d, \qquad C_d \in (0,1), \tag{51}$$

where C_d is the material index, zero value of which means, that the diffuse component is not valid.

$$(S) = I \cdot C_s, \qquad C_s \in (0,1), \tag{52}$$

where C_s is the material index, zero value of which means, that the sharp component is not valid.

Graphically is possible to present each component in the plane element ***dS*** according to figure below.

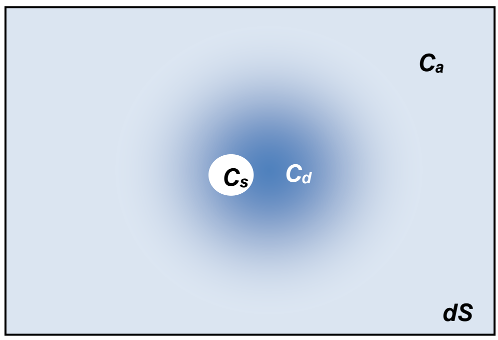

Fig. 5 Presentation of material components in plane element dS

3.7 Results of simulation of design of vehicle interior

The result of the simulation is the final intensity calculation in the critical point. The final intensity is created by direct paths from the source and by indirect paths.

The intensity propagation is affected by ***E*** subsystem parameters (space Ω) and ***V*** subsystem parameters (boundary area $\delta\Omega_{vehicle}$).

The final intensity is important input for human factors implementation (***H*** subsystem parameters) and for system validation, because by ***H*** subsystem parameters implementation there is a way to evaluate the comfort and get the appropriate feedback of the vehicle design and its environment.

4 CONCLUSION

In fine is required to remind, that the travel comfort is not included in TSI targets and is not controlled by governments, European Union. The travel comfort is a subject of competitive market behaviour and of relationship between a customer and seller.

Energetic and environmental profitability of a public transport, especially the rolling stocks, against the automotive industry is indisputable. But this is not sufficient to passenger conversion to the public transport. Is required to motive the passengers. Significant motivation factor of population orientation to the publich transport is the travel comfort. That is the reason to understand this topic, get the know-how to mathematically describe it, evaluate it and targeted solve it.

The design of the mathematical model is splitted into four base parts. The figure below illustrates geometrically current and future development phases:

a) **System creation** – 1st part of the model design: Information inputs and critical components and parameters definition, causes and consequences of travel comfort - publicated in [5]
b) **Simulation of interior vehicle design** – 2nd part of the model design: Mathematical description of relationship between the vehicle and the environment from the point of view of the propagation of traced factors in 3D - subject of this paper
c) **Comfort evaluation** – 3rd part of the model design: Implementation of ***H*** subsystem parameters (human factors) and comfort validation - not publicated yet
d) **Setting of system reliability and stability** – 4th part of the model design: Macroscopic system evaluation - not publicated yet

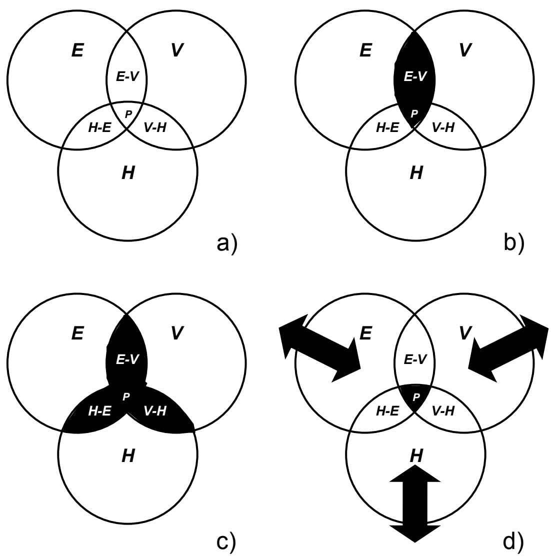

Fig. 6 Method progress and perspective

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LOSS OF STABILITY OF DYNAMICALLY LOADED IDEAL CYLINDRICAL SHELL WELDED TO SADDLE SUPPORT

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Abstract

The article deals with the loss of stability of a cylindrical shell at dynamic transverse load. A typical practical example of this kind of construction is a road tank welded to saddle supports. All known domestic or foreign standards or recommendations for thin-walled shell structures such as ČSN 690010 [1], EN 13445-3 [2], EN 1993-1-6 [3], AD-Merkblätt [4], DIN 18800 [5], ASMECode [6], European recommendation ECCS 2008 [7] etc., provide the solution of stability of thin-walled shell structures for static load only. However, the situation of the traffic vehicles like road tanks is more complex because, in the vast majority of cases, these are loaded dynamically. Within this article, computational FEM analysis of the dynamically loaded cylindrical shell has been applied on a geometrically reduced model, which will later be more suitable for experimental verification. The cylindrical shell is firmly attached to the single saddle support through which both static and dynamic reaction forces are transmitted. The saddle support embracing angle takes values 2φ = 60°/90°/120° in accord with the demand of the standards and recommendations mentioned above. At first, the loss of stability of the statically loaded cylindrical shell has been analysed. Both geometric and material nonlinearities have been taken into consideration. The geometric nonlinearity describes the loss of stability while material nonlinearity describes the limit state of elastic-plastic carrying capacity. The resulting phenomenon is a nonlinear stability snap-through of the saddle support into the cylindrical shell in the elastic-plastic field due to the static load. At second, the dynamic analysis of the same problem follows. The initial load velocity is selected in the range of 1 to 15 $m \cdot sec^{-1}$. The upper limit of the initial velocity corresponds to the maximum possible piston speed of the hydraulic pulsator installed at Education and Research Center in Transport (ERCT) of the Faculty of Transport Engineering, University Pardubice. The hydraulic pulsator will be used for the planned experimental testing designed based on the analysis results presented in this article. At the end of the article, the static and dynamic load capacities of the computational model have been compared and then conclusions have been made based on this outcome.

Keywords

Road tank, cylindrical shell, saddle support, linear buckling, nonlinear buckling, snap-through, static stability, dynamic stability

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1 INTRODUCTION

The shell structures are represented in the transport technology significantly. Their main advantage is low weight at relatively high rigidity and strength. The largest share of the shells used in the transportation technology is evident from the design of the self-supporting skeletons of cars or road tanks, which are subjects to this article. A typical road tank is a horizontal cylindrical shell firmly attached (usually welded) to saddle supports. The existing standards and recommendations [1 to 7] only offer the methodology and analytical formulas for stability evaluation of statically loaded shells on the saddle supports such as horizontal storage tanks and reservoirs in chemical and energy industries. The load is represented by the radial reaction force acting on the cylindrical shell from the saddle support side. In the field of transport, however, it is essential to know the behaviour of dynamically loaded road tanks. The time-varying load imitates the real load of the shell when driving a road tank on uneven terrain. **Fig.1** shows a typical example of a road tank which is attached to the truck with a saddle supports [8].

Excessive static load of the thin-walled road tank results in a snap-through of the saddle into the shell in the elastic-plastic area. Both geometric and material nonlinearity is applied. The cylindrical shell loaded with transverse force (saddle reaction) needs to be considered as a substantially geometrically nonlinear structure as the shell is thin-walled and as there is a high proportion of bending stresses in relation to the basic membrane stresses [9]. Therefore, the linear buckling analysis (LBA) suitable for elastic stability problems can only be used for basic orientation with the utmost caution.

Fig. 1 Road tank anchored on the saddle supports [8]

Even though the determination of the carrying capacity of the statically loaded cylindrical shell on the saddle supports is possible based on the standards and recommendations [1 to 7]. A comprehensive methodology for dealing with this problem for dynamic loading still has not been available. However, an increasing carrying capacity with increasing load speed can be expected. This has to be proved by following computational non-linear analyses.

2 ANALYSIS

The computational analysis of the carrying capacity of the cylindrical shell on the single saddle support of various embracing angles 2φ = 60°/90°/120° and various initial velocities v_0 =1÷15 m/sec has been performed. The weight of the model identical to the weight of the planned reduced test sample of the road tank is m_{TOT} = 8,3 kg. Neither the various saddle support width *2b* nor the initial shape imperfections of the shell have been taken into consideration yet. All the analyses have been performed by means of the computer program SIMULATION [10].

Before the actual dynamic analysis of the computational model, several assistive computational procedures have been made. These include Linear buckling analysis (LBA), Geometric and material nonlinear analysis (GMNA) and Modal analysis (MA). The LBA provides a very rough stability estimation of the computational model in the linear field, while GMNA provides a relatively precise carrying capacity of the model in the elastic-plastic field. MA leads to the lowest significant eigenvalue necessary for the calculation of the simplified Rayleigh's damping coefficients α, β (proportional damping). The used methods are described in more detail later.

2.1 Computation model of the road tank

The computation model of the road tank on saddle supports is not in 1:1 scale, but it is diminished to allow the easier performance of the planned experiments in a laboratory. A non-dimension thin-wall *r/t* parameter is used for this purpose. For simplicity, saddle support fixed at the base is not equipped with backing plates (in the shell-saddle joint) as a real road tank. The basic input parameters of the computational model are listed in **Tab. 1**.

Tab. 1 Basic input parameters of the computational model

Length of the cylindrical shell L	[mm]	300
Radius of the shell r	[mm]	75
Thickness of the cylindrical shell t	[mm]	0,55
Thickness of the end t_f	[mm]	30
Width of the saddle support $2b$	[mm]	20
Embracing angle of the saddle support 2φ	[°]	60,90,120
Material of the calculation model	[-]	P235GH
Yield stress at the room temperature $R_{p0,2}$ [11]	[MPa]	235
Total weight of the calculation model m_{TOT}	[kg]	8,3

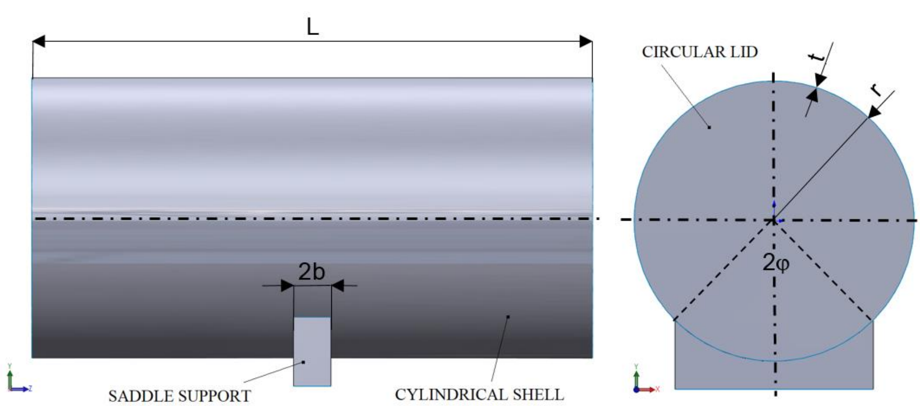

Fig. 2 Illustrative view of the computation model of a road tank with basic dimensions in [mm] for embracing angle of saddle support 2φ = 90°

Significant bending stresses induced by the saddle reaction are in the area between the circular lids and saddle support. This area is called the large shape discontinuity *a* [3] within which the bending stress is damped to an insignificant value. The specified shell length of the computational model guarantees that the stability analysis results in the saddle support area are not influenced by stiff circular lids. The large shape discontinuity for a cylindrical shell loaded with internal and external pressure can be expressed by the following equation [3]:

$$a = 2{,}5 \cdot \sqrt{r \cdot t} = 2{,}5 \cdot \sqrt{75 \cdot 0{,}55} = 16{,}1\, mm, \quad (1)$$

where *a* represents the distance of 16,1 mm in which the maximum stress drops to 4%, *r* and *t* are the parameters from **Tab. 1**. In the distance of 32,2 mm, the maximum stress drops to 4 ‰ as follows:

$$a = 5 \cdot \sqrt{r \cdot t} = 2{,}5 \cdot \sqrt{75 \cdot 0{,}55} = 32{,}2\ mm \cdot \quad (2)$$

In case of a cylindrical shell loaded with the saddle support reaction, a slower drop in stresses is expected. In spite of this, the results are supposed to be quite satisfactory, due to the sufficient shell length of 300 mm. It is, therefore, possible to expect relevant results, unnoticeably influenced by rigid circular lids.

2.2 Linear elastic bifurcation analysis (LBA)

The following chapter describes the linear buckling analysis (LBA), solving the static linear loss of stability of the cylindrical shell on the saddle support. The rough optimistic results were expected since the used LBA is only convenient for structures with quite predominant membrane stresses over the bending stresses. The main result is the lowest eigenvalue which represents the critical force F_{CR} for the unit load force F = 1. The corresponding eigenvector represents the shape of the deformation of the computational model at the moment of the loss of stability induced by the critical force F_{CR}. The physical sense has only the lowest eigenvalue and its corresponding eigenvector [12,13].

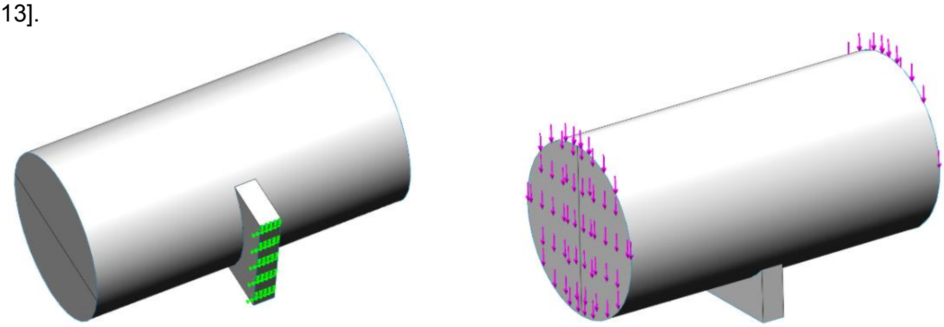

Fig. 3 Boundary condition (left), load (right)

The boundary conditions of the model and the calculated critical force for the various saddle support embracing angles are shown in **Fig. 3** and **Tab. 2**. In fact, significantly lower values of limit forces F_{LIM} obtained by geometric and material nonlinear analysis GMNA can be expected.

Tab. 2 Critical forces of considered saddle support embracing angles

Embracing angle of the saddle support		**60°**	**90°**	**120°**
F_{CR1}	[N]	7 576	17 082	29 029

2.3 Geometrically and materially nonlinear analysis (GMNA)

This chapter is devoted to the static geometrically and materially nonlinear analysis (GMNA). It results in a static carrying capacity of the shell represented by the limit vertical force F_{Slim}. The boundary conditions are the same as in the LBA in the previous chapter i.e., the saddle support is fixed at the base. The unit vertical force in the gravity direction is applied to both circular lids. The computational process has been controlled by the load curve arc increment process (Riks method) described in detail in literature [9]. The limit static forces for the considered embracing angles of the saddle support are shown in **Tab. 3**. The forces are compared with the significantly conservative forces $Q_{pl,Rd}$ obtained by the approximate analytical calculation [7]. It is evident, that the limit force of the approximate analytical solution for embracing angle 2φ = 120° is nearly 3 times lower than the limit force obtained by much more precise complete numerical analysis GMNA.

Tab. 3 Limit forces for considered embracing angles of the saddle support

Embracing angle of the saddle support		**60°**	**90°**	**120°**
F_{Slim}	[N]	2 452	4 630	9 866
$Q_{pl,\,Rd}$ [7]	[N]	1 695	2 543	3 390

For completeness, the following analytical formula to determine the approximate conservative limit force is used

$$Q_{pl,Rd} = 2 \cdot \left(0{,}975 \cdot \frac{s \cdot r \cdot t}{l_r} \cdot f_{y,d} \right), \tag{3}$$

where *r, t* and 2φ are defined in chapter 2.1 and other parts of formula (3) are shown below:

s - length of the saddle periphery in touch with the shell $(s = \pi \cdot r \cdot 2\varphi/180)$,
l_r - reference length $\left(l_r = r \cdot \sqrt{r \cdot t}\right)$ [7],
$f_{y,d}$ - yield strength.

2.4 Modal analysis of cylindrical shell welded to saddle support

The main objective of the modal analysis (MA) is to find the lowest significant eigenvalue in the form of a squared natural angular frequency ω^2. This is obtained by solving a homogeneous set of interdependent differential equations of the second order of the discrete FEM system (the generalized problem of eigenvalues and eigenvectors) [12, 13]

$$M \cdot \ddot{\Delta} + K \cdot \Delta = 0, \tag{4}$$

where ***M*** - mass matrix,
K - stiffness matrix,
$\ddot{\Delta}, \Delta$ - nodal acceleration vector, nodal displacement vector.

The subspace iteration method is used to solve the characteristic determinant

$$\det(K - \varpi^2 \cdot M) = 0. \tag{5}$$

Modal analysis has been performed for all three chosen to embrace angles of the saddle support 2φ = 60°/90°/120°. **Tab.4** lists the first four natural frequencies ($f_i = \omega_i/2\pi$) of the model for all considered embracing angles of saddle support.

Tab. 4 Summary of the natural angular frequency of all considered saddle support embracing angles

Embracing angle of the saddle support		**60°**	**90°**	**120°**
1.Mode	[Hz]	26,0	51,8	89,7
2.Mode	[Hz]	42,7	81,2	127,6
3.Mode	[Hz]	146,9	218,3	290,8
4.Mode	[Hz]	200,8	271,5	321,4

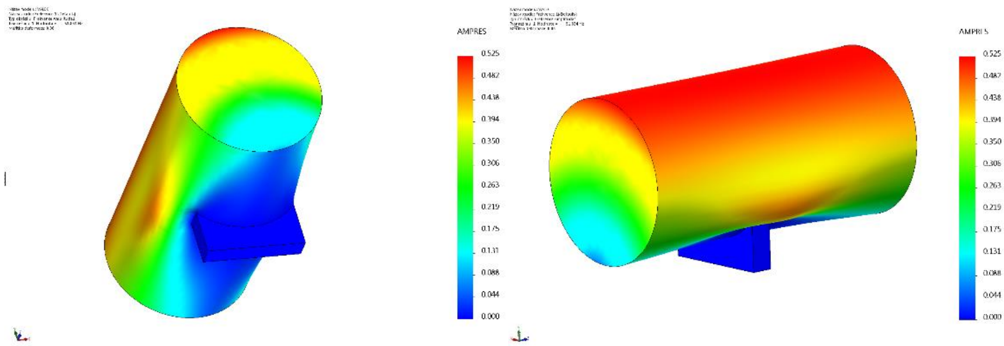

Fig. 4 The first nature mode (eigenvector) for saddle support embracing angle 2φ = 90°

For all the three cases of the embracing angle, the first natural frequency was significant since the corresponding modal mass m_1 reached about 60 % of the total mass of the model m_{TOT}. It means that 60% of the total mass vibrates in the first natural frequency with the first natural mode.

Based on the first natural frequencies, and further on the damping ratio $\xi = c/c_{CR} \approx 0{,}04$ valid for welded steel structures vibrating in the elastic-plastic limit state [14], the Rayleigh damping coefficients α_1, β_1 are determined. Due to the fact that the structure is damped at the first natural frequency at least, uniform damping at all frequencies $\xi = \xi_1 = 0{,}04$ is conservatively considered. Therefore, it is possible to write $\alpha = \alpha_1$, $\beta = \beta_1$. In the case of the cylindrical shell on the saddle support, damping has rather the numerical stabilization effect (it does not represent permanent vibration). For this reason, the Rayleigh coefficients for the angle 2φ = 90 ° may be used for all three embracing angles 2φ = 60°/90°/120°.

The procedure for the determination of the Rayleigh damping is given below. The damping matrix **C** can be simply expressed as a linear combination of the mass matrix ***M*** and stiffness matrix ***K*** [13,15]. It means that the damping forces are proportional to both the inertial forces and stiffness forces.

$$C = \alpha \mathrm{M} + \beta \mathrm{K} \tag{6}$$

Rayleigh's coefficients for saddle support embracing angle 2φ = 90° are:

$$\alpha = \xi \cdot \varpi_{01} = 0{,}04 \cdot 325{,}5 = 13{,}01\,\mathrm{sec}^{-1}, \tag{7}$$

$$\beta = \xi / \varpi_{01} = 0{,}04 / 325{,}5 = 1{,}23 \cdot 10^{-4}\ \mathrm{sec}, \tag{8}$$

where the corresponding angular velocity is:

$$\varpi_{01} = 2 \cdot \pi \cdot f_{01} = 2 \cdot \pi \cdot 51{,}8 = 325{,}5\, rad \cdot \mathrm{sec}^{-1}. \tag{9}$$

The above-specified Rayleigh coefficients α and β are further used in the nonlinear dynamic analysis.

3 DYNAMIC ANALYSIS OF CYLINDRICAL SHELL ON SADDLE SUPPORT

The computational model dynamic nonlinear analysis is solved by a direct integration of the system of interdependent ordinary differential equations of the 2nd order of the discrete computational FEM model [13]:

$$\mathrm{M} \cdot \ddot{\Delta} + \mathrm{C} \cdot \dot{\Delta} + \mathrm{K} \cdot \Delta = F(t)\,, \tag{10}$$

where ***M*** - the mass matrix,
C - the damping matrix,
K - the stiffness matrix,
F(t) - time-dependent load vector,
$\ddot{\Delta}, \dot{\Delta}, \Delta$ - nodal acceleration/velocity/ displacement vector.

This is a dynamic problem with the consideration of geometrical and material nonlinearity. The Newmark integration method is used in the maximum time interval $t \in \langle 0 \div 0{,}001 \rangle$ *sec* with the integration step of approximately *t/50* (automatic selection of the integration step length) to calculate the response to the time variable load. The initial velocity v_0 = 1/2/3/4/5/10/15 m·sec^{-1} in the gravity direction is specified on both rigid circular lids. The saddle support is fixed at the base where the resulting time dependent vertical reaction is detected.

The load characteristic of **Fig. 5 to Fig. 8** expresses the time course of the resulting reaction for selected initial velocity v_0 = 1, 3, 10 m·sec^{-1} and embracing angle 2φ = 60°,90°,120°. The figures show that the course is higher and steeper with a higher load speed and vice versa. **Fig. 8** shows a deformed cylindrical shell with the saddle support of embracing angle 2φ = 60° in time 0, 0006 sec.

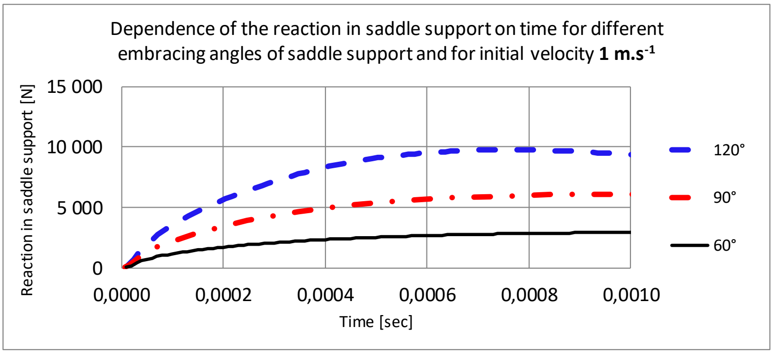

Fig. 5 Saddle support reaction for v_0 = 1 m.s^{-1}

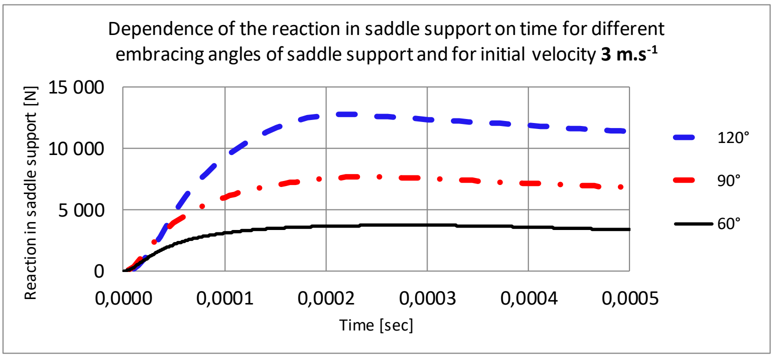

Fig. 6 Saddle support reaction for v_0 = 3 m.s^{-1}

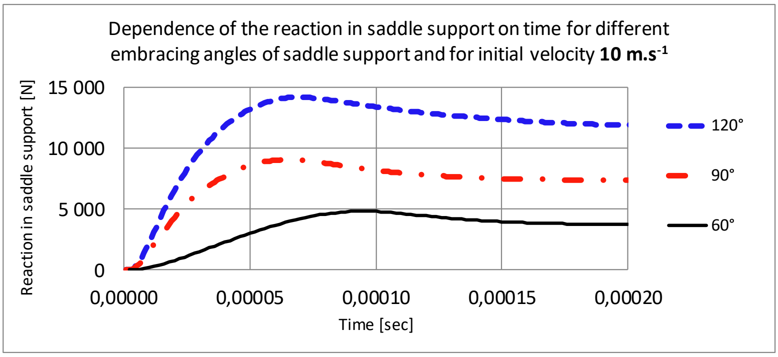

Fig. 7 Saddle support reaction for $v_0 = 10$ m.s^{-1}

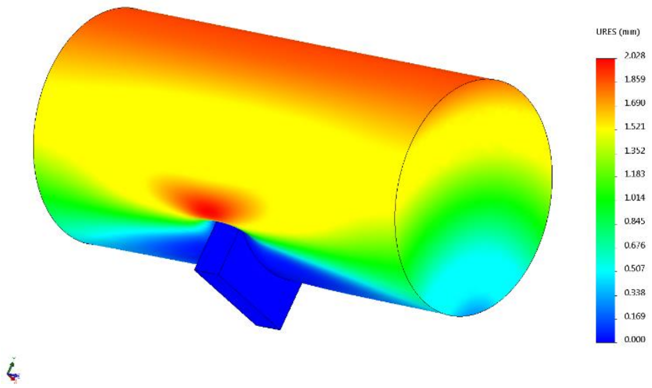

Fig. 8 Dynamic GMNA – total displacements for 2φ=60°

An important parameter of dynamic analysis is the magnitude of the maximum force F_{max}=-F_{Rmax} which leads to a stability snap-through of the saddle support into the cylindrical shell. These values are normalized to the static limit force F_{Dlim}/F_{Slim} and are built for all considered embracing angles and initial velocities into the diagram in **Fig. 9**. The higher carrying capacity of the dynamically loaded model is obvious. The computational model is more than two times more effective than a statically loaded model for embracing angle $2\varphi = 60°$ and initial velocity over 8 m·sec^{-1}.

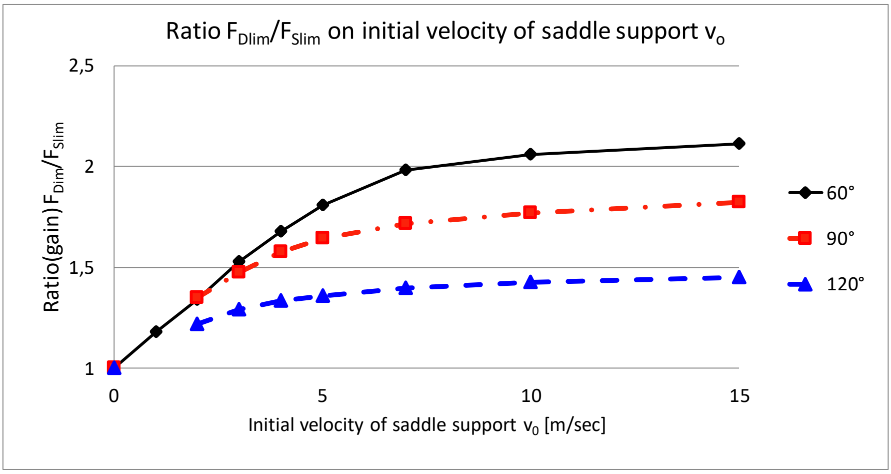

Fig. 9 Diagram of the ratio F_{Dlim}/F_{Slim} versus the initial velocity v_o

It is also evident that the saddle support does not snap-through into the shell for the initial velocity v_0 = 1 m.s^{-1} and the saddle support embracing angles 2φ = 90°, 120°. This is caused by the small initial momentum $p_0 = m.v_0$ of the computational model with the considered model weight of m_{TOT} = 8,3 kg.

4 CONCLUSION

Based on the results of the analysis, the behaviour of the cylindrical shell welded to the saddle support has been investigated. The limit loads leading to the stability snap-through of the saddle into the shell in the elastic-plastic field have been found. The dynamic analysis has been performed for various saddle support embracing angles 2φ = 60°/90°/120° and for various initial velocities of the cylindrical shell v_0 = 1, 2, 3, 4, 5, 10 and 15 m·sec^{-1}. It is evident that the limit force of the shell is increasing with the increasing initial velocity. The shell exhibits higher load carrying capacity at a dynamic load (stability resistance) than at a static load. In case of the saddle support embracing angle 2φ = 60° and the initial velocity v_0 = 15 m·sec^{-1}, the difference is more than twice as big. On the other hand, it is obvious that for a low initial velocity at a given weight of the structure, the stability snap-through does not occur. The shell oscillates around the established equilibrium position (v_0 = 1 m/sec, 2φ = 90° and 2φ = 120°.

The work introduced in this article is the basis for a research in dynamic loading of a cylindrical shell firmly attached to a saddle support. In the next phase of the research, the attention will be drawn to the influence of initial manufacturing imperfections on the dynamic stability of this type of construction. The results will be verified by planned experiments on a reduced model at Education and Research Center in Transport (ERCT) of the Faculty of Transport Engineering, University Pardubice.

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MODERN TECHNOLOGIES IN VEHICLES

Jan Němec[1], Petr Jilek[2]

ANOTATION

This paper discusses modern systems built into the means of transport. Nowadays, with more and more things being fully automated, some operations that have been clearly linked to the management of the vehicle have been gradually abandoned by the driver. Thanks to advanced computers and many applications, we can almost monitor everything on the vehicle today. In this article, we will focus more on, for example, on an emergency car call system. We are dealing with new systems that are expected to become part of the autonomous management of transport means in the near future.

KEYWORDS

Active safety, passive safety, autonomous control, automotive, radar, E Call, technology, traffic accidents, legislation, development of security systems, development of autonomous control

1 TECHNOLOGIES USED TO INCREASE ACTIVE SAFETY

Active safety has been solved in vehicles since the beginning of their production. The basic task of active safety is to prevent accidents, ideally to prevent them today. It helps the driver in his activities.

1.1 History of Active Security Elements

The basic elements of active safety are effective early, which must guarantee the appropriate deceleration until the vehicle stops. Historically we know the fact that the active elements of safety also include a good view from the vehicle, which was solved with glasses in the first vehicles and motorcycles. Not only a good view, but also a seating comfort and is important for the driver. Therefore, adjustable seats, rearview mirrors are used.

Accurate and reliable driving is also a matter of course. Another essential element is the tires and wheels together with their suspension and suspension with damping, it is also important to keep the wheels and the road in contact with the effective brakes.

All of these elements are currently being developed and, thanks to fast microprocessors, are often driven by computers. Many elements already have their memory, so changing drivers in the vehicle does not mean a new set-up, but only instructions for tasks that are done by themselves with controlled actuators.

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1.2 Basic used elements

The basic, now used in each vehicle vehicle features include ABS, ASR, EBS, ESP individual systems we will briefly introduce.

ABS

ABS is an abbreviation of the system with the name of an anti-blocking system, which allows slippery roads to constantly rotate the wheels at maximum braking effect. On a road with a different friction coefficient of the left and right sides, the vehicle allows the vehicle to drive in the right direction by altering the braking effects on the individual wheels.

ASR

The ASR system is based on the English name and means the wheel slip control system. The system can work on two principles. The first is the braking of individual spinning wheels; the second is the power reduction on the drive axle. The system collects information from ABS sensors.

EBA

Electronic Brake Assist EBA is a system that helps the driver braking faster to achieve maximum braking performance faster. It senses the speed and pressure of depressing the brake pedal. Legislation is mandatory for new vehicle models from 11/2009 and older models from 2/2011. [3]

ESP

The electronic stabilization system is a superstructure of the ABS system. Its function is to create a torque for vehicles in a revolving or non-retractable condition. The torque is generated around the center of gravity of the vehicle by braking one of the vehicle wheels.

1.3 Developed technologies and above-standard features

Brake systems

Brake systems are still evolving, mainly because we can drive them faster and better with sensors, processors and actuators.

Multi-collision brake

Among the new systems is a multi-collision brake, which, in an accident where the airbags are activated, brakes the vehicle with the maximum braking effect with respect to ABS, thus stopping the vehicle to prevent further accidents. The system also activates warning lights.

Hill Start Assist

Hill Start system manages to maintain the braking effect of the brake pedal sešlápnutého two seconds after release. This allows the driver to move the foot from the brake pedal to the clutch and move safely without reversing the vehicle. After the gas has been added, the system is gradually deactivated. It works when driving uphill both forward and backwards.

Front assistant

The predictive brake system works in conjunction with the ESP or ESC system together with a radar that controls the space in front of the vehicle. It alerts the driver to individual obstacles. The system's function is to alert the driver that near the vehicle, only the radar function, sends a warning signal when the approach is closer; the vehicle stops if the driver stops braking.

Warning lights

Activating the warning lights is not new. It should be noted that a vehicle moving at a speed higher than 60 km / h with a deceleration of more than 7 m / s^2 will automatically trigger warning lights. [3]

Control systems

Nowadays, the advancement of modern technologies advances and there is no longer any problem driving the vehicle without driver intervention. So far, however, these systems are predominantly used for the comfort of driving.

Adaptive cruise control

The adaptive cruise control is the innovator of the classic cruise control, which has the task of keeping the speed specified. The adaptive cruise control co-operates with several systems. It manages to guard the obstacle in front of the vehicle according to the radar; it can adjust (decrease) the specified speed and keep a safe distance from the front of the vehicle. It runs from 30 km / h to 160 km / h. With the manual gearbox, the speed will be reduced to approximately 30 km / h and automatic braking will stop. [3]

City safe drive

It is a system similar to the adaptive cruise control, but it works at speeds of up to 30 km / h to guard the driver's inattention in urban traffic. The laser CV sensor monitors the distance up to 10 m in front of the vehicle. With an impending obstruction, the brakes will produce the maximum effect and can safely stop the vehicle. [3]

Lane assisitant

Lane asistant prevents the vehicle from lurching from its lane. The correction force is small, so the driver is still driving. If the driver fails, the system can keep the vehicle in the lane, start the hazard warning lights and stop the vehicle.

Colon Assist

Colon Assist is a combination of several advanced systems. With the automatic transmission, the Lane Assistant and Adaptive Cruise Controls communicate with each other in a safe way to control the vehicle in the column, move slowly around the vehicle, and move safely out of the column.

Self parking

It is a superior system that can find a large parking space, both transverse and longitudinal. The vehicle spontaneously spins the wheel, the driver pedals and ranks. This increases parking safety. This system has a number of subsystems necessary for its operation, such as ultrasonic sensors for detecting the vehicle's distance from the obstacle. The system can also be equipped with a parking camera or a 360 ° view of the vehicle. Also, the assistant maneuver system stops when the vehicle approaches the obstacle before impact.

Lighting systems

Smart vehicle lighting is a major trend today. The illumination at the beginning was made by a stronger and weaker bulb and could be determined by a parabola. Gradually switching to halogen bulbs, the quality of lighting increased. A significant transition was through the use of xenon lamps, their separate adjustment according to the load or switching of the driving lights by turning the lens. But today's systems handle much more.

Smart light assist

The system that monitors traffic in front of the vehicle records both the vehicle in the same direction and the vehicle in the direction of the vehicle and manages to shade the high beam. After switching on automatically, it will start and shut down at the appropriate time. The passing vehicles are not dazzled; the driver gets a great view.

Adaptive headlights

Adaptive headlamps can only be built into xenon headlamps. It can change the light angle depending on the speed and weather conditions or on steering the steering wheel. At speeds of up to 40 km / h, the steering wheel turns the driver into the curve with fog light. Dynamically changes the inclination of the lights according to the tilt of the vehicle.

Night vision

The night vision system has been used in vehicles for many years. Today's technology goes forward. The display is on a spacious multifunction display. The driver sees the obstacle clearly and far before his own sight. It is alerted to the acoustic tone and the vehicle can stop and stop without the driver's reaction.

Light asistant

The system is now almost on all modern new vehicles. Locks or unlocks the lights for safe travel around the vehicle. When the ignition is switched on, the daytime running lights switch on and, when entering the tunnel, daytime running lights switch to conventional headlights.

Above standard systems

Among the above-standard systems, we can include systems that use the best-equipped vehicles. It is worth mentioning, for example.

Tire pressure check

Tire pressure monitoring alerts the driver to the tire pressure and prevents the risk. In time, he warns of a defect.

Recognition of traffic signs

The Traffic Signaling System works by comparing the image from the multifunctional camera and the tagging database to the GPS. It can warn of the ban on overtaking, the maximum speed or the ordered directions and their expiration.

Area wiev

The system wiev Area thanks to its four wide-angle cameras in the front, rear and mirrors manages to create a great view of the entire vehicle and the space around it. Thanks to it, the lifts can be more easily coupled or a pedestrian or vehicle center can be prevented from walking in a confined exit or junction.

2 TECHNOLOGIES USED TO INCREASE PASSIVE SECURITY

Passive crew safety is undoubtedly an integral part of road vehicle systems. Although we try to prevent accidents very actively, there may be collision situations that vehicle systems cannot yet evaluate. One of the causes is also the age of the fleet; older vehicles have insufficient active safety systems.

2.1 History of Passive Safety Elements

The history of passive safety features is very extensive. However, it should be noted that for the first vehicles, the safety of the driver is so much avoided. But this is also related to the fact that the vehicles were not running very well, as well as the accidents, and it was not necessary to deal with this direction in the beginning of production of serial vehicles.

2.2 Basic used elements

The headrests of all seats, the three-point seat belts of the whole crew, the airbags, the generally well-developed vehicle body with all the deformation zones can be taken as the basic elements used today in vehicles. Although there has been a series of years between serial use of individual elements, today without them no vehicle can do without.

Self-supporting body

The bodywork itself, as we can imagine today in modern vehicles, is a set of several sophisticated tasks that, from individual parts, create a self-supporting bodywork. It is necessary to mention the most important parts of the body that can keep the undeformed part of the bodywork, and the space for the crew. These parts are mainly A, B, C pillars, door reinforcements, front crossbar, front rail, threshold, defoelements. The body can be divided into two basic parts, a crew compartment that cannot be deformed, and the deformation zones, which on the contrary have to absorb all kinetic energy.

Seat belts

In 1967, the obligation to use seat belts in front passenger seats was introduced. But they were developed much earlier in the 19th century. The five-point seat belt was then adjusted to three-point.

The seat belt works in a way to fire a pyrotechnic patch that extends the belt by up to 10 cm. In the event of a greater load than 500 kN, the belt starts to deform by shaft deformation. This situation can occur when the crash and unattached crew in the rear seats. [3]

Airbags

Airbags are used to minimize the consequences of an accident by filling the space between the crew and the fixed part of the vehicle to minimize impact on the fixed part of the vehicle. Previously, airbags were used only as fronts, and today there are many more. In today's vehicles, side airbags, head and knee airbags can be found.

The airbags are filled in approximately 0.04 s and are expelled in a controlled manner so that the body does not flip, but is slowly absorbed into the cushion [3]

Baby seats

The safety of our small passengers needs to look a little from another perspective. Their body is considerably smaller and more fragile. Most invulnerable movements for an adult can lead to their killing.

The distribution of child seats is based on the age of the child in the 3 categories. Within one year, one to four and four or more years. A child over 150 cm can be transported without a child seat. Exceptions to transport are law, firefighters, police, IZS, mountain service and taxis. [3]

2.3 Developed above-standard elements and technologies

E-Call system

The E-Call system is not a system that will be born in recent years. It is talked about it for decades, the first use, to date very outdated models, dating back to the eighties and nineties of the last century. At that time, he worked on the principle of radio broadcasting.

System Features

The E-Call system has two basic functions that are built on one powerful idea and is to help the crew as quickly as possible in a traffic accident. The first option is that the vehicle is part of a traffic accident, so it crashes and blows its airbags at this time the system automatically calls on the emergency line and sends a GPS signal to determine the exact position of the vehicle. Using the Emergency Line, rescue units can be launched immediately. The system and its own code will tell you what kind of vehicle is, how much fuel you drive, how many activated safety belts and more. The second feature is that the driver can automatically turn on the system and call the emergency line if it is only witnessing a traffic accident.

Legislation

The European Parliament has approved the mandatory incorporation of E-Call for new models of passenger cars and light commercial vehicles from March 31, 2018. Within three years, an evaluation report will be prepared to decide on the incorporation of E-Call into other vehicle categories. [2]

Abuse

The system is activated only in an accident or manual start; otherwise, it is inactive, therefore unattainable. All data is forbidden to entrust to third parties unless the consent of the owner.

3 AUTONOMOUS CONTROL OF VEHICLES

Autonomous vehicle management has been developing for many years. A lot of new modern vehicle systems resemble almost autonomous driving. But it's just a certain situation, fully autonomous driving, that is, a vehicle driving without a driver, is not yet legislatively approved. but there are several degrees of autonomous control.

3.1 First degree of autonomous management

It is nowadays well known for use in modern vehicles. These are, for example, adaptive cruise control or Lane assist system and the like. These systems may slightly interfere with driving or change direction slightly, but the driver is superior to them. There can always be one action element. This is driver support

3.2 Second degree of autonomous management

Partial automation can be called, for example, an automatic parking system, which can also use multiple actuators at once, turning the steering wheel and adding gas. However, the driver must be prepared to intervene if necessary.

3.3 Third degree of autonomous management

This category includes vehicles with a system so sophisticated that, for example, on the highway, with well-marked bands, the driver does not need to notice the steering. But it must respond to all vehicle alert messages.

3.4 Fourth degree of autonomous management

This category is another technical upgrade to category three. For example, the driver must be in bad weather, reduced visibility due to fog or heavy snowfall. If the driver is not responding to the challenge to take control, the vehicle stops safely.

3.5 Fifth degree of autonomous management

It is a fully automatic control, the driver only nudges and enters the destination destination. The vehicle is not equipped with pedals or steering wheel. [4]

4 CONCLUSION

The future of autonomous governance is quite out of the question. We are currently in Automation Level 2, some systems have been introduced in previous chapters. Many of the older systems are now at a great level, the general public and drivers believe the systems are believed. The problem of launching other new systems on the market is not only technical but mainly legislative. Of course, systems are developed at all levels of automation, but their price, size, energy intensity, but also reliability are solved. If this is not an accident caused by a human factor, but a machine or a failure of a subsystem, the public might lose interest in development and confidence in technical progress.

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INFLUENCE OF IMPACT VELOCITY ON ENERGY ABSORPTION PERFORMANCE OF THICK-WALLED TRUNCATED CONICAL SHELLS

Erdem ÖZYURT[1], Haluk YILMAZ[2], Petr TOMEK[3],

Abstract
The paper deals with the energy absorption capabilities of truncated conical structures with low base angle under quasi-static and dynamic axial loading. The simulation results were compared by means of several performance parameters such as mean crushing force F_m, absorbed energy E_A, specific energy absorption (SEA), crash force efficiency (CFE), dynamic amplification factor (DAF) and absorbed energy per unit deformation. Results are summarized by means of the performance parameters and main conclusions are made.

Keywords
finite element method, energy absorption, truncated cone, crashworthiness

1 INTRODUCTION

With the development of the transport technology, there is a substantial demand for developing more powerful and faster vehicles. On the other hand, same demand also led to an increase in undesirable situations such as fatal accidents and injuries. The authorities have become aware of this safety situation in transportation and have begun to pay attention to the possible causes of the death and injury incidents. The prevention of collisions may not always be possible despite all collision avoidance systems. So, it is of utmost importance to control the possible deformation of the vehicle as a result of the collision. Controlling the deformation basically means to transfer the impact forces to the appropriate sections selected by the designer. The aim here is to ensure that the collision energy is absorbed by the energy absorbers and to minimize or prevent the possible damage to the structural elements of the vehicle. Thus, the undesired damage to the important sections of the vehicle enclosing occupants can be minimized.

Commonly used geometrical shapes in most studies are cylindrical tube, square tube and truncated conical tube, also known as a frustum. Although most of the studies are focused on cylindrical and rectangular tubes, crashworthiness of conical structures has been studied by many substantial authors.

Mamalis et al. [1] have investigated the crash behaviour and energy absorbing characteristics of axially loaded steel thin-walled tubes of the octagonal cross-section. A test series of axially compressed octagonal tubes have been carried out under quasi-static loading. Tai et al. [2] have

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analysed the axial compression behaviour and energy absorption of the thin-walled cylinder under impact load. Analysis outcomes showed that the impact kinetic energy is more sensitive to speed than impact mass. Gupta et al. [3] have performed an experimental study on aluminium conical frusta of different semi-apical angles under axial compression. Authors have proposed an analytical model for the prediction of load-deformation and energy-compression curves of the metallic conical frusta. Aljawi and Alghamdi [4] have examined deformation modes of frusta as a collapsible energy absorber. Authors obtained that within the experimental impact speed range of $0 - 7\ m/s$, the speed of deformation had no effect on the process of inversion and flattening. Eswara and Gupta [5] have examined spherical domes and conical frusta of various sizes. Load-deformation curves and collapse modes of frusta have shown similar behaviour in quasi-static and dynamic tests.

The main scope of the present study is to determine the effect of the impact velocity on the energy absorption of conical geometries of low base cone angle. In this manner, a selected geometry with low base conical angle and relatively higher thickness values is investigated under static and dynamic loading conditions with various impact velocities. All models have been studied numerically with the influence of parameters such as load-deflection curves, crash force efficiency and specific energy absorption values.

2 PERFORMANCE PARAMETERS

Even if the most important parameter of an energy absorber is the amount of dissipated energy, it is not sufficient to estimate the overall performance of a structure. For a reasonable performance estimation, it is needed to define and investigate following parameters:

Mean Crushing Force (F_m) is the average force during the impact. It can be calculated by using force response and total deflection length of the absorber.

$$F_m = \frac{\int_0^{d_{max}} F dx}{d_{max}} \tag{1}$$

where $F\ [kN]$ is the crushing force and $d_{max}[mm]$ is maximum crush distance.

Peak Crushing Force (F_p) is the maximum value of the axial force during crush. Peak force occurs when material yields or buckles. Peak crushing force should be kept relatively low or in other words, it should not be far beyond the mean crushing force.

The total absorbed energy of an energy absorber can be defined as the work done by the crushing force at a deformation distance. By using basic mechanics, absorbed energy is simply the area under the force-displacement curve and can be expressed as;

$$E_A = \int_0^{d_{max}} F dx \tag{2}$$

(1)

where $d_{max}\ [mm]$ is maximum crush distance and $F\ [kN]$ is the crushing force.

Crash force efficiency is described as the ratio of mean crushing force to the peak crushing force during the deformation caused by the impact. It is desired to have CFE close to unity; to approve the system has good crash performance.

$$CFE = \frac{F_m}{F_p} \tag{3}$$

Crash force efficiency can be improved by using trigger mechanisms such or holes to make an imperfection and raise the stress at initial loading to ease buckling and reduce peak force.

Specific Energy Absorption (SEA) is an important parameter for an energy absorber and defined as the ratio of total energy absorbed in the system to the mass of the structure. The higher SEA value refers to a more lightweight absorber, which means more energy can be absorbed with a lighter structure.

$$SEA = \frac{E_A}{m} \tag{4}$$

where $E_A\ [kJ]$ is total absorbed energy and $m\ [kg]$ is mass of the absorber.

Dynamic amplification factor is simply defined as the ratio of the energy absorbed under dynamic loading to the energy absorbed under quasi-static loading as given in equation 5.

$$DAF = \frac{E_{dynamic}}{E_{quasi-static}} \tag{5}$$

Despite being an uncommon performance parameter, it is very useful to investigate the dynamic effects such as inertia and strain rate effects. It has been used by several authors for both investigation and estimation of the dynamic effects on the energy absorbers.

3 FINITE ELEMENT MODEL

The numerical models for the simulations were created using the CAE user interface module of the FEM software Abaqus. [6] Depending on the subject of the present study, Abaqus/Explicit solver package have been used to simulate the dynamic loading of the structures. Results obtained from the simulations have been viewed and exported by using the Viewer module of the software.

3.1 Model Geometry

A basic sketch of the absorber structure is given in Figure 1 with dimension parameters. Dimension parameters used to model the structures are, inner radius r_1, outer radius r_2, edge ring width b, edge ring height d, thickness t, cone angle β and deformation length h. Values used for all parameters are given in Table 1.

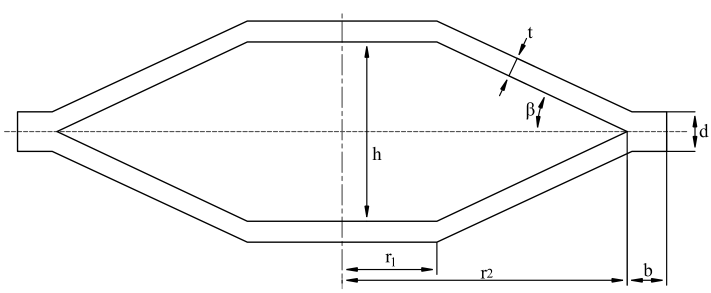
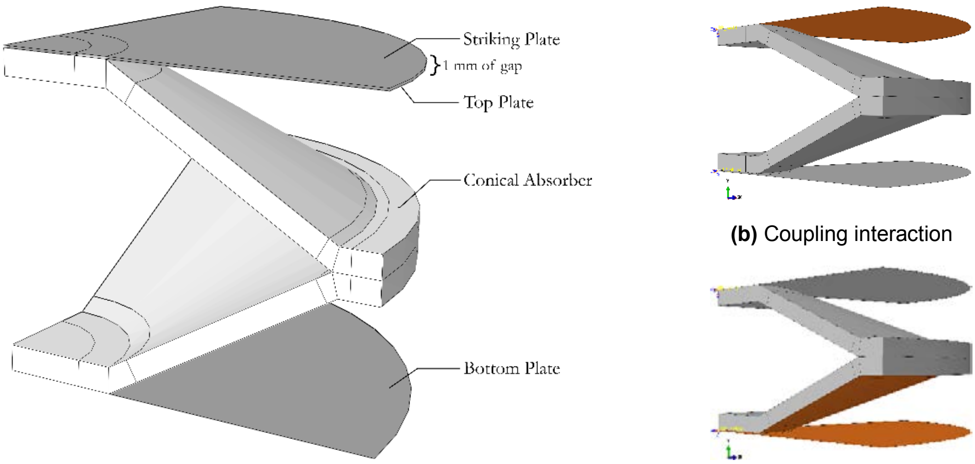


Fig. 1 Geometry and dimension parameters of the absorber structure.

Structures were modelled by creating each plate and the absorber as quarter models of real dimensions of structures. The model assembly includes three equally designed rigid plates and a conical absorber. The conical absorber was positioned between two rigid plates (top and bottom plate) to simulate a crush box and also to control the deformation of the structure. The third plate (striker plate) is used to simulate the striking mass crushing to the conical absorber. A gap of $1\ mm$ between the striker plate and the top plate of the absorber was modelled to examine the effect of the first contact more conveniently. General assembly of the numerical model is given in Fig. 2 in detail.

Tab. 1 Dimension values of the absorber structures used in simulations.

β	***h***	***t***	***b***	***d***	***r₁***	***r₂***
$[deg]$	$[mm]$	$[mm]$	$[mm]$	$[mm]$	$[mm]$	$[mm]$
30	115.5	10	20	20	50	150



(a) Assembly of the absorber and the rigid plates

(b) Coupling interaction

(c) Pre-defined contact pair

Fig. 2 Model assembly and the interactions between the parts of the model

3.2 Material Model

The material used for the simulations were structural mild steel denominated as $S235JR$. In numerical analysis, an elastoplastic hardening module was implemented to the material behaviour. Mechanical properties of $S235JR$ are used as; Young's modulus of $200\ GPa$, Poisson's ratio of 0.29 mass density of $7980\ kg/m^3$, yield strength of $294.6\ MPa$ and ultimate tensile strength of $381\ MPa$.

The plastic flow of some materials is sensitive to loading speed, which is known as material strain rate sensitivity. The Johnson-Cook plasticity model [7] is a phenomenological model used to describe the plastic and strain-rate dependent hardening of materials. The model introduces three key material responses, which are the strain hardening, strain-rate effects and the thermal softening. These effects are combined in the Johnson-Cook constitutive model in a multiplicative manner.

$$\bar{\sigma} = \left[A + B\varepsilon_{pl}^{n}\right]\left[1 + C\ ln\left(\frac{\dot{\varepsilon}_{pl}}{\dot{\varepsilon}_0}\right)\right]\left(1 - \hat{\theta}^{m}\right) \tag{7}$$

where, $\bar{\sigma}$ is the yield stress at nonzero strain rate [Pa], $\dot{\varepsilon}_{pl}$ is the effective plastic strain, $\dot{\varepsilon}_0$ is the reference strain rate, A is the initial yield stress at $\dot{\varepsilon}_0$ [Pa], B is the strain hardening coefficient [Pa], C is the strain-rate hardening coefficient, n is the strain hardening exponent, m is the temperature exponent and $\hat{\theta}$ is the homologous temperature. In this study, the model is assumed to be simulated in room temperature, thus the effect of temperature on thermal softening of the yield stress is neglected.

Previous studies have indicated that $S235$ steel displays a significant positive strain rate effect on the yield stress of the material. Verleysen et. al. [8] have investigated the influence of the strain rate on the forming properties of three commercial steel grades. The static tensile test results of the present study and the results from the article by Verleysen et. al. [8] are found to be essentially identical for the $S235JR$ steel. Due to the technical impossibilities and the lack of equipment for dynamic tensile testing, the Johnson-Cook model of the $S235JR$ steel with strain rate properties are adapted to the numerical models of the present study. Consequently, the Johnson-Cook plasticity model parameters used in this study are given in Table 2.

Tab. 2 Johnson-Cook plasticity parameters of $S235JR$. [8]

A	B	n	C	$\dot{\varepsilon}_0$
$280\ MPa$	$667\ MPa$	0.72	0.071	$5.6x10^{-4}$

3.3 Loading and Boundary Conditions

In quasi-static numerical simulations, the load is applied to the rigid striking plate as a predefined velocity along the longitudinal axis. Quasi-static velocity is selected to be $0.01\ m/s$. In dynamic simulations, the load is applied as kinetic energy. The kinetic energy is generated by defining a velocity and a mass to the striking plate. Used mass quantities are calculated to obtain $100\ kJ$ of initial kinetic energy for each model.

Interactions between parts were defined using self-contact and surface to surface contact algorithms. To simulate a crush box, the conical energy absorber was coupled to two rigid plates from the top and bottom surfaces using a kinematic coupling definition. Any movement of the bottom plate was restrained using an encastre boundary condition definition. The top plate and striker plate were allowed for translations on the y-axis direction and any other movements were restrained. Structures were designed as quarter models to reduce the time cost of the simulations.

4 RESULTS AND DISCUSSION

One of the most important performance parameter is the crushing force during the deformation of the absorber, which may change under different conditions. In this case, the effect of loading on the energy absorbing performance of the conical structure is investigated. The force-displacement responses are plotted in Figure 3.

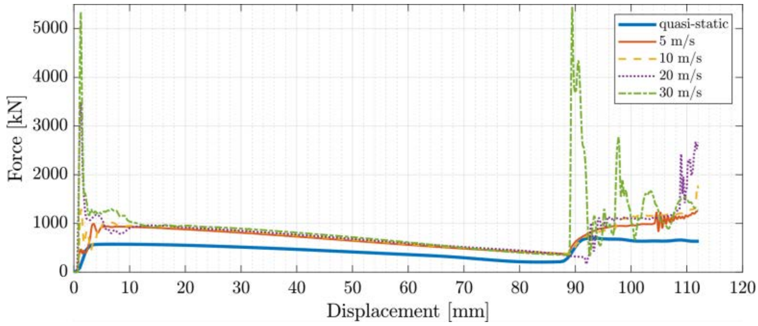


Fig. 3 Comparison of quasi-static and dynamic Force-Displacement response of the model.

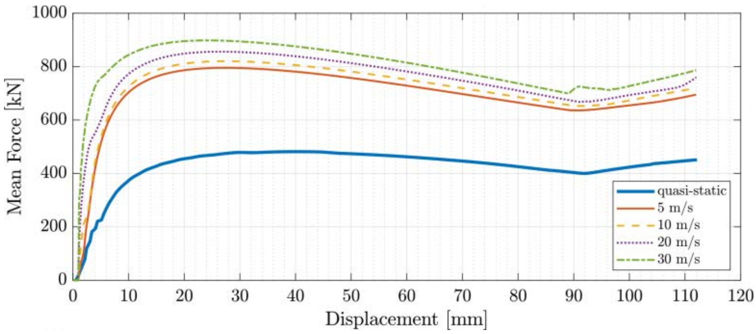


Fig. 4 Comparison of mean Force-Displacement response of the quasi-static and dynamic models.

It is observed that there is a significant difference between the quasi-static and dynamic cases in terms of mean crushing force response. This is caused by the strain-rate dependent material model, which changes the structures response under different initial impact velocity conditions. The force-displacement responses indicate that up to a certain value of impact velocity, the response of the structure has a similar behaviour with the quasi-static case. In other words, the inertia effects on the impact response of the structure become apparent for the velocity values more than $10\ m/s$.

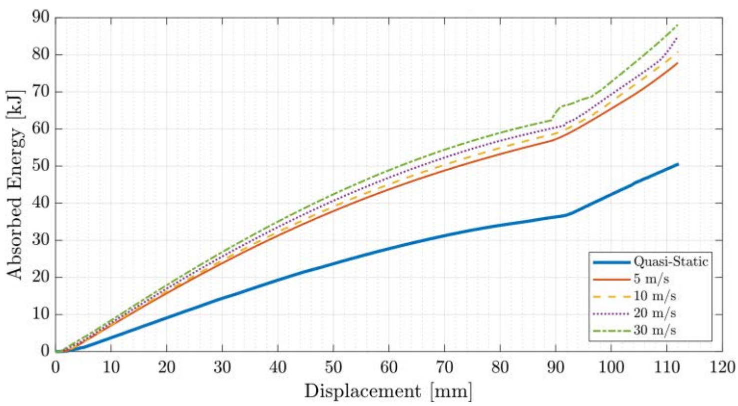
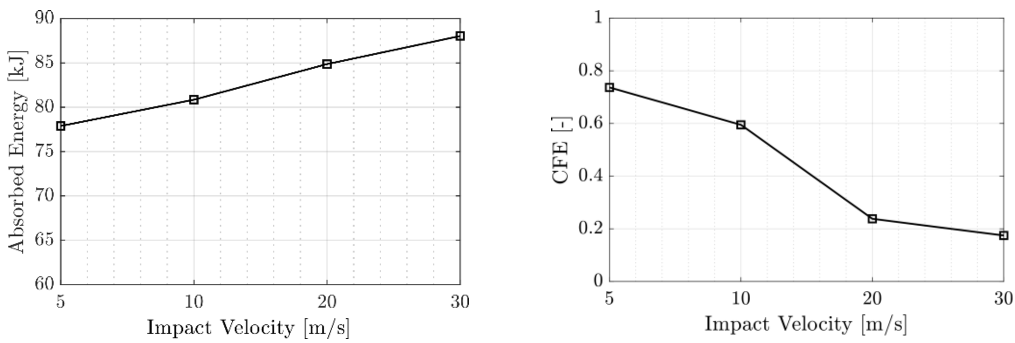


Fig. 5 Comparison of energy absorption for quasi-static and dynamic models.

As the energy absorbing capacity of the structures are strictly related to the crushing force response, the absorbed energy curves conform with the force-displacement curves. Absorbed energy response of the models are given in Figure 5 as a function of displacement. The energy absorption capacity of the structures increases with increasing impact velocity. For the impact velocity values of $20\ m/s$ and $30\ m/s$, both crushing force and the absorbed energy plots have a slightly different behaviour.

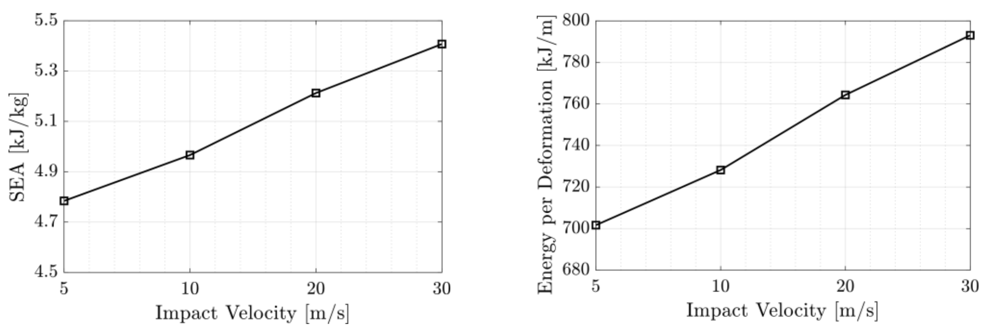


(a) Absorbed energy **(b)** Crash force efficiency

Fig. 6 Effect of the impact velocity on the absorbed energy and the CFE values of dynamic simulations.

The increase of the first peak crushing force also significantly change the crash force efficiency values of the structures. CFE values are plotted in Figure 6b as a function of impact velocity for models with different absorber thickness and base conical angle. The CFE values significantly decrease as the impact velocity increases.

The change of the SEA values are shown in Figure 7a as a function of impact velocity. SEA values also increase as the impact velocity increases. This is an expected behaviour because this parameter is directly related to the mass of the structures and the absorbed energy values.



(a) Specific energy absorption **(b)** Absorbed energy per unit deformation

Fig. 7 Effect of the impact velocity on the SEA and the absorbed energy per unit deformation values.

The models with same conical angles have the same constant maximum deformation lengths due to the geometry and all models are completely deformed. Therefore, the absorbed energy values per unit deformation have an increasing behaviour as the absorbed energy values increase with increasing impact velocity as seen in Figure 7b.

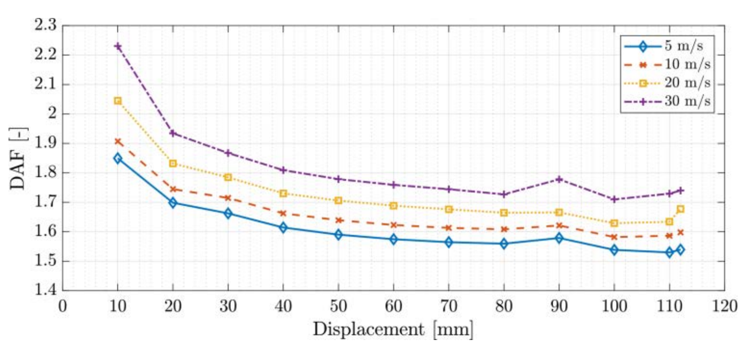


Fig. 8 Comparison of dynamic amplification factor of the dynamic models.

The same situation can also be observed in the dynamic amplification factor values. As seen in the Figure 8, DAF values have decreasing trend with increasing deformation which may be caused by the decremental effect of strain-rate and inertia effects as the crushing of the absorber continues. However, DAF values have a notable difference as the impact velocity increases. DAF values at the displacement values of $10mm$ and $90mm$, at which contact between surfaces occur, are of great importance. It is seen that the increase on the DAF values of the models with impact velocities of $20\ m/s$ and $30\ m/s$ are greater than the models with lower initial velocity. This situation indicates that some inertia effects may be present at the impact velocity values higher than $10\ m/s$.

4.1 Presence of the Inertia Effects

In structural dynamic problems, dynamic loading is modelled using the initial kinetic energy of the system. The increased kinetic energy by changing the impact mass has no influence on the crushing force and absorbed energy values of the models. [9] However, the increase in the impact velocity affects the general response of the structure even if the kinetic energy is kept constant. The increase of the absorbed energy with increasing impact velocity may be associated with the inertia effects including plastic stress wave propagation and nonlinear response. A similar effect has been observed for axial impact loading of square tubes with a strain rate insensitive material model. [10]

In the present study, the strain-rate dependency of the used material is taken into consideration. Thus, the increase of the absorbed energy with increasing impact velocity may be associated with the velocity sensitive material model. For this reason, the strain-rate sensitivity properties of the current material model are removed, and the simulations were repeated.

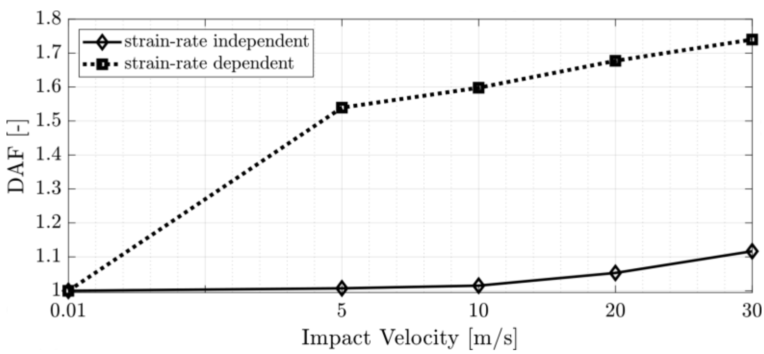
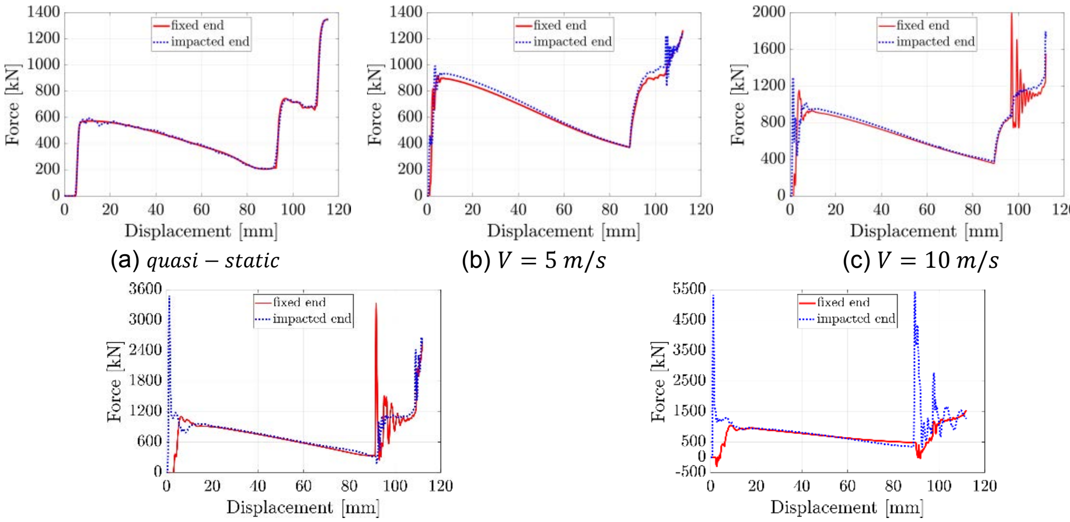


Fig. 9 Effect of strain rate dependency of the material on the dynamic amplification factor of the models.

Figure 9 shows the dynamic amplification factor values of the models with and without strain-rate properties. It is clearly seen that the dynamic absorbed energy values increase with increasing velocity even if the strain-rate dependency of the material is neglected. Thus, the increase may also be associated with the inertia effects including plastic stress wave propagation and nonlinear response. The presence of the axial inertia effects can be identified by comparing the force response of at the impacted end and the fixed end of the structure. This approach has been used by several authors to investigate the inertia effects on various structures. [11]



(a) $quasi-static$ (b) $V = 5\ m/s$ (c) $V = 10\ m/s$

(d) $V = 20\ m/s$ (e) $V = 30\ m/s$

Fig. 10 Force-displacement response of the models for different impact velocities.

As seen in Figure 10, the load response, at both ends of the structures have similar values for the models with impact velocity values up to $10\ m/s$. For the models with higher impact velocity, the force-displacement responses significantly change. Moreover, the initial peak load seems to be much higher at the impacted end of the structures. Also at higher initial velocity values, negative forces were observed during first impact due to the oscillations of the top surface of the absorber.

As a result, the dynamic response of the conical structure under axial loading is affected by the impact velocity at relatively higher velocities $(\geq 10m/s)$. Thus, the effect of the inertia forces emerge with increasing velocity, even if the strain-rate dependency of the material is neglected.

5 CONCLUSION

A numerical investigation of the conical energy absorbing structure was examined in this study. To investigate the presence of the inertia effects during loading, both strain-rate dependent and independent material models were implemented into the simulations and compared. In the view of obtained information from the current study, some of the significant conclusions on the design of a low base conical angle structure are summarized below.

According to the results of this study, it can be said that increasing the impact velocity of the loading increases the absorbed energy. As the absorbed energy increases, the crush force also increases. The crash force efficiency values have a decreasing trend as the impact velocity increases due to the increasing initial peak crushing force response of the structures. The presence of the axial inertia effects was identified by comparing the force response of at the impacted end and the fixed end of the structure. The initial peak load seems to be much higher at the impacted end of the structures. The dynamic response of the conical structure under axial loading is affected by the impact velocity at relatively higher velocities $(\geq 10m/s)$. Thus, the effect of the inertia forces emerge with increasing velocity, even if the strain-rate dependency of the material is neglected.

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CURRENT STATE OF PRELIMINARY PROCESS OF HIGH SPEED RAILWAY LINES IN THE CZECH REPUBLIC

Marek PINKAVA[1]

Abstract

The article is focused on current state of preliminary process of so called "Rapid Services" in the Czech Republic. The concept of "Rapid Services" and approach to high speed railway in the Czech Republic are characterized in a brief way. Current state of preliminary process as well as proposed following steps are mentioned.

Keywords

High-speed railway, high-speed line, preliminary process of construction works

1 RAPID SERVICES

The concept of "Rapid Services" was defined by the resolution issued by government of the Czech Republic in May 2017. The "Development Programme of the Rapid Services in the Czech Republic" was approved. "Rapid Services" are defined as operational and infrastructural system of fast railway in the area of the Czech Republic consisted of constructions of new high-speed railway lines (HSL), upgraded conventional lines with high speed features as well as upgraded conventional lines with higher parameters including rolling stock and concept of operation. [1]

High-speed railway line (HSL) is one of many components of high-speed railway according to this definition. Individual HSL has such form and extent as it is required by the transport system. The Czech Republic going to operate an open operation concept due to this government resolution. It means that high-speed trains will take a part of a common transport system accessible to general public and for common every-day use. This system will be compatible with all neighbour countries thanks to this.

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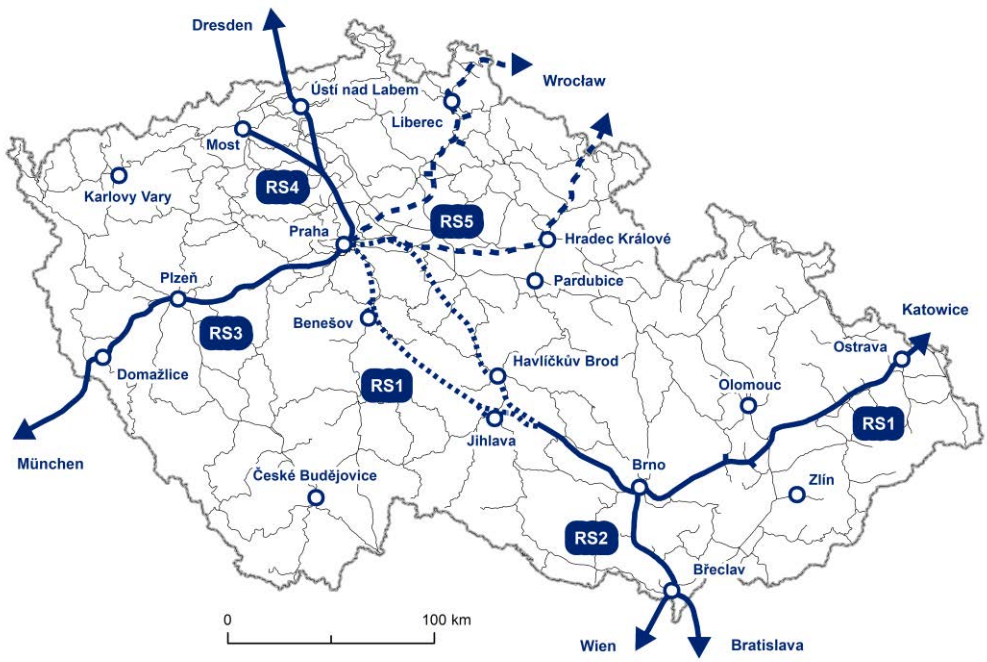

Fig. 1 Proposed network of “Rapid Services” (HSL as well as modernized conventional lines)

2 INFRASTRUCTURE PRELIMINARY PROCESS FOR “RAPID SERVICES”

2.1 Technical Studies

Elaboration of technical studies [2] was the first step by preliminary process of lines taking a part of future system of “Rapid Services”. These studies have been elaborated for all directions displayed by the Fig. 1. Territorial corridors for some directions is stabilized and (at least roughly) corresponding to planning documentation (Principles of territorial development).

There are more variants of route alignment at some locations. In some cases, by the point of view of overall conception (e.g. line Praha – Wrocław or in the part of line Praha – Brno). In some cases, there are more variants on the level of detailed track alignment. There is proposed a number of possible interconnections to network of conventional lines in the frame of the conception of “Rapid Services”.

2.2 Feasibility Studies

Feasibility studies are used to choose the final variant of infrastructure in each direction of “Rapid Services” system. Feasibility studies extend our knowledge about transport and economical parameters of intention. Technical proposal of route and verification of territorial continuity are taken from the first step.

Prognosis of passengers’ transport demand as well as prognosis of freight traffic development, evaluation of direct as well as society benefits and final evaluation of intent efficiency are included. It is evaluated by feasibility study, which route is suitable for following preparation and which interconnections are needed.

Elaboration of feasibility studies for the directions RS1/2 Praha – Brno – Břeclav and RS4 Praha – Dresden is in process nowadays. The second one is in advanced processing stage. Interesting transport solutions are suggested by the study. These solutions are beneficial not only for international transport, but also for national long distance and fast regional transport.

Elaboration of feasibility study for backbone line RS1 in the segment Brno – Ostrava will be commissioned in the near future. Commissioning of the feasibility study for the direction of RS5 Praha – Wrocław will follow.

3 PILOT SEGMENTS

3.1 Selection of Suitable Segments

The SŽDC made an analysis of possibilities [3] how the preliminary and construction of HSL can be accelerated. The aim of the analysis was an identification of segments of proposed HSL network in the Czech Republic, which can be incorporated into the system of “Rapid Services” and realized as pilot. Selection criteria were defined and the selection made according to them.

Criteria can be divided into 4 fields (transport, territorial, technical and process field). At least partial fulfilment of all criteria is a presumption for successful and quickly realization. If one of the criteria is not met, it has been considered whether or not it is a major barrier.

There are 3 segments potentially suitable to be selected as pilot segments. The set of segments based on criteria mentioned above is consisted of the segments: Praha-Běchovice – Poříčany (HSL POLABÍ), Přerov – Ostrava (HSL MORAVSKÁ BRÁNA) and Brno – Vranovice (HSL JÍŽNÍ MORAVA).

Construction of pilot segments as a base for future HSL network is a great opportunity in the Czech Republic. Construction of the first segment and successful setting-up into operation were a successful step in foreign countries. It reduced criticism of construction of subsequent HSL, verified positive passengers’ feedback and feedback by transport operators, and also allow infrastructure managers to prepare subsequent parts of network in higher parameters. It is an advantage to construct as pilot such segment which technical form is relatively independent on speed and capacity demands. It is for prevention this segment not to create possible speed or capacity bottleneck.

3.2 Analysis of Contributions, Opportunities and Risks

Simplified analysis of contributions, opportunities and risks has been made by selected segments. Former documents elaborated for given segment or general documents to HSL (e.g. Technical and operation study) were utilized as a base for identification and evaluation.

Creation of a space for future development of railway (incl. conventional lines in surroundings) and creation of a base for future network designed for the speed of 350 km/h are able to be mentioned as opportunities. In pilot segments, this standard does not need to increase costs compared with selection of lower speed level. It is necessary to mention risks related to construction preliminary process in process and technical points of view as a part of risk analysis. Risks related to environmental impact assessment as well as to process of obtaining a building permit must be considered as well.

All selected segments have an important contribution for current transport operated on other lines parallel in direction of considered new segments as well. New high-speed infrastructure will improve capacity of railway in given direction. It improves transport reliability and allows next development of transport. This development is limited by limited capacity nowadays. The trains can be faster due to reduction of overtaking of trains of different categories and due to reduction of slowing down of speed caused by high volume of track (line) occupation. These effects are related to capacity improvement.

3.3 Recommendations to Following Parts of Preliminary Process

Overview of basic steps necessary for preliminary of pilot segments in accelerated mode and brief schedule of the probably shortest possible preliminary process and realization of construction are taking part of the analysis mentioned above.

It is recommended to continue in consideration of all 3 selected and analysed segments based on all known facts. Higher probability of successful acceleration of preliminary process and of construction works is seen by the HSL JIŽNÍ MORAVA (Brno – Vranovice) and HSL MORAVSKÁ BRÁNA (Přerov – Ostrava). The advantage is higher probability of match in transport and technical solution and possibility of realization with no intervention to important railway junctions.

HSL MORANSKÁ BRÁNA (connecting central and northern parts of Moravia) is the segment of suitable length to shorten travel times. The trains can fully reach designed speed. If the connection in the area of Přerov will be suitable, a comprehensive segment minimally for the speed of 200 km/h can be created between Olomouc and Ostrava. "Fast connection" of the largest Moravian cities can be created in combination with planned modernisation of the conventional line Brno – Přerov as well.

HSL JIŽNÍ MORAVA (HSL South Moravia) is short segment with relative low costs needed for realization. The trains will not reach the maximum speed before construction of following segments due to short length of segment. Contribution in the field of improved capacity is seen as more important.

HSL POLABÍ (HSL in region of the river Elbe) has a significant contribution for improvement of capacity and for improvement of operational reliability. There is more significant risk of extension of preliminary process compared with other HSL pilot segments. It is caused by the fact that it is necessary to intervene the railway junction of Prague.

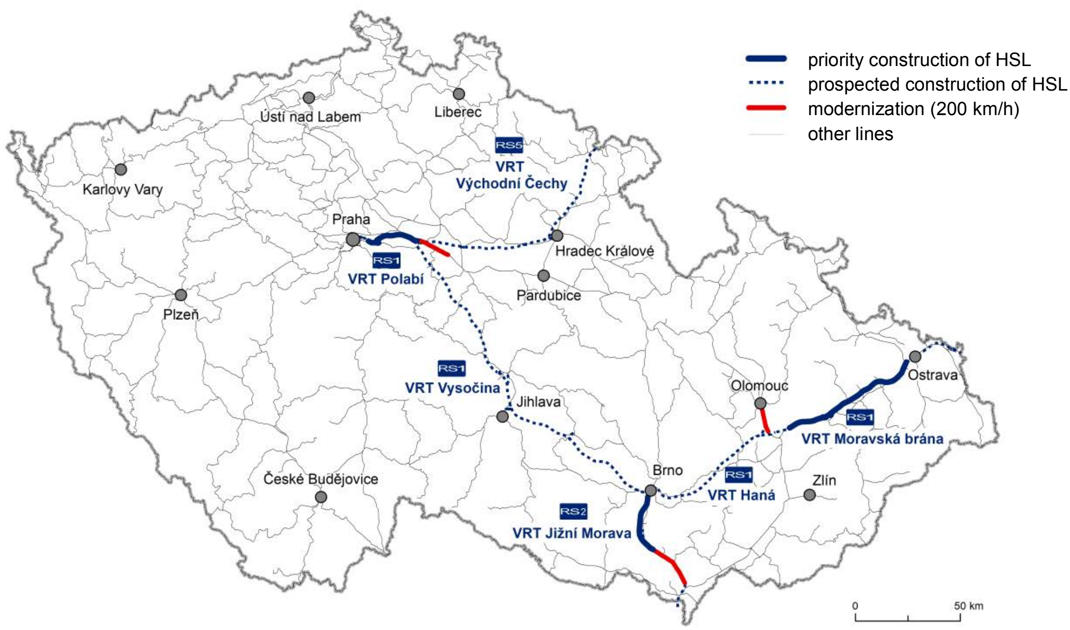

Fig. 2 Pilot HSL segments and protentional continuation in the future (there are HSL variants following-up the pilot segments only)

4 TECHNICAL SOLUTIONS

4.1 Internal Point of View as well as the Assumption of Foreign Know-How

The proposal of technical design of railway lines and following-up infrastructure is a crucial part of HSL preliminary process. Technical and operation study focused on technical and operational aspects of high-speed railway was finished in 2017. Proposal of basic features across all the subsystems incl. the preview of possible future operation is the outcome of this study.

The parameters are not defined in a flat and collective way for all the future network, but the definition follows specific requirements on individual lines according to their purpose. Possible lines are divided into 4 categories according to maximal speed and operational purpose (passenger traffic, mixed passenger and freight traffic).

Elaboration of an internal guideline of the SŽDC for designing of high-speed infrastructure follows up this study. The manual is based on the results of the study in content and in proposed parameters. It will be possible to design new railway lines minimally in range of feasibility study according this guideline. This can also be used to upgrade more detailed technical standards of SŽDC.

Possibility to implement foreign technical standards for specified type of lines is considered as well due to preliminary process of pilot segments and for refining the technical solution in short time horizon. Implementation of standards from France is in discussion nowadays. It is in relation to the purpose of pilot segments (high speed lines, passenger transport only). French approach to technical solution of lines is verified by decades of years of operation on the hundreds of kilometres of lines in France and also abroad. Technical solution of lines in other countries can be based on those standards as well. On the other hand, no standard can be applied in the Czech Republic without its locating into local conditions of the Czech Republic. The same will in this case.

5 CONCLUSION

Nowadays, the preliminary process of HSL and of high-speed railway as a complete set is more and more intensive in the Czech Republic. The work is coming to feasibility studies after the years of conceptual considerations. The ideas are getting a specific look. Updates of spatial-planning documentation based on the newest proposals is presupposed for next time. It is necessary for continuation of construction preliminary processes. Preparation of technical standards for design and construction of this infrastructure is lasting in a parallel way. It is a long-lasting process. It will take several years in spite of the fact that it has high support of society.

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RAIL VEHICLES FOR THE SUSTAINABLE MOBILITY

Jiří POHL[1], Roman PRELL[2]

Abstract

- sustainable mobility as part of sustainable development,
- objectives of sustainable mobility,
- interdependence of objectives in the areas of reducing energy consumption, stopping climate change and protecting the environment,
- extramodal and intramodal energy savings,
- technical innovation as a tool for the development of sustainable mobility in the field of urban rail transport vehicles,
- technical innovation as a tool for developing sustainable mobility in the field of regional rail transport vehicles,
- technical innovation as a tool for developing sustainable mobility in the field of conventional and high-speed rail transport vehicles,
- technical innovation as a tool for developing sustainable mobility in rail freight transport.

Keywords

Sustainable mobility, rail transport, energy savings, fossil fuels

1 INTRODUCTION

The discovery, mining and using of fossil fuels (initially coal, consequently oil and natural gas) has given and still gives humanity a large amount of energy which has shifted our civilization forward. Thanks to fossil fuel power, industry, transport and housing have grown significantly. Thereafter, the level of education, medical care and social security has increased.

Already many years ago, the negative phenomena of intensive burning of fossil fuels were also identified and analyzed:

- global carbon dioxide emissions that cause undesirable and irreversible climate change,
- the formation of local exhalations, especially polyaromatic hydrocarbons, nitrogen oxides and fine dust particles, which seriously harm human health

However, for almost whole twentieth century, these facts have not been solved. Only when their consequences have grown into gigantic proportions, humanity has been committed to a program-driven shift away from the use of fossil fuels.

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Replacement of fossil fuels with renewable energy sources is real, both physically, technically and economically:

- the energy equivalent of all global consumption of coal, oil and natural gas is 40 minutes of sunlight impacting the Earth's surface
- electricity from renewable sources is thanks to technical innovation becoming cheaper than electricity from fossil and nuclear power plants
- the principles of Industry 4.0 (Internet of Things) allow the coordination of power supplies and power consumption of appliances
- new forms of efficient energy accumulation are being developed
- a significant source of energy is its savings

2 DECARBONISATION OF MOBILITY

Similar to other industries, also transport faces a major challenge in reducing energy consumption and getting rid of fossil fuel dependency. This is not an easy task because in the Czech Republic, for example, 97% of the energy for transportation is supplied by oil products (diesel, automotive gas) and their substitutes (biofuels and natural gas) and only 3% electricity. But in fact, only unrestricted orientation on electric powered transport is a solution to sustainable mobility. That means mobility characterized by low energy consumption, zero local emissions and (in connection to the change in the structure of power generation) also zero global emissions. The decarbonisation of mobility is therefore solved by combination of two sub-tasks:

- replacement of fossil fuels powered vehicles by electric powered vehicles
- replacement of fossil fuels, till now used to produce electricity, by renewable natural resources

In a society with a developed division of labor, the first task is in the field of transport and the second role in the competence of the energy sector.

The specific issue of decarbonisation of mobility is that, compared to other technical devices, that transport vehicles are mobile energy consumers. Field of ground transport is based on two ways of powering vehicles:

- use of line electric power supply to vehicles (dependent electric vehicles)
- use of mobile electric energy storage on vehicles (semi-electric vehicles)

Both of these methods are not in a competitive position. They can mutually complement and use (or co-create) a common energy infrastructure:

- high-power and high-efficiency line power supply of the vehicles is suitable for heavy and regular transport streams, where it is worthwhile to set up and operate investment-intensive linear fixed traction systems (traction lines and traction power stations)
- mobile power storage, which are characterized by lower performance and lower efficiency, are suitable for power supply for weak and irregular transport streams, where it is not worthwhile to set up and operate line rigid traction devices.

3 SUSTAINABLE, NON-EMISSIVE MULTIMODAL MOBILITY

Transport of persons and things are traditionally ensured by more methods of transport. They are in a competitive position, and they also seek to obtain transport tasks which are inappropriate for them, where they are not effective. For example use of public transport capacities for weak transport or, on the contrary, the use of individual cars to travel in the direction of strong transport flows.

In contrast to this, non-emission multimodal sustainable mobility is based on cooperation and complementarity of individual modes of transport. It operates on a hierarchical principle, structured according to the intensity of the transport stream. From the weakest transport streams provided by individual means of transport on a not-so-perfect transport route to the most powerful transport streams, provided by means of mass transport on a high-quality and highly sophisticated transport route.

4 INTRA-MODAL AND EXTRA-MODAL ENERGY SAVINGS IN TRANSPORT

Residents of the Czech Republic belong with production of about 12 tonnes of carbon dioxide per inhabitant and a year of very significant initiators of climate change, exceeding not only the average of the world but also the EU average. This is directly related to the high energy demand of the Czech economy. This fact is excused by the claim, that the Czech Republic is an industrialized country. However, this is not exactly the right defense, as transport with its 27% in the Czech Republic contributes to final energy consumption almost the same as industry (it has a 30% share). The current dynamics of energy consumption in the Czech Republic is so, that despite increasing production volumes, the final energy consumption in industry has remained roughly unchanged in recent years. However, final energy consumption in transport has increased by 12% in the last three years, 4% per year. Both the global emissions of carbon dioxide (with a negative impact on irreversible climatic changes) and the local emissions of toxic fumes (with a negative impact on human health) have increased proportionally. Such a trend is unacceptable, fundamental changes are a must. Citizens' demands for the regulation of the street transport are fully justified. Structural changes are necessary and should be supported by targeted technical innovations.

There are quite significant differences between energy demands of different category of transport:

- The rail transport systems have a lower resistance of the rolling of the steel wheel on the steel rail. Due to the low aerodynamic resistance of the long slim vehicles forming the train, roughly 3 times lower traction resistance. With that is lower energy consumption than the individual moving road vehicles
- Electric traction drives have approximately 2,5 times higher efficiency and therefore a proportionally lower power consumption than internal combustion engine drives

In the product of these two factors (3 x 2.5 = 7.5), electric powered rail vehicles are roughly 7.5 times less energy consuming than road traffic provided by cars with internal combustion engines.

From this reality there are two basic options for energy savings in transport:

- intramodal energy savings resulting from increased energy efficiency in a particular type of transportation
- extramodal energy savings resulting from the transformation of a transport from energy-intensive type of transportation to less energy-intensive type of transportation.

An effective tool for achieving both intramodal and extramodal energy savings in transport is the technical innovation:

- new technologies reduce the energy demands of each type of transport
- new technology increases the attractiveness (speed, comfort, ...) of less energy demanding types of transportation. This motivates the population to switch from more energy-intensive modes. Increasing the speed and comfort of public transport are therefore a significant way to save energy.

The fact, that the both way of the transport (transport of persons and the transport of goods) has dominated the energy-intensive road car transport in the Czech Republic, creates a great potential for the benefits of extramodal savings.

5 TECHNICAL INNOVATION AS A TOOL FOR DEVELOPING SUSTAINABLE MOBILITY IN THE FIELD OF URBAN RAIL TRANSPORT

In the sense of the mentioned principles, it is necessary to assess the relationship of individual transport (mainly ensured by cars powered by internal combustion engines) and mass transport (mainly provided by rail systems with electric power) in cities. For example, the City of Prague demonstrates the energy and environmental impacts of both:

- individual car transport provides about 50% of the transport capacity of the urban transport in Prague and consumes 88% of the energy spent on Prague passenger transport
- urban public transport also provides about 50% of Prague's public transport services, but uses only 12% of the energy for Prague's passenger transport.

By the assessment of the exhalation of harmful substances (NOx, PAH, especially benzo(a)pyrene, PM 2.5 and PM1 fine particulate elements) the disproportion between individual and mass transport is even sharper.

The basic aim are therefore extra-modal savings, so such solutions of the public transport systems, that motivate people to move away from the use of cars. Automobile transport is available for the population (material poverty has passed) and creates basic criteria for urban transport:

- traveling by public transport must not be slower than traveling by car
- people are sitting in a car, it does not make sense to offer them stand places, even worst in crowded vehicle
- modern cars are normally equipped with air conditioning, and there will be no success to offer them vehicles without air conditioning.

Of course, importance in urban transport also has intramodal energy savings. Territorial operation of public transport, based on the principle of stopping, that is, based on the constant periodic creation and abatement of the vehicle's kinetic energy. There are two basic requirements for urban public transport vehicles:

- weight minimization (as a parameter weight/seat)
- wide application of electrodynamic regenerative braking

Both in light vehicle construction and in the field of electric traction drive management, ways to reduce of the energy consumption of the driving cycle are still sought and found. However, given the matured state of the technic, there are no longer potential of significant saving.

Attention is paid to the savings of the secondary energy consumption, especially the energy needed to create thermal comfort inside the vehicle. With respect to the relatively low travel speed (and therefore long time needed to travel a certain distance) and the frequency of the opening of the doors at stops, urban public transport vehicles have a secondary energy consumption comparable to traction consumption. Therefore, measures to reduce non-traction consumption are important. A very positive contribution can, for example, be achieved by controlling of the amount of fresh ventilation air based on the carbon dioxide concentration inside the vehicle.

Another very important and very perspective trend is the extension of the electric car to sections without line power supply. That means the application of electric energy storage on vehicles. Depending on the time available for charging and the required range, either the fast-reacting two-layer capacitors or the slower lithium electrochemical accumulators are used. Or combination of both above mentioned solution.

6 TECHNICAL INNOVATION AS A TOOL FOR DEVELOPING SUSTAINABLE MOBILITY IN THE FIELD OF REGIONAL RAIL VEHICLES

Regional passenger rail transport has two fundamentally different forms:

- suburban regional transport, which takes place on main lines radial heading to large cities. The tracks are electrified, two-track, with a relatively high speed (typically 160 to 200 km / h). Regional passenger trains are operated on tracks with passenger and freight trains. They are the slowest segment of train traffic, limiting the track performance
- rural regional transport, which takes place on regional lines, usually departing from the main lines. The relevant tracks are not electrified; they are only single rail, with low speed (typically 60 km / h). Regional passenger trains are almost the only kind of the train traffic.

These two different forms of regional passenger rail transport determine a pair of different vehicle requirements:

- for regional suburban trains running on main lines, high-capacity vehicles are required as the interval between regional trains can no longer be reduced. The lines must remain also free for other types of the transport, especially long-distance passenger coaches and freight transport. The solution could be semi-double-deck vehicles. Complete electric units combine double-deck non-traction wagons, fully used for passenger transport, and single-deck traction wagons with electric equipment on the roof. Vehicles of this type achieve the highest ratio between the number of seats and the required platform lengths, which is the decisive parameter in providing traffic on the heavily loaded main lines. The second basic requirement for these vehicles is the highest operation speed. It assists in addition to the fast changing of passengers at stops (double-leaf doors placed along the whole length of the vehicle), especially the proper driving dynamics. That cause rather big technical speed of the vehicle. Its achievement is conditioned by a high proportion of driven and dynamically braked wheelsets and high traction power, as well as even higher braking power. Dynamic operation, typical by periodic alternation of the acceleration and braking, that means the creation and dissipation of kinetic energy, leads to the demand on low vehicle weight (more precisely: the low weight of a vehicle per seat) and using only electrodynamic regenerative braking. This is on the rail, in the case of AC power supply, able to transmit recovered brake energy to other (just starting) vehicles but also back through the traction power stations to the general three-phase distribution network
- in order to enable regional railways to motivate the population to use them, they must be integrated into the regional transport system. The way how to achieve that, are no-stop trains without that switch from main electrified lines to secondary non-electrified lines. It is not in many cases useful to electrify these tracks. Therefore, a two systems (pantograph / accumulator) are needed to provide direct trains using the network of both electrified and non-electrified railways. In case of the tractionless operation, the traction accumulator uses the traction battery not only with the basic energy source for driving but also with the use of regenerated kinetic energy during stopping and braking.

A very important technological innovation that has significantly shifted forward traction technology are bogie frames with an internal bearing. Their use was conditioned by the construction of traction drives and brakes into a more limited space. However, the result in the form of savings of about one third of the weight achieved on the bogie, that is very big benefit for a component which determines the total weight of the rolling stock. It has very positive consequences for rail transport:

- there is a significant saving in the overall weight of a vehicle with a positive impact on driving dynamics and energy consumption

- the reserve obtained in the weight balance of the vehicle can be used to extend wagon length and thereby increase its transport capacity. There will be further reduction of the vehicle's specific weight per seat
- Due to the extension of the carbodies, the same length and capacity can be realized with units with fewer vehicles, that mean with fewer bogies, which further increases the weight reduction effect and corresponding energy savings
- the reserve obtained in the weight balance of the vehicle can be used for the application of light Jakobs bogies with inner frame also in the vehicle, where the use of the Jakobs bogies with traditional heavy frames with the outer frame did not seem appropriate. Particularly in combination with the extension of the vehicle bodies, it is possible to make concept of very light and simple (with a small number of wagons and bogies) units with low energy consumption
- obtained reserve in the vehicle's weight balance can be used to place energy storage lithium accumulators needed for the creation of two-source (trolley/accumulator) vehicles with a range of approximately 80-100 km, suitable for the operation of 40 to 50 km of non-electrified lines. Charging their accumulators is carried out from the traction line while running or when standing on electrified lines, or in electrified stations. These vehicles can be provided with clean, non-emissive operation even on lines without line electrics
- obtained reserve in the vehicle's weight balance can also be used alternatively to place hydrogen cells

7 TECHNICAL INNOVATION AS A TOOL FOR THE DEVELOPMENT OF SUSTAINABLE MOBILITY IN THE FIELD OF LONG-DISTANCE AND HIGH-SPEED RAIL

The ability of rolling stock to complete a train, a long group of cars moving in mutual overlap, has a major impact on their aerodynamic resistance and also on the energy consumption. Importance of this ability increases with the second power of driving speed. The practical usability of individually moving vehicles (cars) ends around speeds just over 100 km / h, which leads to very long transport times even when they are operating at medium distances. This limits for example business trips to a distance of about 200 km, with longer distances more than half of eight hours of work time is lost. This limit undesirably growth of social and economic activities only in the near of the capital (typically in the Czech Republic: Prague and the Central Bohemian Region) and separates them from the wider area. Even the airplane is not a suitable solution for one-day business trips, which are the basis of functional territorial integration. The minimum travel time is (in addition to the trip to the airport) even at a short distance of 2 to 3 hours. On the rail, thanks to long slim aerodynamically shaped vehicles with low air resistance, the speeds of 300 to 350 km / h can be used, and thus short transport times, without being accompanied by high energy consumption, in addition with non-emission electricity.

Until the construction of high-speed railways is finished, long-distance passenger rail transport is provided on conventional lines by speed of 160 to 200 km / h. In this service, the locomotives operated (pushed or pulled) non-traction units are very well proved:

- delivering intramodal energy savings because they achieve a low aerodynamic resistance, which determines the energy performance of fast-moving vehicles
- delivering extramodal energy savings. The high level of travel comfort of a branded transport product with a guaranteed level of travelling motivates citizens, traditionally using energy-intensive automotive transport, to switch to rail.

In the high-speed rail segment, a continuous technological development is taking place on both the railways (CCS subsystem: switching to ETCS level 3, ENE subsystem: continuous single phase 25 kV 50 Hz (or 2 x 25 kV 50 Hz) using IGBT multilevel traction power stations 3 AC / DC / 1 AC) as well as on the vehicle side.

As in the area of regional transport, bogie frame technology with an internal bearing also comes into the field of high-speed vehicles. In addition to the already mentioned extension of the unit length, which the bogies with the inner frame allow (usually 200m long unit could consists of 7 wagons 28m long instead of 8 wagons 25m long), there is also lower aerodynamic resistance on narrower and more covered bogies with an internal frame at high speeds. The result is a reduction in the train's aerodynamic resistance and, therefore, 30% energy consumption compared to the former vehicles solution of the previous generation. This is a very significant step forward, bringing the energy demands of high-speed trains with aerodynamic trains to the energy demands of conventional railways run at half-speeds by traditional train. The doubling of speed does not mean higher energy consumption.

8 TECHNICAL INNOVATION AS A TOOL FOR DEVELOPING SUSTAINABLE MOBILITY IN RAIL FREIGHT VEHICLES

Also in the rail freight sector are innovative vehicle trends, represented in particular by the development of interoperable high-performance electric locomotives which replacing older, less efficient locomotives, motivated by extramodal and intramodal energy savings. In the field of freight transport, energy savings have strong economic accent. Transported goods do not require as much care as the transport of persons. Freight wagons are therefore both investment and operating significantly cheaper than passenger transport vehicles. As a result, the cost of energy in the total cost calculation of rail freight is a relatively more significant item than the cost of energy for the rail transport of persons. This motivates rail freight operators to take energy-saving innovative solutions.

In the area of extra-modal savings, that mean savings achieved by replacing energy-intensive and environmentally high-cost road freight transport by rail transport, the basic motivational factor is travel or transport speed, which determines the attractiveness and productivity of freight rail transport. Traditional freight trains with a specific output of around 1 kW / t (using 2 MW locomotives to transport 2 000 tons trains) are moving slowly, so they have difficulty to reserve the route on the heavily loaded lines. Freight trains transported by high-performance 6-MW electric locomotives have a specific output of around 3 kW/t and are therefore able to be operated with fast trains and thus have a higher travel speed.

In the area of intramodal energy savings, the used frequency-controlled asynchronous traction motors technology positively demonstrates not only lossless start and recuperative braking, but also lower losses in fixed traction systems of the 25 kV 50 Hz as they only take active power (sinusoidal current in phase with voltage). Modern electric locomotives do not burden (unlike older locomotives with diode rectifiers) the traction network by taking reactive or deformation power. Also, they do not need filtering compensating devices for their operation in traction power stations, which work with high energy losses.

9 CONCLUSION

In the nineteenth century, the development and construction of railways was essentially connected with the mining, transport and use of fossil fuels, mainly coal. Nearly two hundred years have passed, during which the whole society (including the railways) has shifted due to the fossil fuel energy forward. The related development of technology and education gave human society the knowledge and the economic power to reduce its energy consumption, to stop using fossil fuels and replace it with electricity from renewable sources. The goal is to stop irreversible climate change and harming of the human health through toxic exhalations. However, this is not a reason to limit traffic. This can be further developed on the basis of sustainable and non-emission multimodal mobility.

PEER COACHING

Kateřina POJKAROVÁ[1]

Abstract
There are many professional coaches that help people in many areas in their life. In some companies they think of coaching as a benefit for their employments. Professional coaches are quite expensive and that could be reason for not using this “method”. Nowadays, there is another option, which is peer coaching. It means coaching in not so professional way, but in more friendly and familiar way. This paper will describe what peer coaching is, the benefits of it and it will give some advices how it could start, even in transport company.

Keywords
peer coaching

1 INTRODUCTION

There are many organizations of professional coaches at world level (such as The International Coach Federation or The International Coaching Community), at European level (European Mentoring and Coaching council) or national (like Czech association of coaches). These organizations associate thousands coaches and offer professional services. Despite of that there is another way how to achieve benefits of coaching, even at workplace. The way is called peer coaching, which means coaching between teammates or workers at the same level in organization. Whitmore [1] states that coaching is “unlocking a person’s potential to maximize their own performance“. In contrast to teacher, coach helps others to learn even when he doesn’t teach them. International Coach Federation [2] describe coaching process this way: “A qualified, trained, and paid coach works in partnership with a client in a thought-provoking and creative process that inspires them to maximize their personal and professional potential.” Thanks to coaching is coachee able to find for himself decisions and become a leader for his own live.

The whole idea of coaching comes out of assumption that coachee is the expert in his life, that means that he can discover what he wants to achieve and how. He doesn’t need mentor who give him not wanted advices. He is responsible and accountable for his decisions and for his life. What coachee needs is someone who encourages him to discover answers for him.

According to research done by ICF [2] there are positive results of coaching in general. Here are some results:

- 70 % higher productivity,
- 61 % better business management,
- 57 % better time management,
- 51 % better teamwork.

It also can bring more satisfied employers, with higher self-confidence (80 %), better relationships (73 %) and better communication skills (72 %).

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2 EXPLANATION OF PEER COACHING

The difference between classical coaching and peer coaching is in the coach, who is not well trained professional, but one of teammate. It is someone who work at the same organisation at similar level, or it could be someone who works in other organization but still in similar level. Robbins [3] said: *"Peer coaching is a confidential process through which two or more professional colleagues work together to reflect on current practices; expand, refine, and build new skills; share ideas; teach one another; conduct classroom research; or solve problems in the workplace.*"

Robbins also se benefits of peer coaching, which can be analysing practices and their consequences, implement new strategies, build new skills and solve workplace challenges.

So the peer coaching is based on a professional (not only social) dialog, which can be held during formal or informal meetings, meals or walks. The relationships between peers should be founded on trust, without any type of competition. Both should feel confidential and know that it is voluntary. Peer coaching helps learn, share now ideas and solve problems connected with job. It's not about giving advices – and it could be quite difficult for coach in the beginning. He needs to learn how to actively listen, be a partner in discussion and help the coachee find answers for himself. He gives he an opportunity to search for own ideas, even if it takes more time. When coachee has the opportunity talk loudly what he thinks, it helps him make clear the whole problem, doubt previous assumptions, evaluate various ways for solving the problem and commit to one of them.

Coach and coachee can change their role, so both has the opportunity to think about their own problems and how to move on. These coaching dialogues are repeated in 2 to 4 weeks, and this process continues for months, as it is needed.

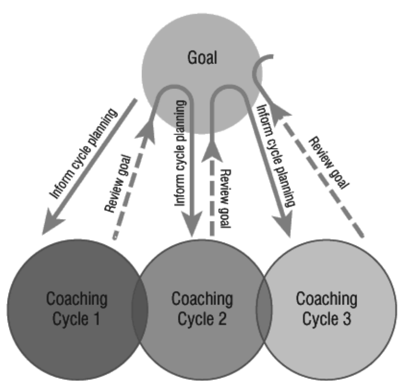

Fig. 1 Coaching cycle – goal based model (Source: [4])

2.1 Benefits of peer coaching

As Steffe Maier [5] says "Individuals use their own resources to find solutions to problems. The peer coach serves as facilitator, helping the other party identify and select the best options. Together, they share knowledge about successful interventions and techniques, redefine goals and opportunities and clarify facts and assumptions." Dialog with peer can be much less frightening than with a manager and yet it could bring good results, such as increase problem-solving capabilities.

Motivation of employees increase when they feel that someone cares for them. As Pink [6] states, the motivation of employees are increase when there is purpose, autonomy and mastery, which is much better than just monetary bonuses. These type of motivation is counter-productive, because the vision of more money distracts brain from focusing on the task and then the productivity goes down. Peer coach can help coachee to find the purpose in his job and also improve his skills, his mastery. And then, the productivity can increase also.

Another aspect of coaching is better conversations in the work place, and better atmosphere. They are more willing to listen to others and are open to new ideas. The proactivity is another benefit of peer coaching. People learns to think more what they can do, what they can change, and they less think like victims. Suddenly there are more responsible employees who want to change things for better and help the whole organization to be better place with better results.

Unlike professional coaching, this is cheap; there is no needed time for long travelling to coach (if the coach is from the same company), no need for special time, which is not suitable for the coachee.

2.2 Tips for start and improving peer coaching in organization

There can be some short training for everyone who wants to participate in peer coaching. In this training there is explanation, what does it mean, how the coaching process looks like and participants would have an opportunity to try some exercises. They need to now, that there are some points essential for peer coaching, such as:

- Trust between partners
- Emphatic listening
- Good questions
- Focusing on a goal
- Voluntariness and commitment

In the beginning, peers needs to make agreement, in which they stated the goal of coaching, times and places for meetings, frequency and other organizational items. In the beginning of every session, one of the first questions should be: What would you like to talk about today? On what you would like to focus? And at the end of the session, useful questions should be: What do you take away from this session? What action will you take next?

Coaches would remember that

- Theirs questions should be open (like What you can do? instead of Will you do that?)
- Why questions hardly bring good results in coaching
- Simply questions are better than complicated ones
- They need to stay focused on the theme

They also need to be good listeners, so they should avoid any distractions, focus also on coachee’s speed, tone and volume, be patient and stay still when the coachee is silent. This is time when he go deep inside, where he can find the best answers.

Reframing or summary is another coach’s skill. It can helps coachee know that coach is really listen and understand, and in the other way, coach will know if he didn’t miss something important.

3 EXPERIENCES WITH PEER COACHING IN CZECH REPUBLIC

Due to simple research, there are quite enough people, who have some experience with coaching and few had an opportunity to try peer coaching (almost 30 %). Their experiences are “positive” and “good”. For them the benefits are: birds-eye view of given situations, finding better directions and onself’s weaknesses and quicker learning.

On the other hand, people who don’t have any experiences with peer coaching imagine these benefits:

- New, impartial, point of view
- Better understanding of solving problem
- More effective work with people, better communication
- Higher accountability of coachee
- Higher self-confidence, finding oneself’s strengths and weaknesses
- Encouragement

- Finding better methods in a work

There are also those who don't know what it is, they think „there are no benefits"in coaching or peer coaching, it is only "new name for well-known practices" or even it means "a medicine man dancing around the fire". Still there are a lot of people who see coaching or peer coaching as classical way, how to gives instruction to the coacheee. More than 36 % respondents don't know what peer coaching is and they even don't try to guess what it could be. These results are quite similar in transport sector, with slightly more people who has experience with coaching.

Subjective evaluation of coaching benefits is 7.5 points (from 1-10 scale) with standard deviation 2.5. 67 % of respondents evaluate coaching with 8 or more points.

4 CONCLUSION

Peer coaching is not new thing but still it is something which is not used often in workplace and lot of employees still don't have any idea how it looks like, what benefits it can bring or how to use it in their job. For managers, or better for leaders, who know that their job is to take care for those who take care for costumers, this could be a way that can help their people and of course their numbers too. It requires a little effort in the beginning and patience for the results, but after a while, the culture and productivity will change for the better.

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FACULTY OF TRANSPORT ENGINEERING 25 YEARS

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TARGET RELIABILITY OF STRUCTURES IN THE CONTEXT OF BAYES' THEOREM

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Abstract

This paper deals with target reliability determination of structures. In the first part, terms risk and reliability are delimited. Further, the difference between the understanding of reliability in civil and machinery engineering is shown. The widely used safety index is a subject of a deeper analysis and its relation to target reliability is presented. The second part of this paper contains a summary of a target reliability estimation, as it is calculated in the present time, and a draft of an alternative approach to the target reliability determination using the Bayes' theorem.

Keywords

risk, safety, structure, probability, Bayes' theorem

1 RISK AND RELIABILITY

The terms of risk and reliability are parts of a quality management terminology. They are basically antagonistic. Whereas risk is widely understood as a combination of frequency or probability of an occurrence of specified dangerous incidents and their consequences, reliability is defined as a stability of utility attributes (functional, ecological, safety, etc.) of a product or an object for certain, preset period of time and under preset conditions of use.

The above-mentioned quality management is (as a part of management in general) hierarchically superior to:

- *Risk management* – focused on identification and analysis of risks, their minimisation, determination of maximum permissible risk, i.e. decision making in order to set an acceptable level of danger while justified public interests are taken into account.
- *Reliability management* – focused on reaching and maintenance of a real risk level on the safe side of the limit level set by risk management and a permanent control of meeting the required criteria.

In the technical point of view, quantitative methods based on theoretic grounds of the theory of probability and statistics are essential. There are two basic ways of quantification used at applications of the mentioned methods, namely:

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- *Measurement* – obtained quantitative signs are variable, i.e. they are subject of a random fluctuation, which shows, however, some internal behavioural patterns. Therefore, it is possible to work with these signs like with a statistically random variable.
- *Numbering* – numbers give the amount of discordant units in a random selection. There are discrete random variables, most often 0 or 1, where only the option yes – no can be declared. These quality signs are called *attributive*.

Traditional (i.e. classic) quantitative statistical methods suitable for this purpose are:

- data files assessment – calculation of basic statistical characteristics and study of obtained histograms,
- use of various graph types designed in order to gain clarity and illustration of studied analyses,
- Pareto analysis – serves to identification of basic decisive reasons of the researched effect. According to Pareto principle, only a few of many possible reasons are significant. It is based on their relative frequency or cumulative relative frequency,
- correlation and regression analysis – for determination or confirmation of stochastic dependency of researched quantities,
- statistic regulation of processes – for statistical stability assessment of researched processes.

2 RELIABILITY OF PRODUCTS AND STRUCTURES

The understanding of reliability problems varies significantly in the structural or machinery engineering point of view. However, at more detailed analysis, reliability in the structural point of view proves to be an organic part of reliability in general.

The seeming contradiction comes in the phase of distinguishing of objects to *repaired* ones and *non-repaired* ones. Basically, it means that:

- *Non-repaired* objects represent the bigger part of factory industrial production nowadays; where product that does not fulfil its function is not more feasible to be repaired and is better to be exchanged for a new one. This applies to e.g. transistors, radios, cookers, etc., as well as to some parts of more complicated machines and instruments (e.g. rotors of electric motors, etc.).
- *Repaired* objects are, for various reasons, not easily replaceable for new ones and are needed to be returned to the working state by repairs, even multiple ones.

Structural objects (structures) belong, obviously, to the repaired set of objects, as it is being confirmed even by the existence and continuous development of an individual discipline of structural production that deals with rehabilitation and reconstruction of structural objects. Only a smaller part of production in structural engineering belongs to the group of non-repaired objects, e.g. prefabrication of structural elements.

3 MEANING OF USED SYMBOLS

Tab. 1 Meaning of used symbols

B	*safety index*
μ_M	*mean value*
σ_M	*standard deviation*
B(p)	*utility from object existence*
C(p)	*price of project and object realization*
C0	*object acquisition price*
C_f	*costs connected to remedy of limit state exceeding*
D(p)	*unknown value*
E	*life expectancy in years*
GDP	*gross domestic product per year and capita*
P_f	*probability of failure*
P_d	*target reliability*
P_{dn}	*probability for n years*
P_{d1}	*probability for 1 year*
P(H)	*probability expression of confidence to H hypothesis before D data receiving*
P(H|D)	*probability expression of confidence to H hypothesis after D data receiving*
R	*structural resistance*
S	*structural loads*
N	*number of years*
P	*vector of all safety parameters*
W	*life share dedicated to economic activity*

4 TARGET RELIABILITY AND SAFETY INDEX

Currently, maximum allowable risk for structures is expressed by two, fully equivalent ways, namely:

- target reliability, marked as P_d in structural engineering, expressing the limit permissible probability of failure P_f,
- safety index, marked as β in structural engineering.

The mutual relation between quantities P_f and β is presented by equation:

$$P_f = \Phi\left(\frac{0-\mu_M}{\sigma_M}\right) = \Phi(-\beta) \quad , \tag{1}$$

where safety requires meeting the condition of:

$$P_f \leq P_d \; . \tag{2}$$

Fig. 1 shows the relation of probabilistic and semi-probabilistic approach of safety. The semi-probabilistic layout is expressed by position of the centre of the white triangle, as an unambiguous result. In reality, it is not that simple and the stochastic character of reality is depicted by the set of points. The boundary between satisfactory and unsatisfactory cases creates the line of:

$$R = S\,. \tag{3}$$

The probability density with a graphic interpretation of probability of failure P_f and safety index β can be well seen in the cross-section.

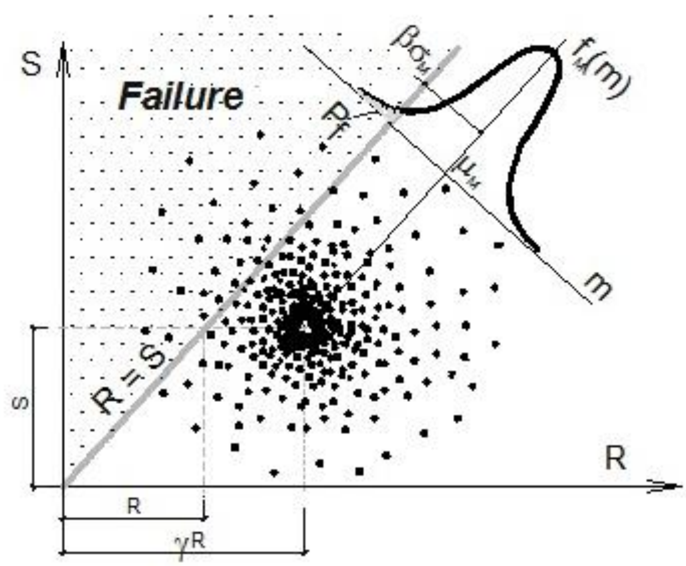

Fig. 1 Relations of various structural safety theories [14, 16]

As expressed in formula (1), quantities P_f and β are fully equivalent. Their calculation is accomplished by methods of statistics and probability. There are many proven procedures of these calculations.

On the contrary, the value of P_d determines the target reliability that is acceptable in the limit states point of view. The determination of this value does not fully comply with the probability characterisation of the structures reliability problems and is burdened, in many cases, by semi-probabilistic way of thinking that is valid in contemporary standards.

5 TARGET RELIABILITY DETERMINATION

Key values of *R* and *S* functions have been determined by deterministic, later semi-probabilistic methods. Currently, a complete shift to fully probabilistic solutions of formulae (2) and (3) is on the way. Simulation methods based on applications of Monte Carlo method are, along with an outstanding development of computers, mighty means to universal implementation of this quality turn.

In the deterministic approach, it is sufficient if the unambiguous solution of formula (3) is located in the safe area $R > S$, in the worst case on the boundary $R = S$. The probabilistic approach is ambiguous, as shown by the set of points on fig. 1. It admits the $R < S$ cases happen inevitably, too. As the reliability and safety measure, a permissible presumable number of these unfavourable cases are accepted.

For the probabilistic solution, formula (2) transforms into formula:

$$P_f = P[R - S < 0] \leq P_d \,. \tag{4}$$

Considering the simulation methods as well elaborated, the problem of probabilistic control of system reliability reduces to a responsible determination of maximum permissible limit of P_d.

Obviously, it is not possible to set one universal limit value of P_d. There are many issues that influence the choice of P_d, e.g.: system operation conditions, external natural forces, severity of consequences of system breakdown, etc. Moreover, it is not completely clear whether an exceptional value of P_d shall be set for exceptional design situations. More frequent catastrophic situations as a result of terrorist attacks and global warming of the Earth, in particular, provide good reasons to this move. However, the only different values of P_d are for ultimate limit states and service limit states.

Examples of exceptional P_d values set for exceptional design situations are following:

- probability of failure of nuclear power plant is set in the USA as $P_d = 10^{-6}$,
- probability of crash of an airliner within one hour of flight is set as $P_d = 10^{-9}$.

Values of ordinary design situations are following:

- $10^{-7} < P_d < 10^{-3}$ for ultimate limit states,
- $10^{-3} < P_d < 10^{-1}$ for service limit states.

Recently, a shift towards service limit states design could be clearly noticed. This approach better characterizes the influences of corrosion and external environment in general as they are deciding in the long-term reliability point of view. The SBRA simulation method shows [1], based on structure importance and limit state group:

Tab. 2 SBRA values P_d

Structure Importance	Ultimate Limit State	Service Limit State
Low	0.000 5	0.16
Average	0.000 07	0.07
High	0.000 008	0.023

Another approach comes from the probability of failure in an interval of one year; for determination of probability of failure in a longer interval, the formula stands as:

$$P_{dn} = 1 - (1 - P_{d1})^n \,, \tag{5}$$

where n is number of years.

The economic point of view respects relation:

$$P_d \approx \frac{C_0}{C_f} 10^{-3} \,. \tag{6}$$

Apparently, the higher the cost connected with remedy of exceeding of the limit state C_f is, the lower the permissible P_d is.

JCCS recommendation [14] takes into account economic viewpoints, too. Preliminary values of P_f and β with respect to the interval of 1 year and the considered limit state are presented in the tables 3 and 4. It is apt to notice that in accordance with our conventions and meaning of eq. (2), P_d appears as a more correct notation in these tables instead of P_f.

Tab. 3 Limit values for interval of 1 year and ultimate limit states

Reconstruction Costs	Low Failure Consequences	Average Failure Consequences	High Failure Consequences
High	β = 3.1 (P_f =10^{-3})	β = 3.3 (P_f =10^{-4})	β = 3.7 (P_f =10^{-4})
Normal	β = 3.7 (P_f =10^{-4})	β = 4.2 (P_f =10^{-5})	β = 4.4 (P_f =10^{-5})
Low	β = 4.2 (P_f =10^{-5})	β = 4.4 (P_f =10^{-6})	β = 4.7 (P_f =10^{-6})

Tab. 4 Limit values for 1 year interval and service limit states

Reconstruction Costs	Limit Values
High	β = 1.3 (P_f =10^{-1})
Average	β = 1.7 (P_f =5.10^{-2})
Low	β = 2.3 (P_f =10^{-2})

It is clear to see that there is not a unifying principle in such important problems like determination of the target reliability of building structures. This results in new tendencies to find a satisfactory theoretical outcome that enables determining of P_d values.

Contemporary efforts aim to define so called optimal and best practice structure, which use “economically considered“ best practice design.

Regardless the theoretical details (published e.g. in [15, 16]), the determination of optimum value of the target reliability leads to consequences in human life loss expressed by LQI (Life Quality Index). LQI is a conglomerate of social indicators and is characterized by definition:

$$LQI = GDP^{w} E^{1-w} . \qquad (7)$$

i. e. that life quality and its value, too, are assessed according to purchasing power of population. This is, apparently, different across different countries in the world. [15] presents a general relation of life expectancy E depending on purchasing power and its graphic presentation is shown on Fig. 2.

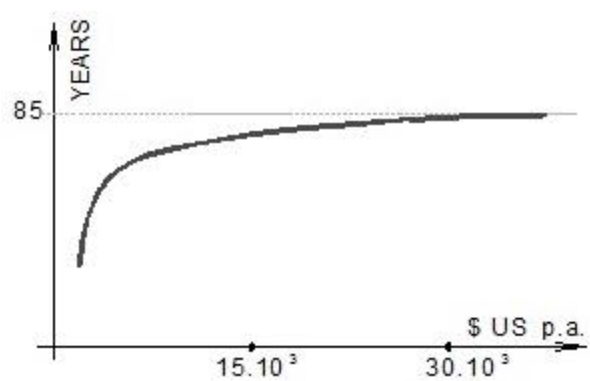

Fig. 2 Curve of life expectancy depending on yearly purchasing power of population [14, 16]

The relation is well defined by the equation:

$$E = a \ln(P - b) + c , \qquad (8)$$

with following values of parameters:

a = 7.1874,
b = 371.5,
c = 6.2075,
P = stands here for yearly purchasing power (horizontal graph axis of Fig. 2):

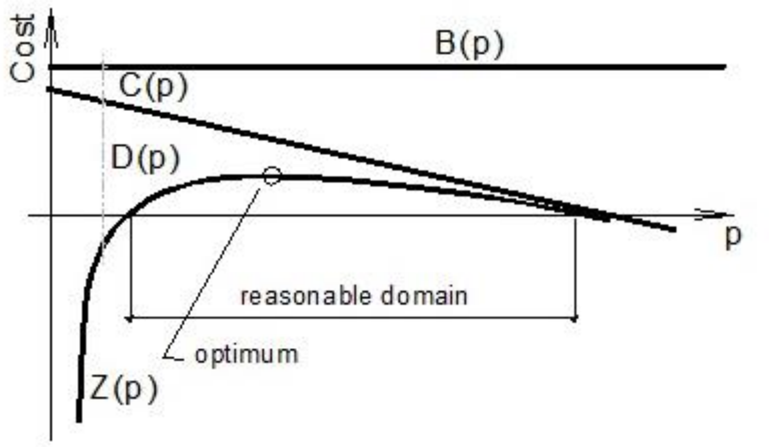

Fig. 3 Progress of the objective function Z(p) – equation (9), [14, 16]

[16] assumes that LQI can be considered as a social indicator for establishing a theory of target reliability and technical objects, including structures, optimization, too. Target reliability of a structure can be considered as optimal, according to [16], if the following objective function is maximized (see Fig. 3):

$$Z(p) = B(p) - C(p) - D(p)\,, \tag{9}$$

All quantities in equation (9) are measured in monetary units.

All other contemplations suppose that the complete equation (9) is differentiable by *p*. At the same time, *C(p)* is considered as rising, whereas *D(p)* as sinking and *B(p)* as constant. Only positive values of *Z(p)* are suitable for reliability calculations – hence target reliability calculation, too. "Suitable" modifications of objective functions for various reliability situations are considered at the same time. Elaborated mathematical theory is indicated and accessible in [11, 15, 16].

6 BAYES‘ STATISTICS POSSIBILITIES

The foregoing text indicates that a target reliability value is valid for a certain group of objects (structures) for given limit state if the target reliability is proposed (by any of the above presented method or value).

It is desired in the economic point of view that not all the individual objects are made on the same quality level, and target reliability value can be changed at every single object based on regular observations (rechecks – measurements). Regrettably saying, building objects are generally not controlled that much over time to make the advantages of Bayes‘ statistics usable.

Bayes‘ theory of probability, called subjective probability, too, provides theoretical apparatus to specification of a priori probability based on running control. It delivers a postulate that:

A priori probability emerging from information before an experiment has been done can be modified to a posterior probability after one or more experiments that are random have been done. A posterior probability respects both initial knowledge and selective information from additionally made experiments.

Bayes‘ formula was firstly published in 1763 in the posthumously edited work of Presbyterian ecclesiastic Thomas R. Bayes: An Essay Towards Solving a Problem in the Doctrine of Chances. Formula, easily derivable with rules of conditional probability, caused confusion and disputes among statisticians, mathematicians and philosophers for coming 242 years (i.e. until present time).

Bayes formula in its most simplified form for hypothesis *H* and data *D* can be expressed in the following way:

$$P(H \mid D) = \frac{P(D \mid H)P(H)}{P(D)}, \tag{10}$$

Instructions for given *P(D|H)* and *P(D)* how to learn from gained data are contained in the theorem.

Bayes‘ theorem is published in different (as needed) variations for practical calculations, e.g.:

- For getting a new information about commence of A effect at conditional probability of B_j, *j=1,2,…n, effects:*

$$P(B_j \mid A) = \frac{P(B_j)P(A \mid B_j)}{P(A)}. \tag{11}$$

- For random selection of *n* range with intentions to study a random quantity X_j, it is possible to set an a posterior probability density *θ* based on selection observations *x = (xj), j = 1,2…n:*

$$f(\theta \mid x) = \frac{f(\theta)L(x \mid \theta)}{\int f(\theta)L(x \mid \theta)d\theta}. \tag{12}$$

where $L(x|\theta) = f(x_j)$ is so called likelihood function and integration in the denominator applies to all possible *θ* values.

7 EXAMPLE OF BAYES’ THEOREM APPLICATION IN CIVIL ENGINEERING

Civil engineering structures are sometimes located on unbearable subsoil. Typical way of foundation procedure in unbearable subsoil is drilling of piles. By drilling of a pile, these failures can, apart from others, occur: when drilling a pile in gravel, a larger boulder or piece of rock can prevent the pile from penetration; when drilling a pile through clay, it is important not to stop drilling until the pile is fully placed, otherwise the clay can stick to the pile and significantly higher force (sometimes more than drilling machine is able to create) is necessary to set it into move again [17].

In an example, take a civil engineering company facing a task to build foundations of a bridge on a certain place with unbearable subsoil. The geological survey has shown, in the area of interest, 50 % of the subsoil is created by gravel, 40 % by sand, and 10 % by clays. If the pile failed to be placed into its final position and the company does not have any other information about probability of failures of this kind, it can assume that there was probability of 50 % that the pile failure was caused by gravel, 40 % by sand, and 10 % by clay. However, if the company was collecting information about the probabilities of failure of pile drilling (e.g. from own research, from other reliable data, etc.), it can estimate the probabilities more precisely using the Bayes’ theorem.

Let us suppose, in compliance with the previous paragraph, event A1: The material in the expected position of drilling of a pile is gravel. The corresponding probability is P(A1) = 0.5. Event A2: Sand, P(A2) = 0.4. Event A3: Clay, P(A3) = 0.1. Event B: The pile fails to get to its final position. The company can have additional information that probability of pile failure in gravel (e.g. due to hitting a larger piece of rock) is 5 %, and in clay 40 % (e.g. due to possible stop and inability to move again). Sands are very well drillable and let us assume the probability of pile failure is 0.1 %. These values correspond to P(B|A1) = 0.05, P(B|A2) = 0.001, and P(B|A3) = 0.4. Total probability of the pile failure is then:

$$P(B) = P(A_1) \cdot P(B|A_1) + P(A_2) \cdot P(B|A_2) + P(A_3) \cdot P(B|A_3), \tag{13}$$

which results in P(B) = 0.0654. Calculation of probability of the pile failure using Bayes' theorem (11) results in P(A1|B) = 0.382, P(A2|B) = 0.006, and P(A3|B) = 0.612. These results show very different perspective on failure source than the results prior to the incorporation of the additional information and the use of Bayes' theorem. Although clay is expected only in 10 % of pile locations, when a pile failed to drill into its final position, there is 61.2 % probability it occurred due to clay. More examples on the use of the Bayes' theorem can be found at [18].

8 CONCLUSION

Methods of probability assessment of structural objects – structures – are theoretically widely elaborated. Calculated results are compared to limit values, here referred to as target reliability. Any strict laws do not control determination procedures of these limits and there is rather a period of seeking after these laws. The key is in answer to this fundamental question: *What target reliabilities are safe enough?*

New information about risk level can be obtained by the use of Bayes‘ theorem independently on the way the limit value was set. This would, however, mean a regular control of important qualitative (essential for safety) indicators of finished “repaired“ work. This does not happen in structural engineering, yet.

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THE IMPLEMENTATION OF THE RFID TECHNOLOGY INTO THE HOSPITAL LOGISTICS PROCESSES: A CASE STUDY

Michal POLÁK[1], Jindřich JEŽEK[2], Jan CHOCHOLÁČ[3]

Abstract
Companies are constantly striving to streamline logistics processes and the functioning of the logistics system as a whole. One of the tools may be automatic identification technology. The aim of the article is to propose the implementation of RFID technology for a selected logistical process within a particular hospital through a case study.

Keywords
automatic identification technology, RFID technology, logistic process

1 INTRODUCTION

Storage is a very important part of the logistics of almost every company, because stocks have a major impact on the satisfaction of customers' needs and wishes. Therefore, it is imperative to store, properly register and manage inventory status. Satisfaction of customer needs ensures profitability for ordinary companies, and in most cases occurs when the customer's needs are not met to his lose and exit into a competing company. However, this is not the case in the health care section to which is devoted this article. Here the dissatisfaction of customer needs may in the worst case cause death of the patient due to insufficient quantity of product or its inappropriate condition. It is therefore important that hospitals always have access to the necessary goods and materials, regardless of whether these goods are from their own warehouses, consignment warehouses or goods that are always delivered at the necessary time under the contract. The aim of the article is to propose the implementation of RFID technology for a selected logistical process within a particular hospital through a case study.

2 THEORETICAL BACKGROUND

Logistics activities are necessary to achieve logistics goals [1]. These activities are part of the supply chain and include:

- Customer Service – serves to promote customer satisfaction.

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- Demand planning – linking production planning and marketing forecasts.
- Inventory management – the objective is to find a compromise between the level of customer service and the cost of holding inventory.
- Logistics communication – is an essential activity for the interconnection and efficient operation of the system.
- Material handling – provides a transfer of material, stocks and finished goods.
- Order handling – receiving and handling orders, communicating with customers.
- Packaging – shall, inter alia trade and marketing function.
- Support services and spare parts – activities under the after-sales customer service.
- Determination of the place of production and storage – is a strategic decision that results in the cost of transporting raw materials and finished goods and also has a significant impact on customer service.
- Purchase – Supplier selection, negotiation of prices and delivery terms, etc.
- Handling of returned goods – a complex and costly process of returning goods from the customer due to his dissatisfaction or malfunction.
- Reverse logistics – deals with the removal and disposal of materials, which are formed during production, packaging and distribution.
- Transportation and transport – own material and goods movement.
- Storage – storage of goods and material for later use. [1]

2.1 Technology of automatic identification – barcodes

Barcodes are the most useful and still cheapest way and therefore are the most widely used for labeling passive elements for automatic identification on the optical principle. Optical sensing is based on the principle of the different properties of dark and light surfaces when irradiated by optical or laser beam. There are about 200 different barcodes that are differ track record and its length coding method used when recording, recording density or way to secure the accuracy of the data. [2]

The most commonly used bar codes today are:

- One-dimensional – these include EAN (European Article Number) and UPC (Universal Product Code). The EAN-13 is the best-known barcode in the business network.

  1D code typically encodes a numeric or alphanumeric string that is the key to identifying the tagged object in an external database.
- Two-dimensional – these include PDF 417 or DataMatrix. 2D codes are less limited by the data capacity they can contain, and therefore usually contain all the necessary information about the tagged item. Both of these types of codes are able to hold up to 2 KB of standard text or raw data (RAW). The DataMatrix consists of dark and light square or rectangular cells. [2-5]

2.2 Technology of automatic identification – radiofrequency identification (RFID technology)

RFID technology is a non-contact automatic identification system for transmitting and storing data using electromagnetic waves. The RFID system consists of a transponder (antenna and chip with data) and a reader. Thanks to the so-called "anti-collision technology," according to the authors, it is possible to read a larger number of transponders at a time, because each of the chips, according to ISO 15693, has its worldwide unique number. [2,6] The advantage of RFID is the ability to read multiple tags at the same time that tags may not be readily visible when read, or the option of additionally editing or adding data [7,8].

The RFID tag is a carrier of information in RFID systems. RFID tags can also be referred to as transponders, this meaning being created by merging the English words transmit and response. The basic function of each RFID tag is to store information in the internal memory and to provide the stored RFID data when needed. RFID tags are divided according to the production technology, the type of memory, the power source and the frequency band in which they work. [9]

RFID tags exist according to power source division into two types:

- Active – these chips are equipped with a battery that lasts about 5 years, thanks to which they can transmit the data contained within them. The battery increases the cost of the tag and causes it to become unusable in worse heat and climatic conditions. These chips use very high frequencies and are capable of responding up to 100 meters.
- Passive – for these chips is the energy source reader. Passive tags with a frequency of 125 kHz have a range of up to 2 meters; with higher frequency chips (up to 2.4 GHz) the range is considerably higher. [2]

The tags consist of the antenna, which is the largest part of the tag and thus directly affects its size, and the microchip, which can be less than 1 mm today. It can be said that with the higher transmission frequency used, it is possible to use a smaller antenna. Different tags have different designs depending on their future use. According to the author, in some cases, maximum durability (against temperatures, humidity, chemical or physical processes) is required, and at other times, the lowest possible dimensions, weight, or cost. [9,10]

The tag may be encapsulated in a different way into a PVC card of credit card size or glass tube that fits into a case suitable for subdermal application (used to mark domestic animals, today mostly dogs). Another possible tag application is sticking to the label surface, but it can also be specially encapsulated according to customer's specific wishes. There are, for example, heat-resistant labels that can withstand temperatures from -40°C to +300°C. [9]

There are three basic tag types from the point of view on storing, reading, and writing information:

- RO (Read-Only) tags – this type of tag is already programmed during production, which can not be changed later. Information from the RO tag can only be readed and their memory size is from 40 to 512 bits.
- WORM (Write Once Read Many) tags – these tags are not programmed as RO tags at the time of production but by the seller or vendor. This type of tag is read-only (some types can be overwritten but not guaranteed).
- RW tags (Read Write) – this type of tag has a highly configurable addressable memory (16 Kb to 2 Mb). The RW tag can be overwritten up to a thousand times by any end customer with the appropriate equipment. [9,10]

Combined RO and RWs – for example, a ROM portion of the memory may indicate a pallet and be invariable throughout the service life while the RW memory can be programmed according to the pallet content.

Middleware is software or specialized hardware used to manage, filter, and analyze data from tags that are loaded with an RFID reader. The author also states that the middleware provides communication with individual readers and initially processes the acquired data. The basic functions of the middleware:

- Communication with several readers from different manufacturers and with different communication protocols.
- Filtering data obtained.
- Storing results in the database.
- Providing acquired data via the specified interface of other applications. [9,10]

The RFID reader connects the RFID tag with the control computer and has several basic functions:

- Power supply for passive tags.

- Read the data written on the RFID tag.
- Inserting data into tags (for RW tags).
- Transferring data from the control computer.
- Basic data filtering or control of integrated I / O circuits. [9,11]

There are two basic types of readers:

- Stationary – This type of reader is usually non-transferable (fixed) and is attached at the warehouse entry or at the start of the production line.
- Mobile – These readers are usually portable and have no cable. There are also hybrid readers that can read both bar codes and RFID tags. [9,11]

3 CASE STUDY

The article is dedicated mainly to the storage of operable material and goods associated with the operation of operating theaters and adjacent spaces. The case study is the method of the qualitative research based on the study of one or a small amount of situations for application of the findings for the similar cases [12].

3.1 Current status

There are four main warehouses in the operating halls:

- The warehouse of sterile containers contains material that is ready for actual use in the halls. The stock has dimensions of approximately 3.5 x 5.0 meters. There are various instruments (pliers, peans, scalpels, scissors, etc.), nails and other goods needed during operations. All goods stored in this warehouse are placed in sterile containers (about 50 x 30 x 15 centimeters). Part of the stored items is here within the consignment and the rest is already purchased
- Bone warehouse contains, as its name implies bone implants. There are also non-sterile instruments that are needed for specific operations and, for example, wrinkle to bone surgery. The aforementioned bone surgery instruments are not part of a sterile container store because frequent sterilization of some of them may reduce their lifetime or functionality. Therefore, given their occasional use only, it is unnecessary to be kept sterile in the long term. The stock has dimensions of approximately 5 x 4 meters.
- Warehouse of sterile material includes mainly drains and wrinkle material. Its dimensions are approximately 4 x 4 meters. Things are stored here, including packaging from the manufacturer, and are intended for direct consumption at any moment or left in the hall for later use.
- A non-sterile warehouse is also called a solution warehouse, but this is not entirely accurate, there are also stored medicines, non-sterile caps, wrinkles and bandages. Its dimensions are approximately 5 x 4 meters. Things are stored here, including packaging from the manufacturer, and are intended for direct consumption at any moment or left in the hall for later use [13].

In these 4 warehouses there is usually no loss of goods (theft). If there is an irregularity, it is mostly due to the failure to sign up for the goods during the operation. Near to operating theaters of the Chrudim Hospital, joint-stock company there is also a warehouse of drugstores and foodstuffs, which contain, for example, cleaning products or syrups. In this warehouse, it is not entirely possible to see who has taken the goods and that is why there are losses that are very difficult to quantify.

The weaknesses include poor security in the warehouse of drugs and food, which leads to theft, which has financial losses. Estimation of damage caused by thefts in warehouses is, according to the competent person, 30 000 CZK per year.

In the analysis of the current labeling and identification system there have been discovered weaknesses that are related to the technological backwardness of the current system. These weaknesses are: high time-consuming manual code depictions and personnel costs associated with it, unclear informations on labels, possible human error factor, inability to track inventory at the current time.

The weaknesses are directly linked to threats in the form of automated systems that bring reduction of time and financial costs, a reduction in error rates and the number of staff required to carry out the required agenda. Another threat is litigation with customers who have suffered damage due to human error.

3.2 The proposal modernizing labeling and identification using RFID

A large number of studies recommend the implementation of RFID technology into hospital logistics processes [14-17]. The introduction of an RFID tagging system should ultimately contribute to the elimination of the technological backwardness of the current labeling and identification system that is causing:

- Higher time-consumtion associated to the manual code depiction when depreciating used goods and subsequently ordering them (causing high personnel costs).
- Unclear informations on labels.
- Fault due to human factor.

Inability to track inventory at the current time, which is problematic due to the need to perform inventories, data expiry checks and the impossibility to record the number of instrument use cycles and the consequent worsening of their condition:

- Wrong anti-theft protection in some areas.
- Inventory management difficulties.

The proposal consists of the creation of a comprehensive system of labeling and registration of goods and materials in the premises of the Chrudim Hospital, joint-stock company using RFID technology.

The number stored in the RFID tag would, as with the 2D codes currently being used by some manufacturers, contain unique information for each item. Thanks to this and the resulting automation, it should be a complete refinement and acceleration of the entire system (inventory, ordering and expiry data control).

The advantage of placing a tool tag is to monitor the number of sterilization cycles and their use in operations. This information could be used to avoid situations when too worn tool comes to the operating theater where is stated tool malfunctioning (needle knife does not cut, needle falls out of needle holder, etc.). Doctors or nurses can, based on their experience, set an individual number of cycles for each tool that can be performed on a particular tool without losing properties, and then the tools can be shipped to the supplier to refurbishment.

In the case of RFID-tagging also in the warehouse of drug and food supplies, this measure could greatly limit the theft from these premises because each worker should have his own RFID chip. In the case that only goods without the identification chip were carried out, an alarm would not be triggered, but a CCTV record (Closed Circuit Television) of the warehouse from the time at which it happened could identify the offender. It is to be expected that the number of thefts will be reduced dramatically, because there are thefts of goods worth the tens of crowns that people carry out because they know that the warehouse is not monitored or properly registered and will therefore not be captured.

Another inherent advantage, apart from those already mentioned, would be the possibility of checking the LOT number on the body substitution already used, for example, if is done RFID markup of operable material, than would be sufficient to attach the reader to the foot of the patient and immediately identify the production batch of the body substitute used and possibly also used nails, etc. This function would be particularly beneficial if, for example, a faulty series was produced, and thus a need for rapid and safe verification of the patients received implants of a faulty batch.

3.3 Technical implementation of the proposal

In this part of the article are facts related to current developments and state-of-the-art trends are still often unused in medicine. Of course, the technical design varies considerably according to the goods to which should be tag attached, therefore will be division to the distribution of the goods as instrumentation, devices, goods packed in a box (medication, etc.), operable material (substitutes, nails, etc.) and absorbent material (tampons, abdominal masks, etc.). [13]

Instruments are today marked with 2D codes by better suppliers, which are used only for a few years to mark this type of goods. However, development has to go forward, and therefore, companies are constantly working on the development of a new, modern generation of chips with resistance to sterilization and their ability to connect with instrumentation. Generally speaking, no medical company dares to put into operation a test series of anything that did not tested beyond the normal conditions.

Three latest designs for RFID chip-to-instrument holding systems designed for medical equipment labeling:

- Putting into the resin mixture directly on the surface of the tool, as shown in Figure 1. For this type of storage, strength tests are still underway, where the basic problem is chemical sterilization and generally the number of sterilization cycles. Chemical sterilization is carried out with a hydrogen peroxide bath, which, due to its purpose, has a strong destructive effect on the resin mixture. Nowadays, chemical sterilization of tools is often not carried out, and only "thermal sterilization" takes place, during which temperatures reach for the resin less detrimental 134 ° C. The problem still makes the number of sterilization cycles, taking into account the durability of tools, which can be many decades, and so hundreds, maybe even more, sterilization cycles are carried out on some tools. Apart from the effects of sterilization, it is also necessary to take into account the mechanical shocks between the various tools. The simulation of these conditions and testing are time consuming and legislative very demanding.

Fig. 1 Putting RFID chip into the resin mixture directly on the surface of the tool [18]

- Create a hole in the tool and insert a tag as shown in Figure 2. This solution appears to be most appropriate to ensure compatibility of old tools with the new system. However, there are still problems with the chip itself (durability, memory and range), and it cannot be forgotten that such structural design is not possible (with regard to strength and other physical properties) for all types of instrumentation.

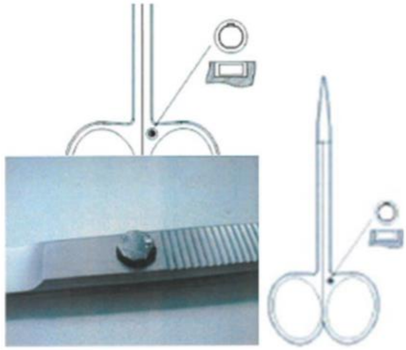

Fig. 2 Putting RFID chip into the hole in the tool [18]

- Create a separate case with a tag that is attached to the tool, as shown in Figure 3. This solution appears to be the best for new tools. In the case of pean, it is a ceramic tag with a frequency of 13.56 MHz (high frequency), a thickness of 2 mm and a diameter of 6 mm. This system is theoretically already ready for practice. The problem with this tag storage is that it would have to buy completely new instrumentation, which is clearly financially unbearable. The second problem is the reading frequency of the used tag, because UHF (ultra high frequency) tag cannot be used here because of its interference. This tag, due to its location in a metal tool and shielding the human body when inserted to a patient, would not read the RFID antenna in the door frames. The same problem also occurs with absorbent material, whose subchapter provides a technical solution to this problem. [13]

Fig. 3 Putting RFID chip into the separate case that is attached to the tool [18]

Devices are, in general, bigger things and with today's technology, is no problem to connect the standard RFID tag with the UHF frequency, which would automatically record their movement when passing through the RFID antennas in the door frames. For the purpose of device labeling, a test set of RFID tags would potentially be purchased and a suitable tag would be selected for that device.

Goods packed in boxes could be marked similarly, as it is already on a large number of products in retail chains (tag standard affixed to the bottom of the bottle with alcohol) or could be used so called smart labels (conventional labels, which include RFID tag). These tags would work on the UHF, and therefore would automatically record their movement when passing through the RFID antennas in the door frames. Operable material cannot be labeled with RFID in today's conditions for several reasons, which are listed in the subchapter evaluating the feasibility of this proposal.

Absorbent materials used during operations (gauze swabs, abdominal masks) are subject of rapid development of marking using miniature RFID chips, similar to instrumentation. The advanced company in this field is the American company Medline Industries. However, this solution is still not commercially available. Available information suggests that these tags will have a low reading distance and therefore will not be good enough to deal with RFID antennas in the door frames after operation, but it will be necessary after every major operation with the suspicion that some absorbent material may remain in the patient, to check patients body by RFID reader. Records in warehouses and during picking will be the same as for other goods packed in boxes that will be marked with a UHF tag.

Labeling of workers could be based on tags that the worker always has with him. However, these should not be not classic tags in the form of keyholes that are used in other enterprises for attendance systems because they are usually at 13.56 MHz and therefore they need to be closer or physically connected to the reader. Zebra offers RFID cards that run on UHF and if these are used, they automatically record employee movement when passing through RFID antennas in door frames. Thanks to automatic staff records, it would always be clear which employee in the warehouse took some goods at the specific time or putted it there. These cards are white, which allows them to print basic employee data and have a similar size as the payment card, which is convenient for inserting into the wallet. From a physician's point of view, the card is more advantageous because he does not always wear keys on which a pendant can hang. From the point of view of management, the card is more advantageous because it can be printed on a photo for identification purposes, and the card is also cheaper than a pendant.

Tag Identification and Information inserting System in Chrudim Hospital, joint-stock company was created on the basis of cooperation with Codeware Inc. As already mentioned, in the premises of the Chrudim Hospital, joint-stock company there are 4 warehouses and 1 adjacent warehouse. In Chrudim Hospital, joint-stock company there is 7 operating theaters. In total, there are 12 rooms for which registration of the goods is required. After selecting a suitable solution, a system consisted of a virtual entry and exit gate for each room was created. Each gate is made of 2 antennas to ensure accuracy. Due to the fact that these 4 antennas will be located on both sides of the door frames, a pair of information will be generated to determine whether the goods were placed in or out of the warehouse. For this solution, Motorola's broadband, one-port RFID antenna was selected. Specifically, the AN480 with IP 54 standard coverage and 2 W transmitting power, which ensures safe coverage of the space by the signal. This antenna is used to read UHF tags. [13]

Antennas would be connected to a UHF RFID reader with four ports. The advantage of a 4-port reader is the ability to connect all four antennas at one point, which, due to the relatively small financial gap between the two-port and the four-port antenna, is not only space saving, but also financial saving. For this purpose, Motorola readers have been selected, specifically the FX7500-4, this, thanks to the built-in USB port, can be easily connected to the whole system via Bluetooth, WiFi or cable.

For upload of informations, Deister UDL5 could be used, with short range and high write speed. The short range is advantageous because there is no risk of accidental rewriting of the remote tags, which could occur during writing over an RFID terminal and a large antenna. Deister UDL5 is both readable and writeable at the same time, and can be connected to any USB device without the need to install the software before. This reader could be used at the central sterilization center of Chrudim Hospital, joint-stock company to write a new expiry date for the instruments and devices. [13]

To check the patients body after bleeding operations (if something was not forgotten in the patient's body), 2 CipherLab CP-9200 mobile readers would be purchased. These readers can work with the whole system via Bluetooth, allowing all information to be handled by the central computer in real-time. These readers are used to read tags at high frequencies (13.56 MHz), and therefore serve only to locate and register instrumentation and absorbent materials, which are marked by chips at high frequency.

4 CONCLUSION

Logistics processes and activities are at the center of business optimization. Correctly set logistics processes can lead to lower business costs. Logistics processes in hospitals are, of course, very specific. Incorrectly set logistics processes and resulting consequences can lead to patient death. That is why it is very important to pay close attention to this area of logistics.

The aim of the article was to propose the implementation of RFID technology for a selected logistical process within a particular hospital through a case study. In the analysis of the current labeling and identification system, there have been discovered weaknesses that are related to the technological backwardness of the current system. These weaknesses were: high time-consuming manual code depictions and personnel costs associated with it, unclear informations on labels, possible human error factor, inability to track inventory at the current time. The use of RFID technology (including the technical implementation of the proposal) has been proposed under the third chapter to address weaknesses resulting from the analysis.

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FACULTY OF TRANSPORT ENGINEERING 25 YEARS

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INFLUENCE OF CLIMATE CONDITIONS ON STRESSES IN CWR ON THE BRIDGES IN SERBIA

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Abstract

Vehicle/track/bridge interaction causes additional stresses in CWR on the bridge, which include stress in rails due to temperature changes in the bridge deck, vertical bending of bridge deck, and braking/acceleration of railway vehicles on the bridge deck. Critical analysis of additional tensile stresses in CWR on the bridge using Smith diagram was performed and presented in this paper. Furthermore, results of rail temperature measuring at several monitoring locations in Serbia were presented. The influence of the local climate conditions and neutral rail temperature on the temperature stress in CWR was analysed. The paper points out that the prescribed values of additional stresses in CWR have to include influence of real local climate conditions on track stability on the bridge.

Keywords

railway, bridge, CWR, temperature, stress

1 INTRODUCTION

The increase of critical temperature in the rail might lead to track buckling and derailment during summer. Furthermore, the decrease of critical temperature in the rail might lead to rail break, which jeopardize the safety of rail transport during winter.

The dangerous consequences of derailment could lead to a loss of human life, injuries, environmental and material damage. The possible consequences of derailment are more severe on the sections on the railway bridges.

In the design and maintenance phase, the consideration of the vehicle /track/bridge interaction has to take into account all the effects on the safety of rail transport.

The considerations in this paper are primarily focused on the temperature changes in rail and bridge structure and their influences on the stresses in continuous welded rail (CWR - Continuous Welded Rail) on the bridge.

Figure 1 shows the influence of the temperature changes in rail and bridge deck on the tensile stress in CWR on the bridge. Similarly, Figure 2 shows the influence of the temperature changes in rail and bridge deck on the pressure stress in CWR on the bridge.

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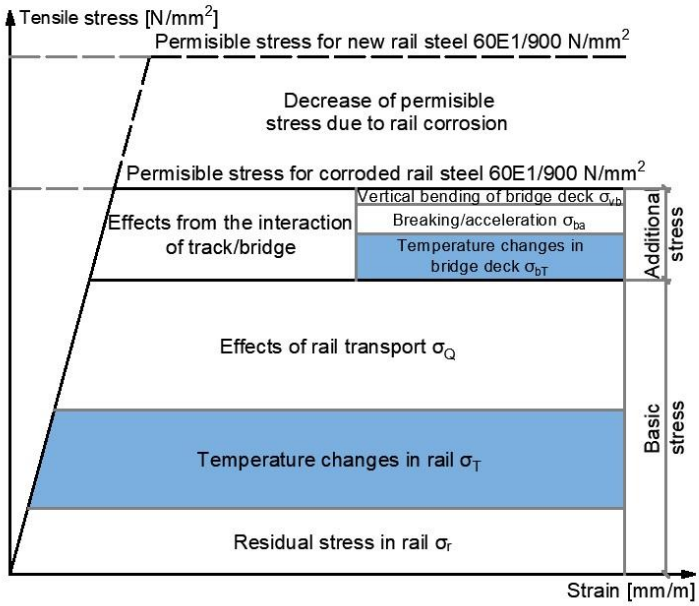

Fig. 1 The share of temperature changes in total tensile stress in the rails on the bridge

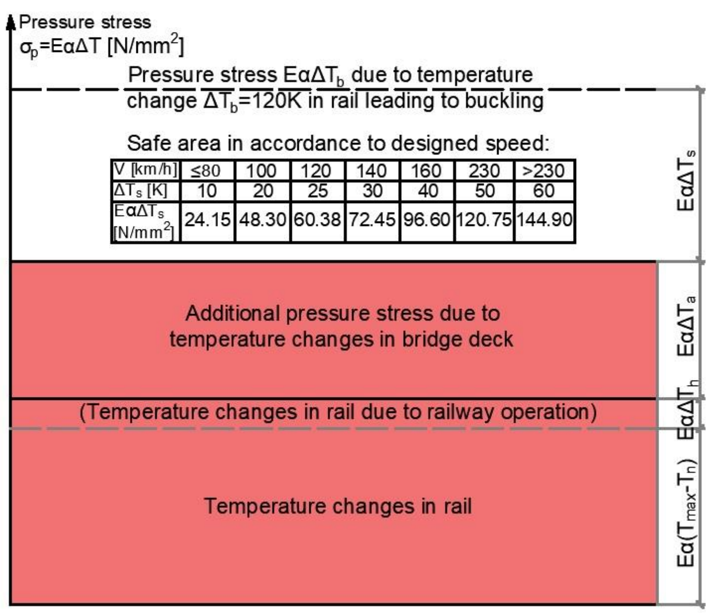

Fig. 2 The share of temperature changes in total pressure stress in the rails on the bridge

The influence of the local climate conditions in Serbia on the neutral rail temperature and the temperature stresses in CWR was analysed.

In accordance with design criteria for rails on the bridge and on the adjacent abutments defined in [1], the permissible additional rail stresses due to the combined response of the bridge structure and ballasted track to variable actions should be limited to 72 N/mm^2 for the pressure stress and 92 N/mm^2 for the tensile stress. The permissible additional rail stress for ballastless railway track on the bridge is 92 N/mm^2 for both the pressure and tensile stress. The detailed structure of the basic and additional stresses in CWR on the bridge was presented and analysed by the authors in [2]. In any case, calculation model for vehicle/track/bridge interaction should include vertical and longitudinal loads according to Figures 1 and 2. Figure 3 shows the example of calculation model.

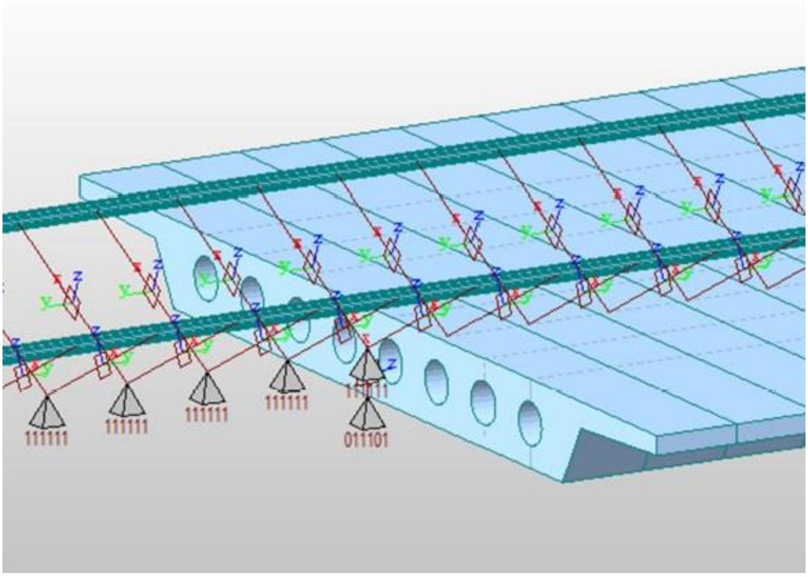

Fig. 3 Calculation model for vehicle/track/bridge interaction
(the bridge on Stalać - Đunis railway section, km 189 + 190.60, Corridor X through the Republic of Serbia)

This paper points out that the prescribed values of additional stresses in CWR have to include influence of real local climate conditions on track stability on the bridge.

2 INFLUENCE OF THE LOCAL CLIMATE CONDITIONS ON NEUTRAL RAIL TEMPERATURE

Neutral temperature in rails during track construction should be defined by Infrastructure Manager in such a way to ensure the safety of rail transport [3 - 7], as follows:

- the compressive stress in rail should prevent track buckling during summer and
- the tensile stress should prevent rail break or limit the gap in the event of rail break in tracks during winter.

Figure 4 shows the influence of the selected neutral temperature on the stresses in the rails during winter and summer. The absolute values of pressure and tensile stresses are equal when the neutral temperature is in accordance with (1).

$$T_n = \frac{\left(T_{\max} + T_{\min}\right)}{2} = T_s , \tag{1}$$

where T_n is neutral temperature, T_{max} is maximum temperature during summer, T_{min} is minimum temperature in rail during winter and T_s is mean temperature.

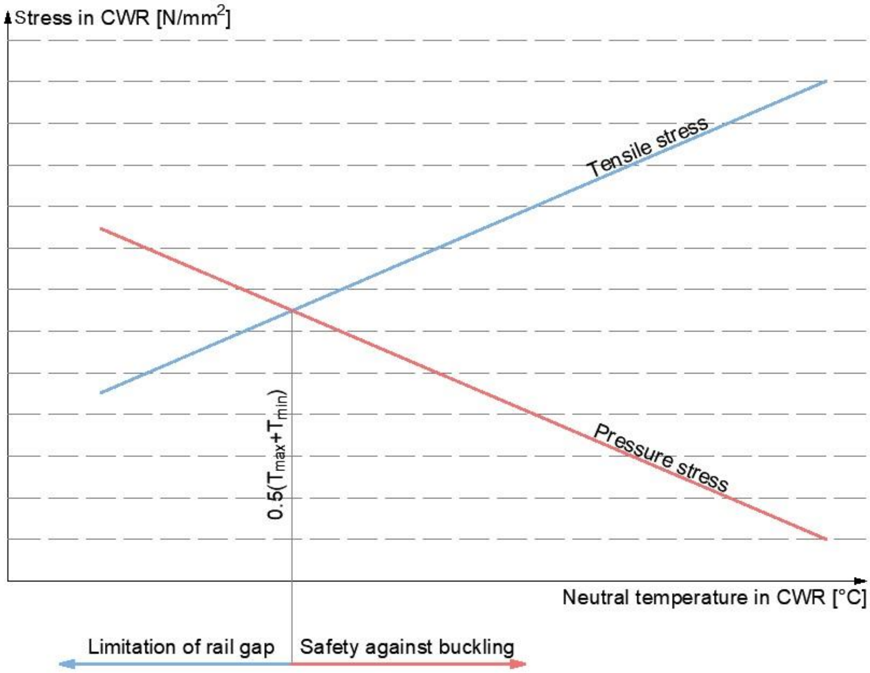

Fig. 4 Influence of neutral temperature on the rail stresses

Obviously, the neutral temperature depends strongly on the maximum and minimum temperature in the rails and influences the stresses in CWR. Table 1 shows the measured values of extreme winter and summer temperatures in the rails at three measurement locations for the last three years (2015 – 2017), which reflect the impact of climate change. These temperature measurement locations are shown in Figure 5.

Tab. 1 Extreme temperature in the rails at three measurements locations in the period 2015 - 2017

Year	Measurement location 1		Measurement location 2		Measurement location 3	
	T_{min}[^{0}C]	T_{max}[^{0}C]	T_{min}[^{0}C]	T_{max}[^{0}C]	T_{min}[^{0}C]	T_{max}[^{0}C]
2015	-5	53	-2	59	-20	55
2016	-8	50	-10	58	-12	58
2017	-10	59	-15	60	-22	60

Serbian Infrastructure Manager prescribed the unique temperature values as follows:

- T_{min} = -30^{o}C,
- T_{max} = +65^{o}C, and
- T_n=T_s + 5 = 22.5^{o}C.

The extreme summer temperatures in rail showed in Table 1 are mostly uniform and do not exceed +60^{o}C (the prescribed value T_{max} = +65^{o}C is in the security area). The measurement locations Sremski Karlovci and Valjevo showed mostly uniform values of winter temperature in rail, which is about 50% of the prescribed minimum value (T_{min} = -30^{o}C). On the other hand, the measurement location Priboj showed the minimum value -22^{o}C, which is about 73% of the prescribed minimum value.

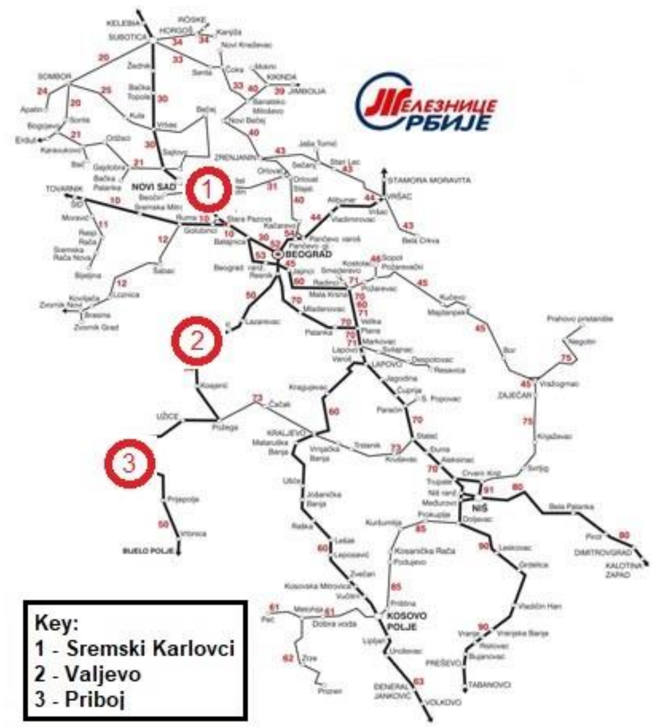

Fig. 5 Measurement locations on the Serbian railway network

Figure 6 shows the standard measurement of the temperature in the rails on the Serbian railway network. A qualified staff performs temperature measurement twice a day (at 7 o’clock a.m. and 2 o’clock p.m.) In Figure 6, the magnetic thermometer shows 40°C in 9 o'clock a.m. on 11 July 2017.

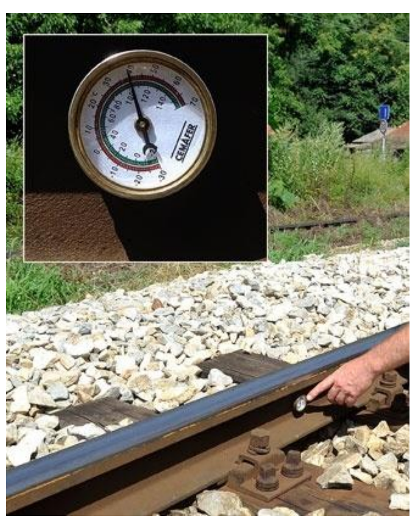

Fig. 6 Standard temperature measurement
(Topčider measurement location in the vicinity of Belgrade, July 2017)

The temperature measurement in rails and bridge decks is organized by the Infrastructure Manager. Temperature data for existing bridges are valuable for the reconstruction of existing and design of new railway bridges.

Figure 7 shows an interactive bridge model, which is linked to both the track and bridge database. Additionally, Figure 7 shows modern temperature measurement in rails, bridge deck and bearings using sensors. Among other representative data on the track, the database has to contain information about the measured minimum and maximum temperatures in the rails. Similarly, the base of representative bridge data has to include information about measured temperatures in the bridge deck and bearings.

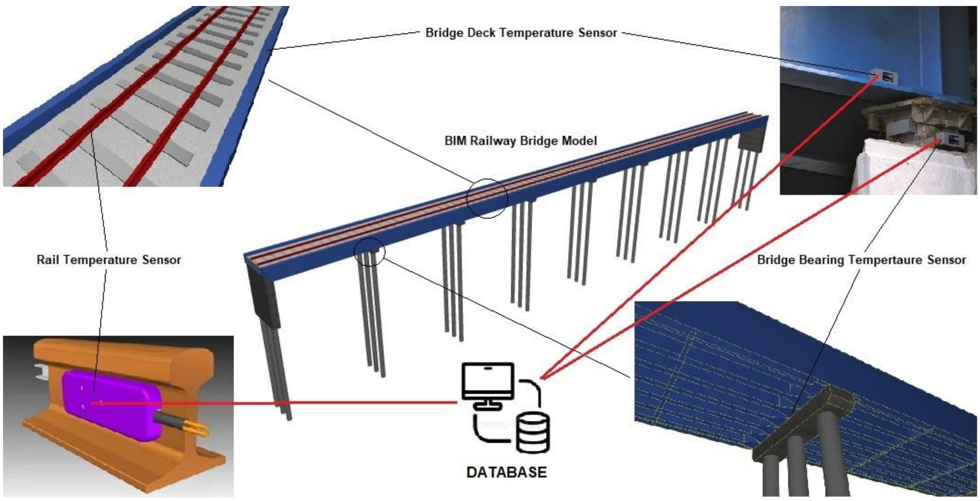

Fig. 7 An interactive bridge model linked to both track and bridge database

Furthermore, the neutral temperature T_n, which is higher than the mean temperature T_s, is favourable against track buckling during summer. Contrary to that, less neutral temperature than mean temperature T_s is favourable for the omitting or limiting the rail gap during winter (Figure 8).

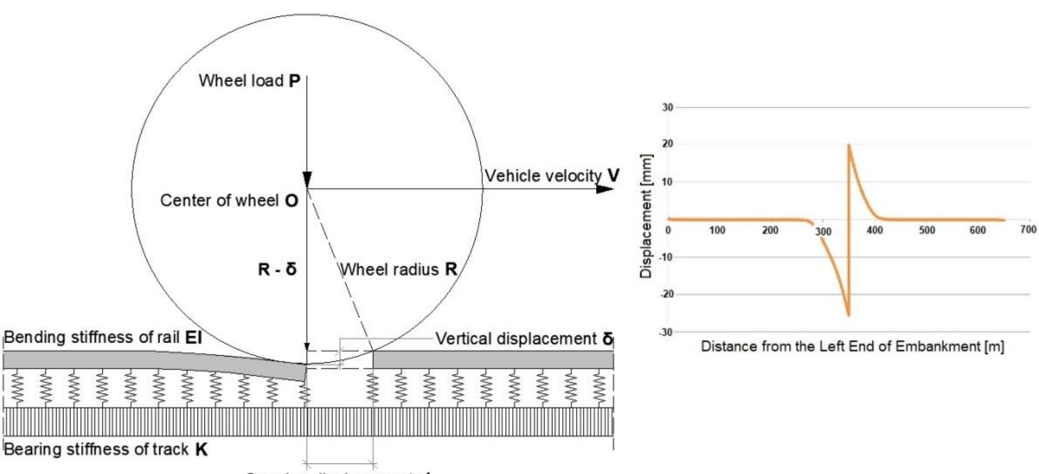

Fig. 8 Rail gap: calculation model (left) and the displacement diagram (right)

Obviously, neutral temperature defined by the Infrastructure Manager directly affects the safety of rail transport and maintenance costs.

Figure 9 shows permissible tensile bending strength in the rail foot centre according to Smith diagram for new and corroded rails with a tensile strength 900 N/m^2.

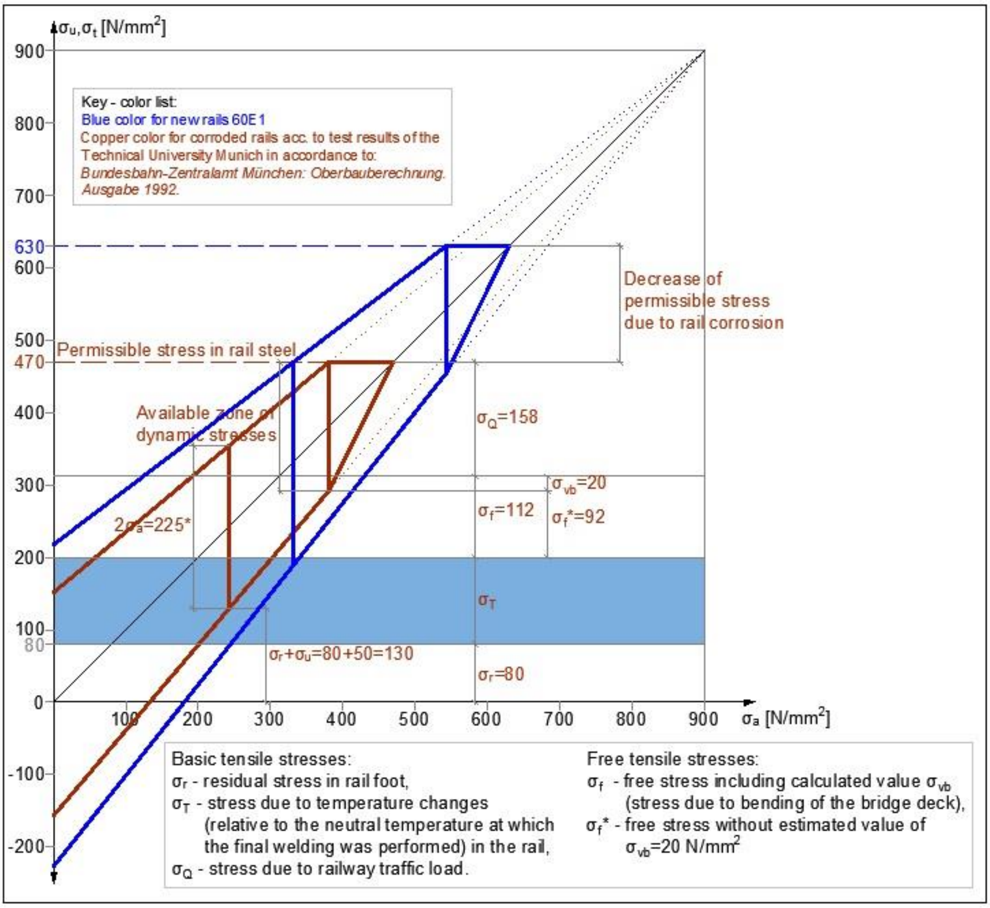

Fig. 9 Smith diagram for new and corroded rail 60E1/900

Stress σ_T (area highlighted in blue in Figure 9) due to temperature changes (relative temperature compared to the neutral temperature at which the final welding was performed) in rail falls into the basic tensile stress and affects the permitted value of the additional tensile stress (92 N/mm^2 according to [1]) in CWR on the bridge. The temperature stress in rail σ_T has to be in accordance with the measured temperature in the rail in the climatic zone in which the bridge is located. In this way, for specific climate conditions, the permitted value of the additional stresses in CWR on the bridge might be greater than, equal to or less than the prescribed value according to [1].

3 CONCLUSION

Considerations in this paper refer to the track with CWR on the bridge from the aspect of climate impacts to additional stresses in the rails. Interaction of vehicle/track/bridge plays a key role in design and maintenance of railway bridges in these considerations. Furthermore, general application of permissible values of pressure and tensile stresses prescribed in the current European standards was critically analysed.

Stresses induced by the vehicles (vertical load and longitudinal loads during acceleration/breaking of the vehicles), as well as temperature changes and bridge displacement, affect track superstructure, especially CWR. Management of the vehicle/track/bridge interaction requires appropriate calculations that correspond to the structure and expansion length of the bridge, vertical traffic loads, longitudinal loads due to acceleration/breaking of vehicles and temperature changes according to local climate conditions [2, 6, 7].

Neutral temperature for prevention of buckling unnecessarily increases due to the exceeded values of the maximum temperature (in relation to the real summer temperature in the rail). Furthermore, this results in an unrealistic increase of the calculated CWR gap during winter. On the other hand, the underestimated value of the maximum temperature decreases the neutral temperature, thus giving unrealistic safety against track buckling and unrealistic small gap. In any case, wrong estimate of minimum and/or maximum temperatures could lead to increased construction and maintenance costs. In the worst cases, it might jeopardize railway traffic safety.

Considering that measured air temperatures were above 42°C in some places in Serbia during last several years, it is necessary to reduce value of permissible pressure stress in rails in such climate zones.

Hot summers and cold winters in recent years imply the necessity for permanent monitoring of temperature in rails and bridge decks, in order to define the real values of permissible stresses. This paper presents the interactive model of the railway bridge, which includes information about measured temperatures in rails, bridge deck and bearings.

The technical regulation should harmonize the prescribed values of the permissible stresses in CWR with the climate zone in which the bridge is located, instead of strictly adhering to the prescribed values in European standard [1].

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FACULTY OF TRANSPORT ENGINEERING 25 YEARS

VII. International Scientific Conference of the Faculty of Transport Engineering

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RADARS IN TRANSPORTATION

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Abstract

The key concept of radar is relatively simple but its practical implementation could be very complicated. An active radar radiates electromagnetic energy and detects the echo returned from reflecting objects (targets). The nature of the echo signal provides information about the target. The distance to the target determines the time of the radiated energy to travel to the target and back. The angular location defines a directive antenna. A radar can derive the target trajectory, and predict future location. With sufficiently high resolution, the radar can distinguish something about a target's size and shape. Usually, the radar is an active device in that it carries its own transmitter and does not depend on ambient radiation, as do most optical and infrared sensors. The radar can detect relatively small targets at near or far distances and can measure their range with precision in all weather. On the other side, the passive surveillance technology provides an unmatched ability to "see without being seen" and provides the very advanced technology. The described properties are very useful for transportation. The students of University of Pardubice and their teachers have cooperated on the development of various kinds of radars produced in the Czech Republic. Several examples such as air traffic control, river and automotive radars, which are used in transportation, are briefly illustrated.

Keywords

radar, transportation, radar principles, radar applications

1 INTRODUCTION

The basic idea of radar is relatively straightforward but its practical design could be very complex. A radar radiates electromagnetic energy and detects the echo returned from reflecting objects (targets). The character of the echo signal offers information about the target. The time, which radar takes for the radiated energy to propagate to the target and back, determines range, or distance, to the target 0 - 0. The received power at antenna terminals, P_R, is given by

$$P_R = \frac{P_T G_T}{4\pi R^2} \frac{\sigma}{4\pi R^2} \frac{G_R \lambda^2}{4\pi} F_T^2 F_R^2 \tag{1}$$

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where P_T is transmitted power at antenna terminals, G_T is transmitting-antenna gain, G_R is receiving-antenna gain, σ is target radar cross section (RCS), λ is wavelength, F_T is pattern propagation factor for transmitting-antenna-to-target path, F_R is pattern propagation factor for target-to-receiving-antenna path, R is radar-to-target distance (range).

Pattern propagation factors, F_T and F_R, account for the possibility that the target is not in the beam maxima (G_T and G_R are the gains in the maxima) and for any propagation gain or loss that would not occur in free space 0 - 0. The most common of these effects are absorption, diffraction and shadowing, certain types of refraction effects, and electromagnetic compatibility (EMC) considering both multipath electromagnetic interference (EMI) and electromagnetic susceptibility (EMS). For a target in free space and in the maxima of both transmit and receive antenna patterns, $F_T = F_R = 1$.

Simulation tools for long-range propagation prediction in the lower atmosphere, including diffraction and refraction effects, are usually based on physical optics (PO), ray tracing and/or parabolic equation method (PEM). Considering PO Ufimtsev's results an improved approach to analyze propagation over irregular terrain could be used 0. The scattered field can be divided into two parts, i.e. the reflected radiation component, S_{sz}^{ref}, (with the reflection coefficient Γ terms) and the shadow radiation component, S_{sz}^{sh}

$$S_{sz}^{ref}(P) = \frac{|E_0|R_0 e^{j\pi/4}}{2\sqrt{\lambda}} \int_a^b f(\theta_1)\Gamma[\sin(\theta_2-\alpha)-\sin(\theta_1-\alpha)] \times \frac{e^{-jk(R_1+R_2-R_0)}}{\sqrt{R_1 R_2 (R_1+R_2)}} \frac{dx}{\cos\alpha} \tag{2}$$

$$S_{sz}^{sh}(P) = \frac{|E_0|R_0 e^{j\pi/4}}{2\sqrt{\lambda}} \int_a^b f(\theta_1)[\sin(\theta_2-\alpha)+\sin(\theta_1-\alpha)] \times \frac{e^{-jk(R_1+R_2-R_0)}}{\sqrt{R_1 R_2 (R_1+R_2)}} \frac{dx}{\cos\alpha} \tag{3}$$

where E_0 is the maximum value of incident electric vector at a distance R_0. R_0, R_1, R_2, θ_1, θ_2 and α are shown in Fig. 1, $f(\theta_1)$ is the normalized antenna radiation pattern with phase center at point A at height h_A over the terrain, Γ is the Fresnel reflection coefficient (local reflection coefficient), $k = 2\pi/\lambda$, λ is the wavelength and a, b are limits of the illuminated part S_{il}.

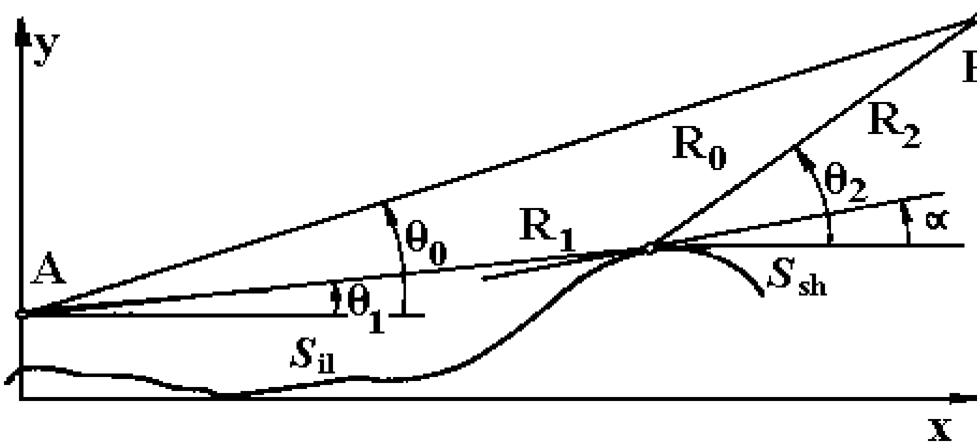

Fig. 1 Propagation geometry.

The reflected component, S_{sz}^{ref}, depends on the local reflection coefficient. On the other hand, the shadow radiation power is equal to the total power incident on a scattering object and it does not depend on the reflection coefficients. According to the shadow contour theorem, it does not depend on the whole shape of the scattering object and is completely determined only by the size and the geometry of the shadow contour. For the shadow region at a finite distance from the scattering object (behind the object), the shadow radiation for very short wavelength can be considered as a wave beam that asymptotically cancels the incident field and the reflected beams asymptotically vanish. The shadow radiation gives origin to edge waves, creeping waves, and surface diffracted rays. That means that (2) and (3) could be used for calculation for both illuminated and shadow region. The computation of scattered field can be done for higher altitudes (greater differences between the reflected and incident rays) as well as for lower altitudes (i.e. it is not necessary to consider the low altitude propagation and transient zone). The numerical simulations using (2) and (3) offer much more consistent solution, which takes into account the polarization (even for the shadow region).

Fig. 2 compares the physical optics (PO) analyses with the maximum (MEAS MAX) and minimum (MEAS MIN) measurement values 0. Fig. 3 shows the comparison of measurements and numerical simulations using PEM and PO, i.e. calculations of (2) and (3) for various heights 0.

The **radar coverage diagram** comprises a volume inside which the field is greater than the minimum useful value. Vertical coverage diagrams of system and radiation patterns of free-space

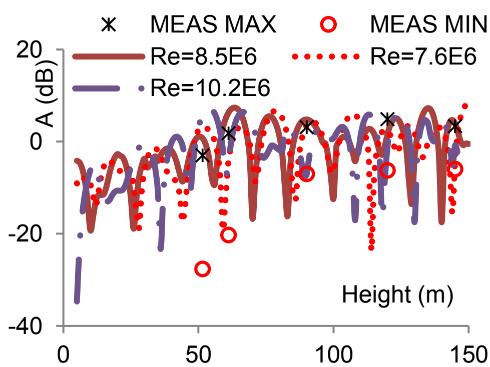

Fig. 2 Comparison of measurements and PO analyses for various effective radiuses R_e.

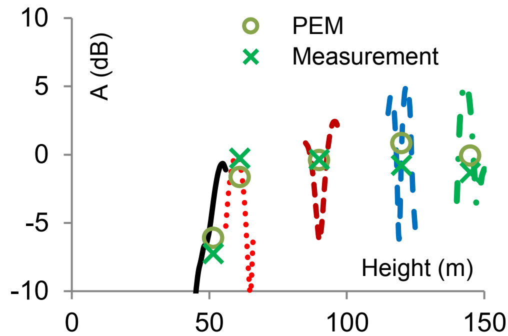

Fig. 3 Comparison of measurements with 0.65 m diameter, PEM and PO numerical simulations for heights of 51, 61, 90, 120 and 145 m.

(Ant. diagram) and PO approximations (Ground refl.) are shown in Fig. 4 0. The vertical coverage diagrams, which demonstrate the effect of transmitting output power, are shown for comparison only. Verifications of the radar coverage diagrams have been done by test flights performed at various flight levels for numerous airports and various radar types. An example of test flight is shown in Fig. 5 0.

Usually the same antenna is used for transmitting and receiving (monostatic radar). The angular location of the target is found with a directive antenna (one with a narrow beamwidth) to sense the angle of arrival of the echo signal 0 - 0, 0 - 0. If the target is moving, a radar can derive its track, or trajectory, and predict the future location.

The shift in frequency of the received echo signal due to the doppler effect caused by a moving target allows a radar to separate desired moving targets (such as aircraft) from undesired stationary targets (such as land and sea clutter) even though the stationary echo signal may be many orders of magnitude greater than the moving target. With sufficiently high resolution, a radar can distinguish something about a target's size and shape. Radar resolution may be obtained in range or angle, or both. Range resolution requires large bandwidth. Angle resolution requires (electrically) large antennas. Resolution in the cross-range dimension is usually not as good as the resolution that can be obtained in range.

However, when there is relative motion between the individual parts of a target and the radar, it is possible to use the essential resolution in doppler frequency to resolve in the cross-range dimension. The cross-range resolution of a synthetic aperture radar (SAR) for imaging a scene such as terrain can be explained as being due to resolution in doppler.

Usually, radar is an active device in that it carries its own transmitter and does not depend on ambient radiation, as do most optical and infrared sensors. Radar can detect relatively small targets at near or far distances and can measure their range with precision in all weather, which is its chief advantage when compared with other sensors.

The Czech industry has been interested in radars since the end of World War II 0 - 0. There were two or three big enterprises in the former Czechoslovakia delivering most of the radar and microwave communication products with their own or closely coupled research plants such as Tesla Pardubice with its Radio Research Institute Opocinek, supported by antenna system producer LET Kunovice. Microwave semiconductor devices were designed and produced by WST Prague both for radar and for communication equipment. They were converted into several private companies. Several well-established companies mastering modern technology and getting relatively stable crews operate at the market. New devices and modernization of their products are developed mainly in their own facilities, and research projects are solved in cooperation with Universities and other academic organizations.

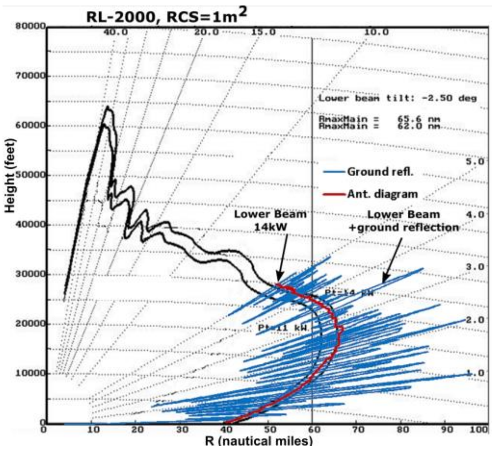

Fig. 4 Vertical coverage diagrams of system and radiation patterns of free-space (Ant. diagram) and PO approximations (Ground refl.).

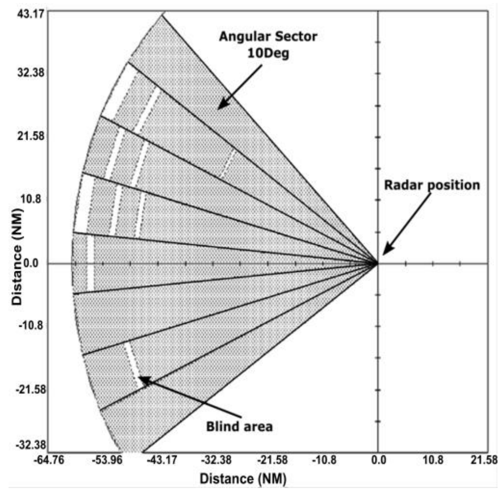

Fig. 5 Test flight.

The paper deals with various radar properties, which are very useful for transportation. The students and employees of University of Pardubice have taken opportunities to cooperate mostly with Pardubice producers on the radar development. Various kinds of radars such as air traffic control, river and automotive radars are demonstrated.

2 RADAR APPLICATION

The principle of radar has been applied from frequencies of a few megahertz (HF, or high-frequency region of the electromagnetic spectrum) to well beyond the optical region (laser radar). The particular techniques for implementing a radar differ greatly over this range of frequencies, but the basic principles remain the same. Radar was originally developed to satisfy the needs of the military for surveillance and weapon control. Military applications have funded much of the development of its technology. However, radar has significant civil applications for the safe travel of aircraft, ships, cars and spacecraft; the remote sensing of the environment, especially the weather; and law enforcement and many other applications.

The high degree of safety in modern air travel is thanks to successful applications of radar for effective, efficient and safe control for air traffic. Airports employ an **Airport Surveillance Radar (ASR)** for observing the air traffic in the vicinity of the airports.

A microwave beacon system, like a radar, transmits a pulsed RF wave to locate a target, using the time delay of the “echo” to determine distance and using antenna directionality to determine angular location. The distinguishing feature of a beacon system is that the target cooperates in this process, using on-board electronics to enhance the returned RF wave with amplification, frequency shifting, or coding. Beacons are thus highly accurate and reliable surveillance systems and also can provide some data-link capability. Beacon systems typically consist of transponders and interrogators. *Transponders* are the active devices carried by the target to provide the enhanced echo. Transponders are usually located on moving platforms, although fixed transponders may be used to mark hazards, navigation points, or calibration points. *Interrogators* employ equipment similar to that of conventional pulsed radars, i.e., a transmitter which produces replies from the transponder and a receiver to detect and process the replies. The most widely deployed beacon system is the military Identification Friend or Foe (IFF) system and its civilian derivative **Air Traffic Control Radar Beacon System** (ATCRBS). The civilian systems are also known internationally as **Secondary Surveillance Radar (SSR).** All systems have similar waveforms and share common frequencies of 1030 MHz for interrogation and 1090 MHz for reply. Polarization is always vertical.

The Precision Approach Radar (PAR) is a type of radar guidance system designed to provide lateral and vertical guidance to an aircraft pilot for landing, until the landing threshold is reached. After the aircraft reaches the decision height (DH) or decision altitude (DA), guidance is advisory only. The Czech radar industry has been interested in the development and production of reflector as well as phased arrays for PAR. Controllers monitoring the PAR displays observe each aircraft's position and issue instructions to the pilot that keep the aircraft on course and glidepath during final approach. It is similar to an instrument landing system (ILS) but requires control instructions.

In the early 80´s Leningrad VNIIRA and Tesla Pardubice agreed on joint development of the microwave landing system (MLS), which is more advanced than the ILS. Tesla was interested in design of the MLS scanning beam antennas including steering electronics and software. It was the most mature phased array program reaching the stage of completely developed and field tested equipment containing azimuth and elevation antennas at the time. The beam positioning as a function of time was kept to an accuracy of hundredths of degree to fulfill the ICAO and FAA recommendations. The whole MLS was tested at a USSR airport under real flight situations. Unfortunately, the program was stopped due to the unclear position of the whole MLS program.

More than 700 **river radars** of several types were done in the Czech Republic and exported to various countries. The slotted waveguide linear antenna arrays were used with the river radars.

Ultra wideband (UWB) radars, which transmit narrow pulses, are used for a location of buried objects and bodies (ground penetrating radars). Special through-wall radars enable looking inside through the walls and thus facilitates the actions such as against terrorists 0, 0. Monitoring and localization systems enable tracking the movement of fire fighters and rescue teams in complicated environmental areas and thus facilitates the organization of these teams. The Pardubice RETIA Through-Wall Imaging System is a **unique small portable radar** detecting living entities behind a wall or a non-metallic barrier. Thanks to its technology, the radar can detect living entities both in motion and at rest. The signal processing optimized for the detection of small changes triggered human or animal movement, enables localization, for example, of a human being based only on breathing. Small dimensions, low weight and long operation period makes this radar a highly portable device suitable for multi-purpose usage, for special police and military units.

Automotive radars are mostly based on the Linear Frequency Modulated Continuous Wave (LFMCW) principle 0. Mastering of low cost high definition continuous wave radar at 77/79 GHz carrier frequencies with maximal frequency bandwidth of 4 GHz enables radar to enter automotive business. Thanks to utilization of 4 radars for one car, the traffic circumstances could be continuously monitored with avoiding of blind areas. That means the yearly production is estimated more than 200 millions of car radars. Nevertheless, the quest to manufacture radar for automotive functional safety purposes in large series while keeping the cost of sensor within reasonable boundaries is still an ambitious task considering new 5G communications.

Close Vehicle Warning for Bicyclists is based on Frequency Modulated Continuous Wave (FMCW) radar 0. The radar works at frequency 24.1 GHz with 180 MHz bandwidth and it is intended to detect cars behind a bicyclist. The implementation of the signal processing is tested in the simulation and it is realized in Field Programmable Gate Array System On Chip and with low-cost FMCW radar. The system is installed on the bicycle.

The Czech Republic is one of world leaders in the field of law enforcement traffic solutions 0. The **radar speed cameras** represent an effective tool how to affect behavior of drivers with the aim of improving road safety and reducing occurrence of hazardous situations on the road. The mobile system as well as the non-intrusive fixed one have won recognition and popularity in many countries of the world.

The **indirect holographic techniques**, previously applied to the determination of antenna radiation patterns, can be adapted for the imaging of passive objects 0 - 0. The transformation of the holographic intensity pattern into the Fourier domain enables the isolation of the terms required for complex field reconstruction to be isolated from the remaining terms. Back-propagation techniques have also been included to reconstruct complex fields at the position of the scattering objects. That could be used for transport safety issues such as resolution of concealed guns at airports or various stations. A composite aperture that produces images using two sub-apertures operating at different frequency ranges was designed 0. The lower resolution, K-band system makes use of frequency diverse metasurface aperture antennas for imaging of human-sized targets, while a high frequency (75 GHz) dynamic holographic metasurface antenna is used for obtaining higher resolution images of smaller regions. Although demonstrated for security-screening applications, the proposed imager has significant potential to be employed in a variety of applications, including biomedical imaging, non-destructive testing and remote-sensing, where high-resolution and fast image reconstruction are required over dynamically adjusted constrains. The synthesized spotlight aperture can readily be extended to even higher frequencies to achieve finer resolution limits.

Passive Radars (Multilateration Systems) use the receiving stations, which receive the signals transmitted by target and retransmit it to the central processing station by microwave links. There the Time Differences of Arrival (TDOA) at the individual stations are measured. Moreover at the central station the signals are analyzed and the messages are evaluated. Typically three receiving stations are needed for 2D location of the aircraft and four stations are needed for 3D location. The system achieves a very high position accuracy, independent altitude measurement (with high accuracy) and is more cost effective than the SSR systems 0 - 0, 0. The Pardubice ERA is a leading supplier of next-generation surveillance and flight tracking solutions for the air traffic management, military, security and airport operations markets.

The **passive coherent location (PCL)** uses commercial transmitters such as FM radio broadcasting. The transmitter-receiver pair creates a bistatic radar. Contrary to applications, where the useful signal is roughly above a noise level (such as in case of the primary and secondary radars and communications), the reflected signal level in PCL systems is many orders of magnitude under the levels of direct signal, clutter and noise. Therefore, very sophisticated signal processing should be used 0, 0 - 0.

The Czech industry has developed several types of **meteorological radars** starting from 1963 0. That are very useful for transportation, especially air traffic control. A few meteo-radars uses variable linear/circular polarizations. The Institute of Atmospheric Physics, Prague, has been developing a 35 GHz frequency-modulated continuous-wave (FMCW) cloud radar 0, 0.

3 CONCLUSION

The radar can detect relatively small targets at near or far distances and can measure their range with precision in all weather. Usually, the radar is an active device in that it carries its own transmitter and does not depend on ambient radiation, as do most optical and infrared sensors. The active radar radiates electromagnetic energy and detects the echo returned from reflecting objects (targets). The nature of the echo signal provides information about the target. The distance to the target determines the time of the radiated energy to travel to the target and back. The angular location defines a directive antenna. A radar can derive the radar trajectory, and predict future location. With sufficiently high resolution, the radar can distinguish something about a target's size and shape. On the other side, the passive surveillance technology provides an unmatched ability to "see without being seen" and provides the very advanced technology.

The described properties of both active and passive radars are very useful for transportation. Even if radars were originally developed to satisfy the needs of the military for surveillance and weapon control and military applications have funded much of the development of its technology, the radar has abundant civil applications for the safe travel of aircraft, ships, cars and spacecraft; the remote sensing of the environment, especially the weather; and law enforcement and many other applications. The Czech industry has been interested in radars since the end of World War II. Today, several well-established companies mastering modern technology and getting relatively stable crews operate at the market all over the world. New devices and modernization of their products are developed mainly in their own facilities, and research projects are solved in cooperation with Universities and other academic organizations.

The paper demonstrates various kinds of radars such as air traffic control, river and automotive radars and deals with various radar properties, which are very useful for transportation. The students and employees of University of Pardubice have cooperated on the radar development. This is confirmed by numerous projects, journal and conference papers, and master and Ph.D. theses.

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INTERFACE FOR OPERATIONAL MANAGEMENT SYSTEM IN MARSHALLING YARDS

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Abstract
This paper considers existing procedures that are performed in marshalling yards with empiric measured times of duration of main operations. In the first part of the paper are mentioned sources which are used for performing of the operations with inbound and outbound trains that are analysed afterward. Following part describes circumstances of non-optimised decisions and the reasons for them. In last part of the paper is stated proposal of data interface which is necessary for improvement of data flow in marshalling yards and is a base for development of considered marshalling yard management system.

Keywords
marshalling yard, processes, interface, sources

1 INTRODUCTION

System of single wagon load based on system of trains that connect senders and recipients through dedicated stations commonly equipped with hump and special devices. These stations – marshalling yards are the crucial part of the system. For ensuring reliability, speed and accuracy of transport according to customer needs seems necessary to develop new quality of information flow to and from marshalling yards. This new quality should be provided by proposed universal interface, that will interchange data between existing network information systems and considered new marshalling yard (MY) operation (management) system which have to involve real-time decision module for optimized operational management of sources.

2 ANALYSIS OF SOURCES AND CHARACTERISTICS OF ČESKÁ TŘEBOVÁ MARSHALLING YARD

For comprehension of the processes is in this part of the paper stated an overview of operations and facilities in the Česká Třebová marshalling yard.

Marshalling yard is a part of the railway station Česká Třebová. The station has standard conception that is common in Czech railway network. It means that the station consists from passenger part, (intermodal container) terminal, industrial area with sidings, locomotive depot with maintenance area and marshalling yard. It has arrival yard, hump, classification yard and departure yard. [1, 2, 6] Hump and classification yard is equipped with automatic classification and braking

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systems (GAC and ARS GTSS). [7] Planning in long-term period integrates arrival main line train paths <–> shunting and marshalling of single wagons and groups <–> departure mainline train paths.

Sources in marshalling yard are in general following

- line locomotive and its driver,
- hump locomotive and its driver,
- yard locomotive and its driver,
- hump,
- arrival tracks,
- classification tracks,
- departure tracks,
- siding tracks,
- dispatcher of yard infrastructure manager,
- dispatcher of yard railway undertakings,
- head shunter,
- shunter,
- brakeman,
- coupler,
- transport agent,
- inspector,
- signalman. [6]

In marshalling yard Česká Třebová, there are three shunting locomotives. They work 24 hours a day, 7 days a week.

- Arrival/Hump locomotive – commanded by radio.
- Classification locomotive – commanded by radio.
- Departure and siding locomotive – commanded by radio and signalling. [6]

Track maximum length is 933 m (arrival yard) and 829 m (departure yard). Train average length is 650 m. Classification yard has 33 tracks in 4 groups of tracks. Minimum empiric time for changing of locomotive is 10 minutes. Minimum empiric time from arrival to departure of the train is about 4,5 hours. Average marshalling times with average wagon consists is about 6 hours. Average numbers of trains are following. Number of transit trains with some operations (e. g. change of locomotive) per day is 10. Number of trains that terminates its journey in arrival yard is 30 per day. Four of them are local connecting trains. Number of trains that starts its journey in departure yard is 27 per day. Six of them are local connecting trains [3]

Nowadays are all operations with train arriving to or departing from marshalling yard provided according to long-term plan. In railway environment long-term plan means timetable and its changes that come into force about every 3 months. Ad-hoc trains are served with no additional capacities (there are some reserves for the reason of ad-hoc trains). For preparation of railway undertaking's long-term plan of operational processes in marshalling is used software application. Namely it is "Timetable of operational processes in station" – TOPS. This application during the preparation of train timetable provide to a train planner (railway undertaking's staff) base tool for planning of all procedures with train. In the final plan of procedures are involved activities of all necessary sources. [3]

3 OPERATIONS

In this part of the paper is placed simplified analysis of operations which are necessary to do with terminating and departing train. Transit trains with no required procedures are not involved. Transit trains with only few operations (except marshalling) – for example changing of locomotive are mentioned in part “general overview” above. Values that are stated are empiric – the measurement had been made from 15th January 2018 to 15th March 2018.

All planned sources are matched to activities and arranged in correct sequence. [3] Common sequence is explained below. At first the trigger of the procedure in marshalling yard is announcement about train arrival that is provided by information system “Dispatcher information system of operational management” – DISOM or by infrastructure manager Dispatcher. This procedure is updated only “manually” by railway undertaking dispatcher according to train composition – system COMPOST. Decision about the order of trains to be processed (marshalled) is only on railway undertaking dispatcher which uses for the decisions support from the application “Operation information system” – OIS. In the OIS system are complete information about train unit. [5] The OIS does not provide any support for optimal decision. The quality of decision depends on how skilled is the railway undertaking dispatcher.

3.1 Inbound train and marshalling procedure

Beginning of the procedure is during the arrival of the train. During the arrival the wagon inspector is watching the train unit and is looking for failures e. g. flat wheels. At the same time is transport agent waiting at the place where stop forefront of the locomotive for taking over of train and shipment documentation. After arrival the train unit is secured by wheel chock or by tightening of wagon hand brakes. Next, the line locomotive is uncoupled. Average time is 3 minutes. Uncoupling is done by line locomotive driver. After that is line locomotive shunted to line locomotive sidings. Signalman set up and lock shunting route. Commands from railway undertaking dispatcher to the line locomotive driver are pursued by radio and signalling. [1, 2, 6] Main activities of inbound train procedure are possible to see in table 1 below.

Tab. 1 Inbound train procedure

Inbound train procedure	Time (min)	Perform
Moving train from surrounding network to yard – arrival	X	X
Taking over of train and shipment documentation (from loco driver to wagon inspector)	1	Transport agent / wagon inspector
Braking the train unit with wheel chocks	1	Line loco driver
Tightening of hand brakes of first five wagons	6	Line loco driver
Command to uncoupling of the line locomotive and to shunting	0,5	railway undertaking dispatcher
Uncoupling of the line locomotive	3	Line loco driver
Shunting from arrival track to the line loco siding	3	Line loco driver

Hump locomotive driver gets the information about track on which is train unit to be marshalled. The hump locomotive is coupled to rear of train unit. Screw couplings of wagons are loosened by shunter and head shunter according to sorting list. Hump locomotive according to commands from signalman and head shunter move train blocks to the hump. Loosened couplings are taken off by coupler with special rod. In case that some wagon is not allowed to be humped, this wagon is during the process of pushing the groups of wagon to hump decoupled and shunted to siding track next to hump. In a while when all blocks are humped, hump loco moves to siding track with non-humping wagons, couples it and shunts to classification yard on dedicated track. [1, 2, 6] Main activities of marshalling procedure are possible to see in table 2 below.

Tab. 2 Marshalling procedure

Marshalling procedure	Time (min)	Perform
Announcement to hump loco about track of unit to be marshalled	0,5	railway undertaking dispatcher
Announcement about dangerous goods	0,5	railway undertaking dispatcher
Shunting from yard loco siding to arrival track	3	Yard/hump loco driver
Coupling of train unit	3	Shunter
Loosening of hand brakes of wagons	6	Shunter
Releasing the train unit (put wheel chock away)	0,25	Shunter
Preparation for humping (e. g. loosening of screw coupling)	25	Shunter
Command to shunting with blocks of train	0,5	Head shunter
Shunting with block of train	5	Yard/hump loco driver
Cutting and humping blocks into classification yard	30	Coupler, brakeman, signalman
Shunting non-humping blocks into classification yard	6 per shunting	Shunter / coupler, Yard/hump loco driver
Securing of the train blocks against movement (wheel chocks and hand brakes)	0,5	Brakeman
Shunting with broken wagons	10 per shunting	Shunter / coupler

3.2 Procedure before departure

In a while when is one of the tracks completed begins procedure of train preparation to depart. The decision about beginning of this procedure is on railway undertaking dispatcher. Track could be completed because of the time norm, weight norm or there is no other wagon to be matched to the train in dedicated direction. During humping brakemen push the wagons or blocks one to each other and tight hand brakes of the wagons. Pushing wagons do brakemen manually. In case that is necessary due to weight or bad weather conditions to push blocks manually, the blocks are pushed by yard locomotive. If there is the completed track, brakemen couple blocks of train. Afterward is coupled yard locomotive. Hand brakes of wagons are loosened and wheel chocks are put away. Brake system of the train unit is filled and brake connection test is done. According to command of railway undertaking dispatcher yard loco shunts the unit train to departure yard. [1, 2, 6]

On dedicated track in departure yard is unit train again ensured against movement and wagon inspector provide technical and shipment inspection. Like is possible to see in table 3 below, this activity takes the longest time. It’s about 60 minutes and its duration except of number of wagons depends on type and length of wagon. Optimisation proposal have to reflect this attribute during calculation of necessary time for this activity. The activity listing of the train vehicles is provided by transport agent and takes about 35 minutes. It is provided at the same time with technical and shipment inspection. Then railway undertaking dispatcher command to shunt and couple line locomotive. The command is provided through radio and signalling. Line loco driver a shunters loose wagon hand brakes and put wheel chocks away. Next command is filling brake system by pressed air and line locomotive driver with cooperation with wagon inspector do the full brake test. Then line locomotive driver receive verbally the results of full brake test from wagon inspector. After that is necessary to take over and sign documents. The last activity is to send SMS “Ready to departure” by line locomotive driver to system DISOM. Afterward in appropriate time according to timetable and situation on surrounding network the train leave the departure yard. [6]

Departure is issue that manage infrastructure manager dispatcher in coordination with railway undertaking dispatcher in the station and railway undertaking regional network dispatcher. Main activities of outbound train procedure are possible to see in table 3 below.

Tab. 3 Outbound train procedure

Outbound train procedure	**Time (min)**	**Perform**
Pushing (manually + yard loco)	20	Brakeman, yard loco driver
Coupling of train blocks	30	Brakeman
Shunting of yard loco	5	Yard/hump loco driver, shunter
Coupling of yard loco	3	Shunter
Filling of train unit brakes	4	Yard/hump loco driver
Shunting with train unit	5	Yard/hump loco driver
Technical and shipment inspection (generally)	60 (2 min per wagon)	Wagon inspector
Technical and shipment inspection (2/4/6/8 axles wagon)	1,5/2/2,5/3	Wagon inspector
Listing of the train vehicles	35 (1 min per wagon)	Transport agent
Command to coupling of the line locomotive to train unit	0,5	railway undertaking dispatcher
Shunting from line loco sidings to departure track	X	Line loco driver
Coupling of the line locomotive to train unit	3	Line loco driver
Command to filling of pressure brake by air	0,5	railway undertaking dispatcher
Loosening of hand brakes of wagons	6	Line loco driver, shunter
Releasing the train unit (put wheel chock away)	0,25	Line loco driver
Placing wheel chocks beside track	0,25	Line loco driver
Full brake test	30 (1 min per wagon)	Line loco driver, wagon inspector
Announcement of full brake test results	0,5	Wagon inspector
Taking over of train and shipment documentation (from car inspector to loco driver)	1	Line loco driver, wagon inspector
Signing of international train braking report	0,1	Line loco driver, wagon inspector
Taking over of commands for route	1	Line loco driver, wagon inspector
Signing of commands for route	0,1	Line loco driver, wagon inspector
Train readiness to depart announcement (SMS)	3	Line loco driver
Departure	X	X

3.3 Resume

At these times there are no bottleneck in marshalling yard except of extraordinary disruptions on the network that are naturally transferred to marshalling yards. Due to that could be marshalling yard used like bumper in case of delays. In case of lockouts on the infrastructure and other circumstances and due to that big delays of freight trains there comes to being problem with decision about order of trains to be marshalled. Like it is stated in this paper above the system OIS which provide to dispatcher information support has no optimisation feature. Decisions about which train should be served first according to direction of shipments in it and according to outbound train in dedicated direction became extremely difficult. In addition, in the inbound train could be placed shipment with so called “firm connection”. It means that dedicated shipment (wagon or block of wagons) have to be travelled by no others that dedicated trains. For railway undertaking dispatcher there is this information the main rule for decision. It is possible to break the rule only in extraordinary cases. Some of operations that are stated in previous chapter of this paper are dependent on each other and their correct providing depends on correct information at right time. In mentioned situation of big delays and many inbound trains there is for railway undertaking dispatcher almost not possible to calculate the time which is necessary for providing the operations and make optimal or at least good decisions.

First inconvenience is following. Though the railway undertaking station dispatcher has in system DISOM actual position of the inbound train is in many cases able to only roughly calculate estimated time of arrival (ETA). [3, 4]

The second inconvenience is that there is no real-time support tool for calculation of necessary time to serve the inbound and outbound train according to list of shipment and type of wagons. So there could emerge delays of outbound trains due to bad decision of train order.

Third problem, which is connected to second one, is that there is not possible to calculate estimated time of departure (ETD). Due to this reason the railway undertaking dispatchers and infrastructure manager of regional network dispatchers do not have information if the dedicated train unit use dedicated ordered train path or use other ordered train path or there will be necessary to order ad-hoc train path. From the other point of view, for railway undertaking regional network dispatcher there is very difficult to decide if is possible to use the train path of dedicated delayed train for other e. g. ad-hoc train. [6]

4 PROPOSAL

Before development of MY information system there should be developed interface to ensure transfer of information between “network” information systems and considered marshalling yard system. Consider only the problem in marshalling yard there is necessary to ensure not interrupted information flow through the whole marshalling process with connection to network processes.

Nowadays is possible to have at least an hour before arriving dedicated train into marshalling yard available relatively reliable information about ETA. The crucial object of proposal is interface between systems to be taking over information. After that there will be possible to build up new “marshalling yard operation system” – MYOS that will be effective supporting tool for railway undertaking dispatcher and in addition for other marshalling yard workers. The proposal in this paper does not involve the system but it is focused on data that should be transferred through interface.

Proposed interface data are divided into three groups. Proposed interface data, precisely attributes are possible to see in table 4 below.

In the first group are technical data, that represent limits for railway undertaking dispatcher or infrastructure manager dispatcher and MY workers. Maximum speed, power rate and braking power rate determine time of approaching to and leaving from MY.

Second group involve technological data, which depends on actual situation. Train with the same number can in some case travel dangerous goods or priority shipment and in other case any of shipments that requires special care. According to actual situation will be prepared actual plan for marshalling of trains and calculated ETD.

In the third group are data for identification of train, train paths and contact to train driver. Some of proposed data are nowadays available in information systems (e. g. DISOM, OIS etc.)

[3, 4, 5]. Other data (e.g. GPS position, maximum time of departure) are not available today. The data in the third group will be used for modelling of optimal procedure (e.g. planning of train routes in the marshalling yard) and to choose optimal train path for leaving of the train according to fluent travel on the network.

Tab. 4 Attributes of interface

Technical data	Technological data	Information system data
Length of train unit	Transfer of wagon (to which train)	Sender info (ID)
Braking power rate	Direction of wagon	Recipient info (ID)
Maximum speed	Transfer of wagon (in which station)	Train driver
Type of locomotive	Train ID number	Phone number of train driver
Length of wagon	Number of wagon	Equipment by tablet
Number of axles	Order of wagons in train	Path ID
Weight of wagon	RID / dangerous goods	DISOM train number
Weight of shipment	Firm/priority transfer of wagon	Actual position (station)
Traction (in-/dependent)	Info for manipulation (limits/regulation)	Actual position (GPS)
	Planed activities (actual) e. g. arrival technical inspection	Arrival track
	Estimated time of arrival (to point e. g. MY)	Departure track
	Estimated time of departure (from point e. g. MY)	Executive railway undertaking
	Number of train unit (case of unit train)	Licenced railway undertaking
	Type of transportation (unit train, single wagon load, special, military)	Available paths in direction
	Maximum time of departure (each wagon) – railway undertaking requirement	Available times for departure
	Train confidence	Other note
	Origin station of wagon	
	Destination of wagon	

Based on these data the system MYOS will be able to calculate necessary time to performance of all planned activities and due to that it will be able to estimate time of departure each train because the system will consider transfers of wagons. In addition, this tool will help dispatchers to make optimized decision which train accommodate and process first according to possibilities to depart connection train. Due to complex information during the whole marshalling process could be simplified process of train listing.

5 CONCLUSION

Non-interrupted data flow between marshalling yards and surrounding network as a base for optimized decisions is nowadays very important issue due to delays caused by engineering works on railway lines and other disruptions at least in the Czech railway business. This paper touches the existing procedures, sources and duration of main activities in marshalling yard Česká Třebová. Outbound of the analysis is resume of inconveniences that should be eliminated in the short-term future. Last part is focused on proposal of universal data interface for transferring information from network information systems to considered yard management system. Proposed interface should be compatible not only with Czech information systems but almost with systems that are operated abroad.

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THE STRENGTH OF GEOPOLYMERS BASED ON RED MUD AND FLY ASH

Pavel Švanda[1]

Abstract

Alkali activated materials (geopolymers) are relatively new materials, thanks to their good mechanical, physical, thermal properties and at the same time environmental friendliness, they could be widely adopted in different fields. The experiments, described in this article, are focused on the investigation of compressive strength of alkali activated materials based on fly ash and red mud. For the following experiments were prepared five series of samples with different ratio of red mud to fly ash. All the samples had the form of cubes with dimensions 30mmx30mmx30mm. The tests on compressive strength were conducted in 7, 28 and 56 days after final heat treatment. The test showed that the highest strength had the samples with the smallest amount of red mud (5%). In 56 days it was 29 MPa. Meanwhile the samples with the biggest amount of red mud (50%) were not even tested because of samples cracking during heat treatment.

Keywords

Alkali activated materials; fly ash; red mud; water glass; compressive strength

1 INTRODUCTION

The wide study of alkali activated materials was started in the first part of the last century. From that time were made a lot of experiments in order to find new alternative materials to concrete and other silicates with good properties and lower price [1 – 5, 7-8].

Nowadays, there are not only the aspects of price and quality important but also of ecology. Utilization of production waste materials or decreasing of CO_2 emission are the next very important tasks which scientists have to solve. Cement production is the biggest emitter of CO_2 among all building materials. With each year consumption of cement grows and these days its production reaches 1.7 billion tons per year [9]. If we take into consideration that during production of 1 ton of clinker it is emitted 0.8 – 1.3 ton of CO_2 to the atmosphere, it becomes obvious, that production of cement plays not the last role in pollution of environment. For that reason in many countries pays special attention to the study of clinker free cements. [10,11,13 – 15].

The other advantage of alkali activated materials is they could be made on the base of waste materials (fly ash, slag) [3,5-8,11,12,14]. Each year on the planet it is produced hundred million tons of industrial wastes. Only a little amount of them finds further usage in different fields, the most part of wastes is stored, which requires huge areas, financial costs, and of course have a negative impact on the environment.

For the experiments, described in this paper, were used two types of waste materials. The first was fly ash – the industrial by-product, generated during combustion of coal. The annual world production of this waste material varies around 500 million tons [16]. And the second was red mud

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– the by-product of the aluminum production from bauxite (the Bayer process). The world production of this waste is 120 million tons per year [17]. It was prepared five series of samples with different proportion of red mud to fly ash in order to find the optimal composition of the substance. The amount of red mud varied from 50% till 5 % and amount of fly ash varied from 50% to 95%, all samples were tested on compressive strength.

2 MATERIALS

For this experiment were used two types of waste materials: fly ash – produced during combustion of coal at electric power station and red mud – the by-product of the manufacture of alumina from bauxite by the Bayer process.

The fly ash was taken from Opatovice electric power station (Czech Republic). Its chemical composition and particle size distribution are shown in the Table 1 and Figure 1.

Tab.1 Chemical composition of fly-ash, wt.%

	SiO_2	Al_2O_3	NaO	K2O	CaO	MgO	Fe_2O_3	TiO_2
Fly-ash, Opatovice	61.4	31.1	0	2.2	0.2	1.6	2.6	0.9

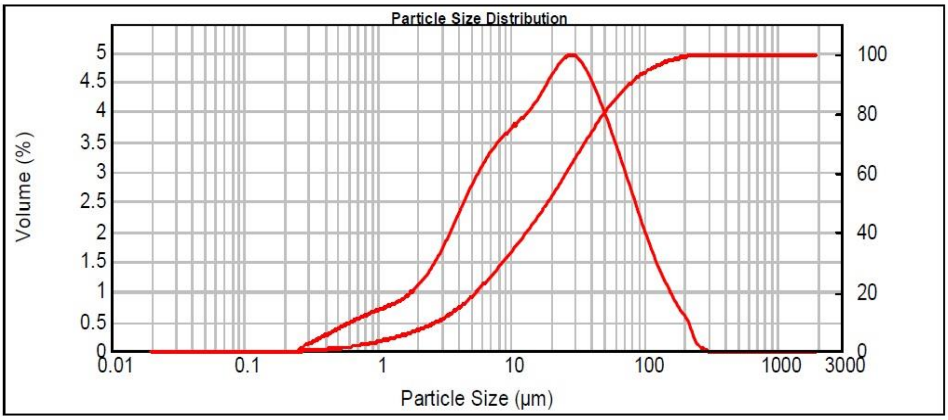

Fig. 1 Particle size distribution of fly-ash

Red mud was taken from Ajka alumina plant (Hungary). Red mud is an alkaline residue (pH about 10) derived from alumina extraction by Bayer process from bauxite ore. Its chemical composition is shown in the Table 2. Red mud contains a significant quantity of entrapped NaOH. During experiments the red mud was used in wet state as it was taken from the alumina plant. Amount of water in red mud was about 14 wt.%.

Tab. 2 Chemical composition of red mud, wt.%

	Fe_2O_3	Al_2O_3	$Si0_2$	Na_2O	TiO_2	CaO	MgO	K_2O	Cr_2O_3	NiO
Red mud, Ajka	33.1	14.8	13.2	9.1	5.4	6.5	0.3	8.8	3.3	5.5

2.1 Samples preparation

We were prepared five groups of samples in a form of cubes with different ration of fly ash and red mud. The compositions of the samples are shown in the Table 3. The fly ash/red mud ratio in solid powder was the next:

- set of samples B50 consisted 50% of fly ash and 50% of red mud,
- B25 – 75% of fly ash and 25% of red mud,
- B15 – 85%of fly ash and 15% of red mud,
- B10 – 90% of fly ash and 10% of red mud,
- B5 – 95 of fly ash and 5% of red mud.

To the mixture of fly ash and red mud was added water glass. Than the mixture was well mixed, formed and put on high frequency vibration table for 30 minutes. In order to make samples were used silicon molds, which had a square form and were suitable for preparing of 16 samples with dimensions 30mmx30mmx30mm. The heat treatment of the samples was provided in two steps. Firstly, the formed pieces were put into the stove for 16 hours under the temperature 65°C. Than the next day, the samples were unmolded and put again into the stove for 24 hours under the temperature 65 °C.

After the heat treatment till testing the samples were left in normal laboratory conditions.

Tab. 3 Composition of the samples (where M is Na or K)

Component / Sample No.	**Fly ash (wt.%)**	**Red mud (wt.%)**	**Water glass (wt.%)**	**SiO_2/Al_2O_3**	**M_2O/SiO_2**
B50	45.9	45.9	8.2	3.04	0.20
B25	59.6	19.9	20.5	3.60	0.11
B15	63.8	11.3	25	3.78	0.09
B10	66.3	7.4	26.3	3.85	0.08
B5	65.8	3.5	30.8	4.00	0.08

2.2 Strength measurement

The tests of strength of cured samples were conducting on testing machine ZD 10/90. The strength of samples was tested on compressive strength in 7, 28 and 56 days after final heat treatment.

The cubes were stressed in one direction by smoothly increasing strength till the appearing of cracks. Than the load was reduced, so that’s why the full crush of samples didn’t take place (Fig.2). Strength was calculated from maximum force during test. Strain rate was 5 mm per minute.

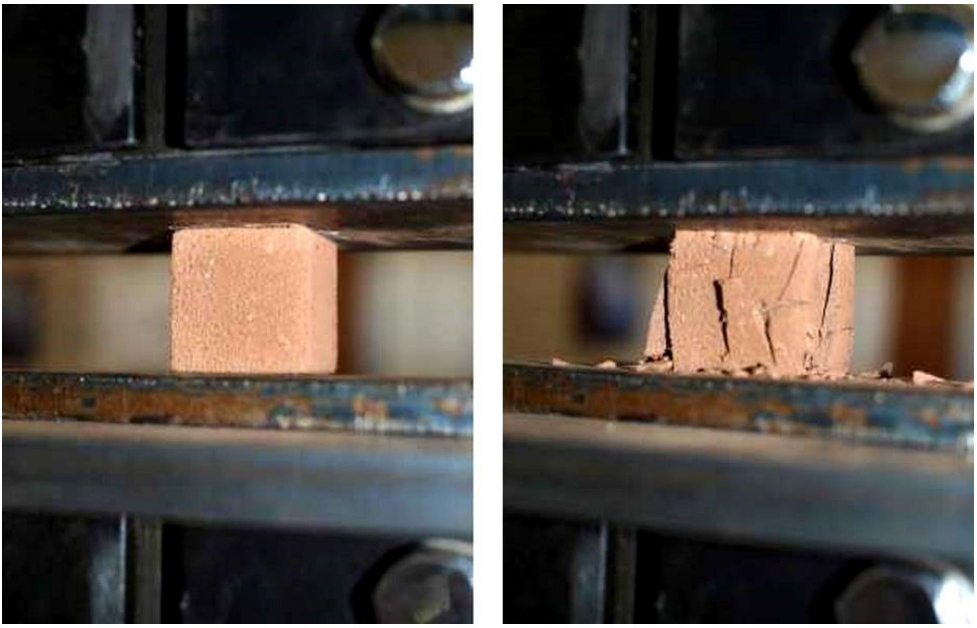

Fig. 2 Compressive strength testing of the samples

2.3 Composition measurement and microstructure

Microstructure of samples after compressive strength tests was observed by SEM (Scanning Electron Microscope) TESCAN VEGA 3 Easy Probe. The chemical compositions were determined by EDS BRUKER probe (SEM component). SEM observation and determination of chemical composition was performing in high vacuum mode with uncoated samples.

3 RESULTS AND DISCUSSION

During the heat treatment of samples B50 all pieces were cracked (Fig.3), so that's why testing of these samples wasn't carried out.

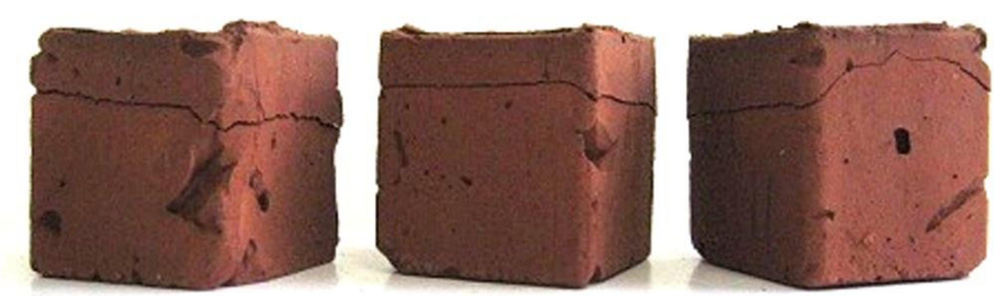

Fig. 3 Samples B50 after final heat treatment

All the rest samples B25, B15, B10, B5 were tested on compressive strength in 7, 28 and 56 days after final heat treatment. All tested samples do not show any visible damage.

The results of the compressive strength tests are shown in the Figure 4.

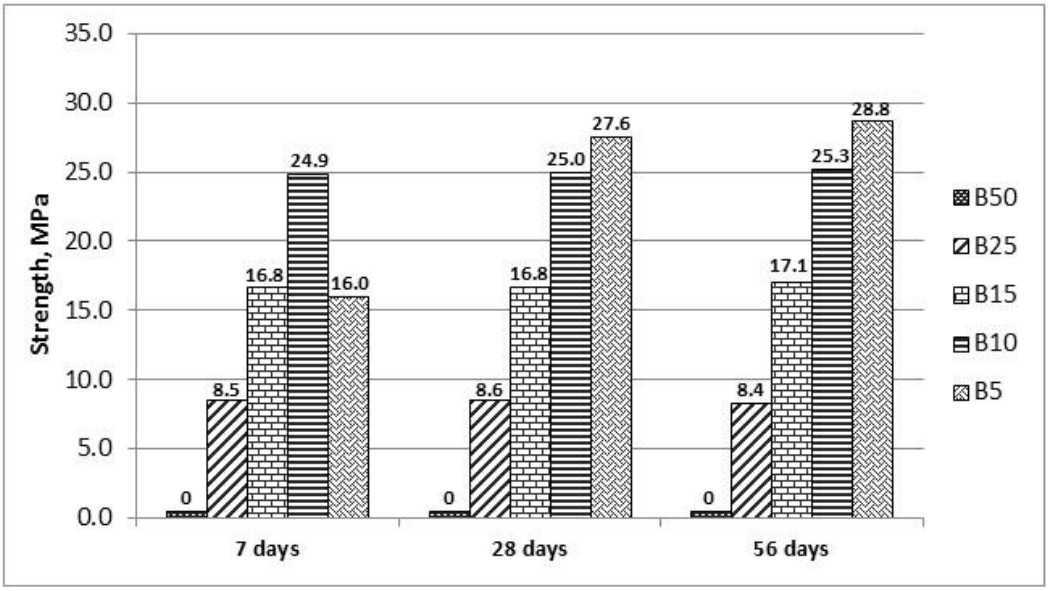

Fig. 4 Compressive strength test results

The smallest strength among the all tested samples had the samples B25, which consisted the biggest amount of red mud – 25%. In 7 days after final heat treatment the average strength of these samples was 8.5 MPa and it remained the same in 28 and 56 days. The samples B15 with 15% of red mud had the strength two times higher than samples B25. Its average was around 17 MPa, it also remained the same in 28 and 56 days. The average strength of the samples B10 (with 10% of red mud) was around 25 MPa and it almost didn't change in one and two month. The highest strength had the samples B5 with the smallest amount of red mud (5%). It varied from 16 MPa in 7 days after final heat treatment till 29 MPa in 56 days.

The relatively small increasing of strength (slow curing) of B5 samples was probably connected with low amount of alkali metals oxide (ratio M2O/SiO2 was 0,08; see Tab. 3). Low amount of alkali metals oxide react very slow with silica/alumina for curing. For this reason the strength increases for about 2 month for full chemical reaction.

Chemical compositions and microstructure of selected samples after compressive strength tests were tested using SEM. Chemical compositions of selected samples is summarize on Table 4. From chemical composition is possible to see the increasing amount of sodium with increasing amount of red mud. Red mud is main source of alkali metals ions – amount of Na increase though the amounts of water glass decrease (see Table 3).

Tab. 4 Chemical composition of selected samples, wt.%

	O	Na	Mg	Al	Si	K	Ca	Ti	Fe
B5	52.0	4.7	0.7	13.9	22.5	1.6	0.7	1.0	2.9
B25	54.4	5.8	0.6	11.2	20.9	1.2	0.9	1.1	3.9
B50	56.1	8.6	0.5	8.3	16.8	1.0	1.3	1.2	6.2

Relatively low strength of samples with high amount of red mud is probably due to very high concentration of alkali metals oxides. These oxides of alkali metals may hydrate during weathering of samples. Product of hydrating weakens the structure of geopolymer – products of hydrolysis of alkali metals salts is show at Fig. 5. The needle shape crystals (visible on Fig. 5) contain lots of sodium.

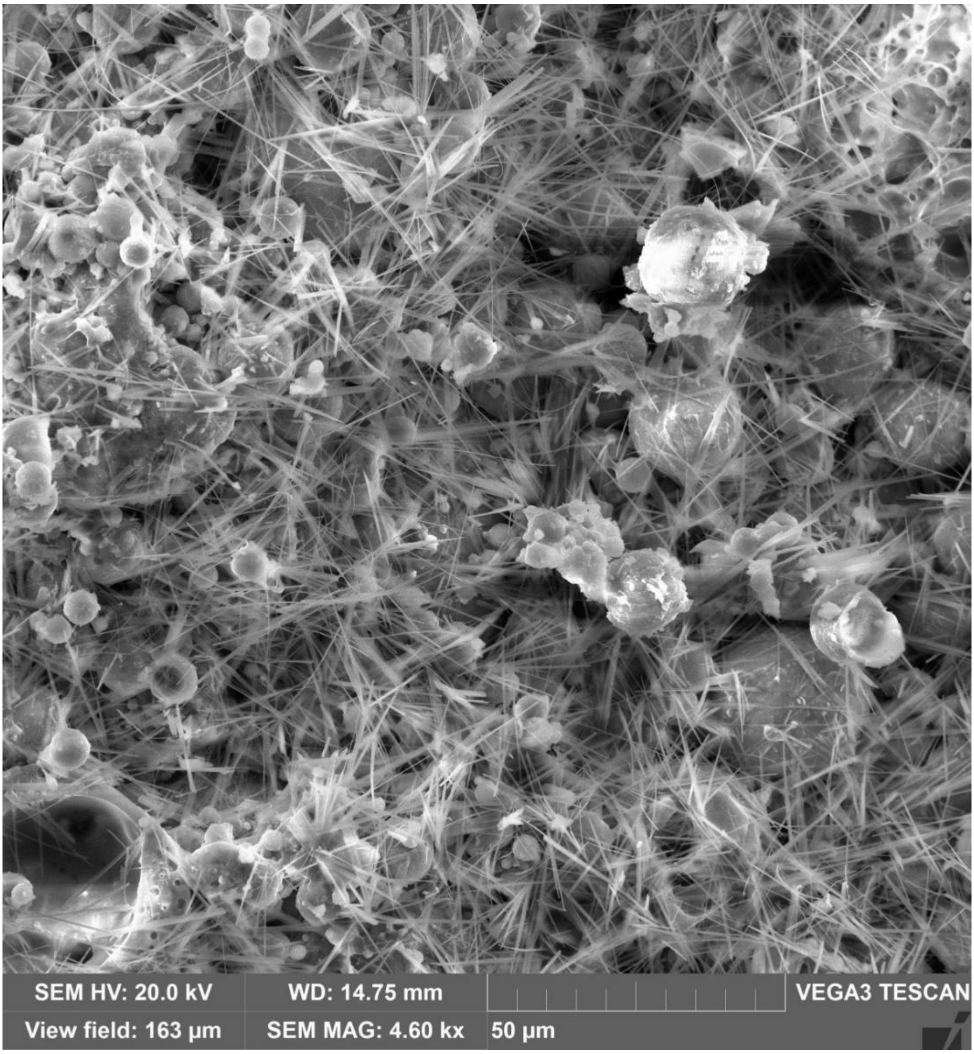

Fig. 5 SEM structure of B25 sample. Products of weathering of alkali metal salts

3.1 Other materials based on red mud/fly ash – comparing

Materials based on red mud and/or fly ash was prepared early with different properties. Our samples based on red mud and fly ash was prepared from waste materials and water glass. For this reason our material is relatively cheap and for sample preparation is produce very low amount of CO_2. Our samples have compressive strength about 25 MPa that is comparable with samples of based on similar materials.

The alkali activated materials based on fly ash and red mud studied Jian He et al. In their paper they compared two types of geopolymers, one based on metakaolin and the second on red mud and class C fly ash. To the metakaolin was added sodium silicate solution and sodium hydroxide and to the red mud-fly ash mixture – sodium trisilicate powder. The results of the tests showed that metakaolin based samples had the higher compressive strength and at the same time shorter period of complete curing than red mud-fly ash samples. Metakaolin based samples achieved the strength of 31 MPa and were cured completely as less as 9 days, while red mud-fly ash samples had the strength 13 MPa and complete curing took more than 21 days. [22]

Gordon et.al. investigated composites formed by the addition of various amounts of hydrated lime, condensed silica fume and limestone to the red mud. The strongest composite had the compressive strength 15-18 MPa in 28 days and 18-22 MPa in 122 days correspondingly. These samples contained equal quantities of red mud and limestone, blended with a 2:1 mix of hydrated lime and condensed silica fume. [19]

Jiakuan Yang and Bo Xiao studied composites based on red mud, fly ash and sand with addition of lime, gypsum and/or Portland cement. Depending on the proportion of the components the strength of the samples varied from 8.7 till 26.7MPa in 7 days and from 11.7 till 29.5 MPa in 28 days. According to their suggestion the optimal composition of the material is 25 – 40% of red mud, 18 – 28% of fly ash, 30 – 35% of sand, 8 – 10% of lime, 1 – 3% of gypsum, and about 1% of Portland cement. [20]

Much higher strength can be reached in case of slag usage instead of fly ash. Zhihua et al. studied alkali-slag-red mud cement (ASRC) and got very good results. ASRC based on slag (70%) and red mud (30%) with addition of alkali activator – solid water glass with modulus 1.2 and sodium aluminate clinker. ASRC cement had high early and ultimate strength and a good strength development, in 1 day the strength was 20 MPa, in 28 days – 56 MPa and in 180 days – 66.5 MPa. [21,22]. Similar results of strength after 28 days reach the Zhou et al. They used the red mud, slag and lime in diverse ratios.

Ke et al. investigated the compressive strength of blend based on thermally treated red mud and blend. They used one-part thermal preactivated red mud/sodium hydroxide powder and water for preparing of paste. Their samples reach the strength up to about 10 MPa after 7 days. After 7 days the samples was a significant strength loss [5].

4 CONCLUSIONS

We were prepared five groups of samples. As basic materials were used fly ash and red mud, as an alkali activator sodium silicate with silicate modulus 3.35. The fly ash/red mud ratio was the next: set of samples B50 consisted 50% of fly ash and 50% of red mud, B25 – 75% of fly ash and 25% of red mud, B15 – 85%of fly ash and 15% of red mud, B10 – 90% of fly ash and 10% of red mud, B5 – 95 of fly ash and 5% of red mud. During heat treatment all the samples of the set B50 were cracked, therefore the further investigation didn’t take place. The rest samples were tested on compressive strength in 7, 28 and 56 days after final heat treatment. The test results showed that with proportional increasing of fly ash and decreasing of red mud in the substance the strength of the samples was increasing. The highest strength had the samples B10 and B5. It was 25 and 29 MPa correspondingly in 56 days after final heat treatment. So, according to results of this investigation it can be told that optimal ratio of the basic components in the substance is 90 – 95% of fly ash to 10 – 5% of red mud.

The investigated materials show strength that is comparable with early prepared similar materials. For our samples is not necessary any heat treatment of base materials. Main advantage of prepared material is utilization of waste materials, low production of CO_2 and low energy consumption for preparation in comparison of classics cement materials.

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THE USE OF THE SINGLE EUROPEAN SKY IN CURRENT MILITARY AND CIVIL AIR TRAFFIC

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Abstract

The aim of the contribution is to define the theoretical background within the operational and economic level of parallel use of the common airspace in Europe. The contribution is divided into 5 parts. The first part deals with the introduction to the Single European Sky. In the second part are presented the general characteristics of the concept, the problems of the functional blocks and the individual phases, through which the SES concept has passed. The third and fourth parts illustrate the cooperation between civilian and military components during the shared use of airspace and the puzzling part deals with the evaluation of the issues discussed.

Keywords

Single European Sky; SES; functional airspace block; FAB; EDA; EUROCONTROL; SESAR; PRISMIL; air traffic control; ATC.

1 INTRODUCTION

Airspace offers a wide range of options for developing and implementing transport not only for the civilian component but also for the military component. Performing military operations, whether direct air fights, exploratory flights, or the transport of military material, are gaining more and more importance. In particular, it contributes to the conflicting situation in which more and more countries, in particular the North Atlantic Organization of NATO, support states occupying the occupation or direct military conflict, whether civil, religious or international, are receiving. The SES project was launched by the European Commission in 1999 and its primary objective was to meet future capacity and security needs through legislation. The development of the project also meant the development of the different areas associated with air traffic control and therefore took a step forward in defining objectives in key areas of safety, network capacity, efficiency and environmental impact. The second part of the program - SES II - contributed to this. Single European or transformed the role of EUROCONTROL, which could become the network manager of the European ATM network. Technologically, the SES project is supported by SESAR, which provides advanced technologies and procedures to modernize and optimize the future European ATM network.

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2 CHARACTERISTICS OF THE SINGLE EUROPEAN SKY PROGRAMME

In response to the dramatic rise in aviation development recorded over the past two decades, the European Commission has approved two parts of the European Single Program or in order to create a legislative framework for the aviation industry in Europe.

The European Air Traffic Management (ATM) system currently processes around 26000 flights a day. Forecasts indicate a doubling of the air traffic level by 2020. In addition to this assumption, European ATM operations, compared to other ATMs in the world, cost about EUR 2-3 billion each year. The SES program is intended to answer the question of how European airspace will be adapted to the increasing air traffic flow in order to reduce costs and improve its performance.

The necessary response came with the initiative to organize airspace into the so- FABs - functional blocks according to traffic flows to replace national borders. Such a project could not be organized without common rules and procedures at European level. Single European or a program built to meet these needs.

2.1 Functional airspace blocks

Although airspace is a common source of air traffic management, ATM is still provided in a less organized way in the European Union, affecting safety, reducing capacity and, above all, increasing costs. The key to improving the capacity and efficiency of increased security and ensuring lower cost of air navigation services is enhanced co-operation and cross-border integration. The establishment of functional airspace blocks will lead to increased cooperation and integration in the provision of air navigation services.

The functional airspace block is defined in the Single European Sky legislative package, in Regulation (EC) No. 1070/2009 amending Council Regulation (EC) No. 549/2004 as an airspace block based on operational requirements and established regardless of frontiers where the provision of air navigation services and related functions is performance-optimized and enhanced by enhanced cooperation between air navigation service providers or, where appropriate, integrated providers. The current reorganization of 67 airspace blocks in Europe (based on state borders) into only 9 functional blocks is the first step towards achieving this.

2.2 Arrangement of airspace

The FAB concept was developed in the first SES legislative package (SES I) as one of the main means of reducing fragmentation of the airspace. The creation of the FAB itself was the second legislative package of SES II, with a view to providing services, in addition to the organization of airspace. The dual aim of the legislative package is to optimize air traffic flows and to increase the efficiency of air traffic services in Europe. SES II sets the final date for the commitment to improve performance by Member States by 4 December 2012. The project is subject to 9 functional blocks, of which two have already been implemented - UK-IRELAND FAB (United Kingdom and Ireland airspace and DENMARK -SWEDEN (airspace of Denmark and Sweden). Below are all 9 proposals received:

- NEFAB (North European FAB): Estonia, Finland, Latvia, Norway;
- Denmark-Sweden: Denmark and Sweden;
- BALTIC FAB: Poland and Lithuania;
- FABEC (FAB Europe Central): France, Germany, Belgium, the Netherlands, Luxembourg and Switzerland;
- FABCE (FAB Central Europe): Czech Republic, Slovak Republic, Austria, Hungary, Croatia, Slovenia and Bosnia and Herzegovina;
- DANUBE: Bulgaria and Romania;
- BLUE MED: Italy, Malta, Greece and Cyprus (as well as Egypt, Tunisia, Albania and Jordan as observers);

- UK-IRELAND FAB: United Kingdom and Ireland;
- SW FAB (South West FAB): Portugal and Spain [1, 2].

2.3 SES I

Since 2004, the European Union has been granted air traffic management powers and the decision-making process has shifted from intergovernmental practice to the EU framework. Its main objective is to reform ATM in Europe with a view to tackling the sustained growth of air transport and operations under the safest, cheapest and most environmentally friendly conditions. This means eliminating the fragmentation of European airspace, reducing delays, increasing the safety of standards and the efficiency of flights in order to reduce the environmental footprint of air transport and reduce the costs associated with the provision of services. Achievements have already been achieved at the operational, technological and institutional levels. Efforts to continue, however, continue to maximize the benefits of the activities initiated under the Single European or European program.

2.4 SES II

The second Single European Sky (SES II) regulatory package was adopted in 2009 and changed the focus of SES from capacity to performance in general. Its main objective is to increase the economic, financial and environmental behaviour of the provision of air navigation services in Europe. The amendments to the SES I regulatory package have in particular introduced a comprehensive EU performance scheme. Redistribute functional airspace blocks (FABs) not only to airspace but to the provision of services in general and to the network administrator to coordinate certain activities at the network level. In addition, it extended the European Aviation Safety Agency (EASA) air traffic management powers, thereby stepping up support for the drafting of technical implementing rules and supervision of Member States from EUROCONTROL to EASA.

2.5 SES II+

The SES II package of 2009 has proven to be a promising contribution to the future of the project, especially as regards the implementation of the performance-oriented economic regulation model. In implementing this approach, important facts have been identified that need to be included in accessibility regulations. In addition, the SES II initiative left some overlapping of legislation, so the same provisions were found in several regulations. In order to implement these updates, the European Commission has proposed an ongoing update of the rules of the Single European Program. The SES II + proposal were submitted in June 2013 and is currently being approved by the European Parliament and the European Council.

2.6 SESAR

The SESAR project is the technological pillar of the Single European Program. Its objective is to improve the performance of ATM by modernizing and harmonizing ATM systems through the definition, development, validation and deployment of innovative ATM technology and operational solutions. These innovative solutions represent the so-called SESAR concept. This concept is defined in the European ATM Master Plan, which also defines the necessary operational changes and the plan for their implementation. The components of the concept will be developed and validated by the Joint Undertaking SESAR JU. Verified basic operational changes are used through joint projects supported by SESAR deployment management and mechanisms. All three processes are part of a virtual life cycle that actively engages stakeholders and the Commission in various forms of partnership [6, 7].

3 THE USE OF AIRSPACE BY CIVIL AND MILITARY AIR TRAFFIC

The Single European Sky concept does not directly apply to military air operations, because defence and security are synergies that remain under the sole responsibility of the state. However, since European transport policy has a direct impact on the organization of airspace, it may also affect access to the airspace of the Single European Sky. As a result, EUROCONTROL's member states must make important decisions on how they intend to align their military forces with the development of the SES. The EUROCONTROL ATM Civilian and Military Coordination Division provide support to Member States in all areas related to the implementation of the Single European Sky (SESIM) and its possible impact on the activities of the Air Force.

3.1 The Master plan of European ATM

The master plan of the European ATM is an approved plan for the modernization of the ATM system and combines the scenarios of its development with the development of the SESAR program. The master plan is a tool for deploying SESAR and provides the basis for timely, coordinated and effective deployment of new technology technologies. It includes plans outlining the main operational and technological changes required by all stakeholders (airspace users, air navigation service providers, airport operators, military component and network manager) in order to achieve the performance set by the SES program [2].

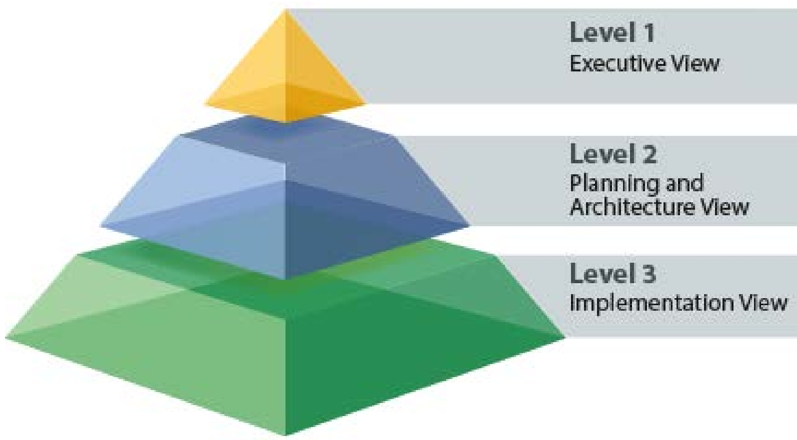

Fig. 1 The pyramid of the introduction of the Master Plan of the European ATM

3.2 Advanced Flexibile Use of Airspace (AFUA)

Targets and business models of airspace requirements vary for both civilian and military airspace users. While civil aviation is developing the program's trajectory with the most cost-effective route, the country's air forces are engaged in the widest possible use of airspace through the FUA program. However, this concept was interpreted differently by different organizations. As a result, the procedures applied by these countries vary considerably, leading to discrepancies affecting the civil-military coordination activity. The AFUA concept, which is a better part of the SESAR deployment process, is expected to provide more flexibility in dynamic airspace management at all phases of flight from initial planning to the flight phase.

The SESAR project, Design 7.5.2, aims to optimize the compromise between civilian and military requirements by defining new types of airspace structures and related reservation processes between the two user communities. It is led by EUROCONTROL with the participation of Aena, DFS, NATS, NORACON and Thales. It defines future airspace structures and aligns design at their European level. These structures will have to be as dynamic as possible, taking into account the performance of aircraft and weapon systems. The current solid structures - the temporary limited area (TRA), the Temporary Area (TSA), the cross-border area (CBA), should in the future be an exception only for a limited timeframe. There will be developments in line with the three steps of the SESAR Concept Storyboard, starting with a more flexible airspace structure, such as the MVPA and the Dynamic Mobile Area (DMA) geometric area (VMA) from 2020.

Benefits for all airspace users:

The FUA concept is intended to contribute to meeting the SESAR performance targets:

- Providing adequate dedicated airspace at the right place and at the right time while providing accurate information;
- The development of airspace structures from fixed to dynamic aims to reduce transit between aerodrome bases and training areas, help to save fuel and allow for greater flexibility;
- Facilitating cooperation and coordination between armed forces has the role of increasing capacity for the benefit of all airspace users.

4 DESIGN OF THE CONCEPT OF USING THE AIRSPACE IN PARALLEL CIVIL AND MILITARY AIR TRAFFIC

The draft concept of cooperation between civilian and military aviation is based on a combination of programs that are used in the long term in the United States and Germany. The complexity of civilian and military transport in the Central European airspace required enhanced civil and military co-operation. In general, military aviation activities do not allow for inflexible treatment and discrete or segregated management of military transport flows.

4.1 Linking the Overseas and European FUA concept

The concept of flexible use of airspace is based on the safety of fluent operation. The complexity of civilian and military transport remains a permanent challenge.

In addition, the military air force will continue to exist with different airspace and mission requirements, albeit probably in a smaller amount. What has been achieved over the last twenty years through good civil-military cooperation is the basis for the future, and therefore:

a) a very high level of safety;
b) more than doubling the capacity of airspace;
c) a national security guarantee;
d) meeting military requirements even in times of crisis.

The concept of military flexible use of airspace is a follow-up to the comprehensive European ATM Harmonization and Optimization Program to cope with the growing demand for airspace in Europe. General Air Traffic (GAT) and Operational (Air) Air Traffic (OAT) formulate different requirements for the use of airspace. Airspace sketched for military purposes prevents economical and efficient flight routes, and training airspace available to the air force is limited due to existing ATS routes.

Airspace management is conducted at three organizational levels:

(a) Level 1 (Policy and Strategic Planning) - Civilian-military authority at government level, which takes political decisions on airspace structure and issues guidelines on airspace management;

(b) Level 2 (tactical pre-planning) - Planning, coordination and defining the activation of defined airspace and contingent routes on the following day in accordance with current requirements. It is the role of the National Airspace Management Cells (AMC).

c) Level 3 (Tactical Civil and Military Coordination) - This is the operational part implementing the FUA concept in practice in day-to-day operations. The management of ad hoc use of airspace and airspace shall be carried out in close cooperation with the air traffic control unit units designated for air traffic control and management / support for air traffic control. For example, Deutsche Flugsicherung GmbH (DFS), in cooperation with the Air Traffic Management Tactical Service as well as the Control and reporting Center (CRC), performs this task in Germany [4].

4.2 Special use of airspace (SUA)

The United States, based on the geographical area and political structure, has formally integrated flexible airspace for over 50 years. Air Navy military air services are divided into military requirements into two categories:

1. operations which could be dangerous for an aircraft without participation or activity on the ground; and
2. those that are not.

Naturally dangerous operations are carried out in segregated airspace, which is called special airspace, which is more known in ICAO terminology than FUA, and hence the flexible use of airspace. However, as this is not a civil air traffic operation, the special use of airspace can be referred to as a subset of the FUA. Its basic requirements include:

a) volume/capacity - sufficient airspace to achieve training / testing objectives;
b) distance from operating airports;
c) time - available if needed;
d) Physical characteristics (environmental and safety issues).

Airspace is available for both civilian and military aviation. However, the USA can be characterized as the airspace needed to protect persons and property, to carry out special training, testing or military operations and is available for that purpose. In such cases, civilian crews are instructed not to enter the airspace or are aware of the hazards and have been advised to use their airspace with the utmost caution if they choose to enter such airspace.

Special use of airspace is not a normal operation of flights used for the carriage of persons or goods. Therefore, for the protection of persons and property in the performance of special operations which do not have the status of ordinary civilian flights, temporary flight restrictions (TFRs) are in place to protect persons and property from the temporary danger which, when performing a specific a special task was caused by the presence of aviation technology to that end.

4.3 SUA as a part of MVPA

Model of military areas with variable profiles MVPA was established as a field study in the northern part of Germany (near TRA 206/306) [4]. The airspace was arranged into 15x15 nautical miles (NM) modules that the military units can reserve according to their operational requirements. This is the concept of dynamic or flexible use of airspace [7].

US Authorization Process and Subsequent Operation:

After entering the requirement for the use of airspace in the electronic reservation system, the confirmation is issued, permission to use part of the airspace, preceded by the consultative process of military components with the relevant civilian ACCs. After this process, airspace is assigned to the appropriate purpose that meets the requirements of the military mission and minimizes the impact on civilian air traffic.

All conditional CDRs remain open while running. RLP personnel will maintain a horizontal distance of 5 NM from active modules representing US airspace blocks that create the boundary between this and civilian air traffic. A military user can use MVPA modules to their limit.

Following an inspection in Germany where the MVPA model is used, ESARR 4, which assesses the degree of risk in providing air traffic control services, has shown that MVPA procedures can be safely implemented. This results in the expected benefits for users:

- easier to carry out the tasks of military users;
- Adaptation to changing mission requirements by military users;

- Reduced redirection of flights compared to the fixed TSA / TRA system for civilian users;
- more favourable economic indicators for civil aviation flights.

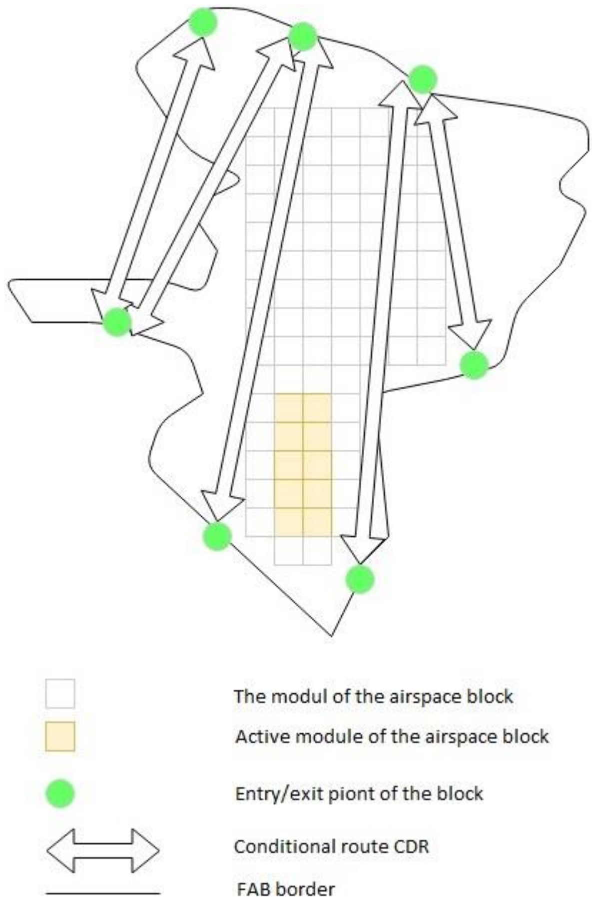

Fig. 2 Dynamic use of airspace

5 CONCLUSION

The idea of a Single European Sky depicting cooperation between the European Union and EUROCONTROL is one of the best practices in Europe that aims to change citizens' lives by increasing airspace capacity, increasing safety and reducing costs. There is a need to continually reinforce the project performance scheme, the focus of which is to achieve the airspace performance targets and to reduce costs, which are two main pillars of success for the whole project. An important fact is the introduction of nine functional airspace blocks.

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RECOGNIZING DRONES TO MAINTAIN AIRSPACE SAFETY AROUND AIRPORTS

Vaclav VLASAK[1], Vladimir SCHEJBAL[2], Dusan CERMAK[3]

Abstract

This article presents the resolution of drones among other means (airborne and ground) captured by an auxiliary airport radar system. The principle of targets recognition uses a novel signal and data processing for preservation information about detected targets and machine learning methods, which are applied to real measurement of different targets. The direction of the design and the methods used are chosen with a view to make it as simple as possible to implement to specific radar systems.

Keywords

Drone, signal processing, recognition of target, classification

1 INTRODUCTION

Recently, it is very popular to use small drones, respectively UAV (Unmanned Aerial Vehicles) or RPAS (Remotely Piloted Aircraft Systems) because of the different needs of their users. Little knowledge of legislation and the irresponsibility of mainly hobby users of drones increase the risk of a serious accident with a lot of aircrafts around airports. Most aircraft are at risk of landing, take-off and low flight manoeuvres. According to German air traffic control, 15 drones broke the airspace of airports in 2015, see [1]. In 2016 it was even 64 drones and 88 drones in 2017. It seems the tendency increases in a scary amount every year.

Drones are very small in Radar Cross Section (RCS) [2], [3] and cannot be detected by conventional radars. The radar must have a high sensitivity. However, if the radar is sensitive enough, it also detects more ground clutter, jammers, and fair no-interest targets at the airport or its surroundings (cars, trains, wind turbines, etc.). These no-interest targets need to be recognized and suppressed because it creates very complicated environment around airport. This environment and birds greatly reduce the reliability of drones of recognition.

2 A NOVEL SIGNAL AND DATA PROCESSING

A typical structure of signal processing in primary pulse-Doppler radar works primarily and mostly only with signal amplitude, see [4]. Doppler processing is primarily used to suppress ground

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and volume clutters. Because of the computational difficulty, single Doppler channels are merged or switched before extraction, see [5].

However, to get the most information, it is necessary to keep the output of Doppler processing itself for further calculations and subsequent classification of targets. The extension of the common signal processing structure is shown in fig. 1 in dotted, along with the completed classifier.

A prerequisite for detecting targets with a very small RPAS reflecting surface is a highly sensitive system setting and minimization of any losses that may occur during processing.

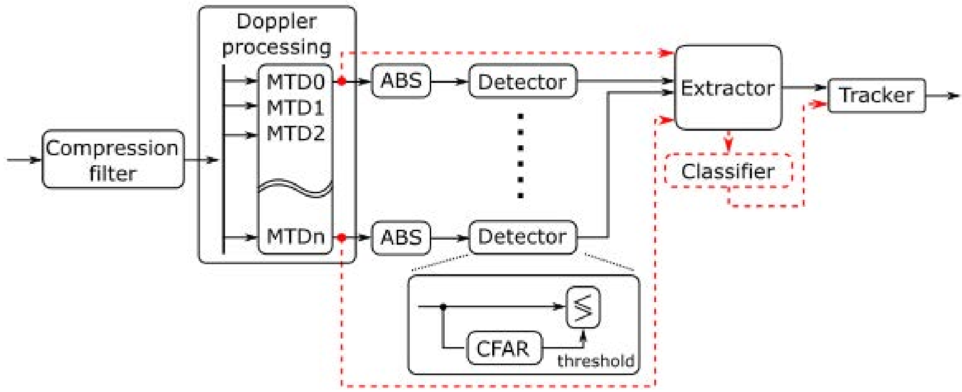

Fig. 1 A novel signal and data processing structure

3 TARGETS ANALYSIS

An important prerequisite for distinguishing targets is a thorough analysis of the specific features of specific types of targets. A large amount of information can be obtained from spectral properties using Doppler MTD processing.

With this technique, it is possible, as with the simpler MTI method, to distinguish the reflection of a moving object from ground clutter. Additionally, it is possible to get an overview of the speeds that the object moves. Characteristic features are also rotating elements of monitored objects (automobile wheels, helicopter rotors, wind turbine rotors, etc.). Under certain conditions, using the microprocessor effect, see [6], it is possible to distinguish the reflections of the radar signal from RPAS target rotating elements and differentiate them primarily from birds.

Of a large number of measurements and analyzes, for example for car type targets the specific expression is reflection from the wheels. This can be seen on fig. 2, which shows the virtually always present reflection from ground clutter - GC (such as road, causeway, trees), the car bodywork itself and the reflection from the wheels (seen in certain directions of rotation - the specific side lobes of the main reflection from the car bodywork).

4 DISCRIMINATORS

From the results of various analyzes carried out above the radar signal, it is necessary to define the so-called discriminators. These are parameters that describe the identical properties of each target type.

The choice of discriminators is primarily based on the principle of use. For example, the amplitude of the signal cannot be used since it is dependent on the distance in which the target is being observed. For this reason, it is advisable to standardize some parameters. One of the appropriate parameters is the effective reflective area of the RSC target. Apart from the principle selection, it is important that the selected parameters are statistically significant among the target groups, there was no need for them and thus the classifier did not succeed.

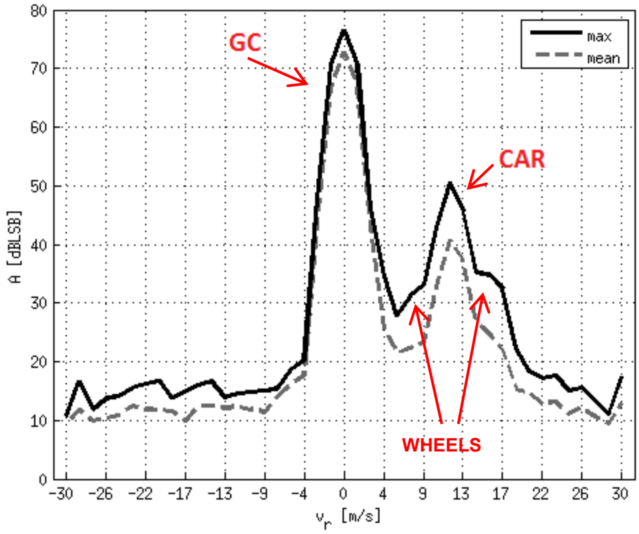

Fig. 2 Spectrum of a car in the general direction

As a suitable discriminant, the bandwidth that the target occupies in Doppler frequency spectrum is shown. It can be defined for different basic frequency components, such as zero frequency, maximum or a certain range of interesting frequencies. Likewise, RCS and so on can often be judged.

Significant discriminators then create a training set of correctly classified targets. These data are used to construct the prediction model, respectively decision rule.

5 CLASSIFICATION

The classification task can be addressed by different approaches to machine learning. With regard to the training set considered, it is appropriate to choose one of the teaching methods with the teacher. For ease of implementation in the target radar system, a discriminatory analysis (DA) seems to be appropriate. The analysis can be solved by the trainer's properties by means of a linear (LDA) or quadratic (QDA) function.

Fig. 3 shows the situation of resolving targets of type RPAS and car using QDA for selected discriminators BW_0 (signal bandwidth for zero Doppler processing component) and BW_{fast} (bandwidth for a certain selection of non-zero frequency components).

RPAS destination training data is shown as dots. Trainer data for the car group is marked with crosses here. The new measured data (test) for the RPAS group is marked with wheels, and the measured data for the car group as squares. Using the QDA, a curve - decision boundary was proposed based on the training data. Based on this decision criterion, new test objects are then assigned to specific groups.

To determine a model error, it is advisable to perform a cross-validation (kloss) or also resubstitution (rloss) error. In this case, errors are not greater than 1%.

In order to assess the overall accuracy of the model, it is also necessary to make matrix confusion.

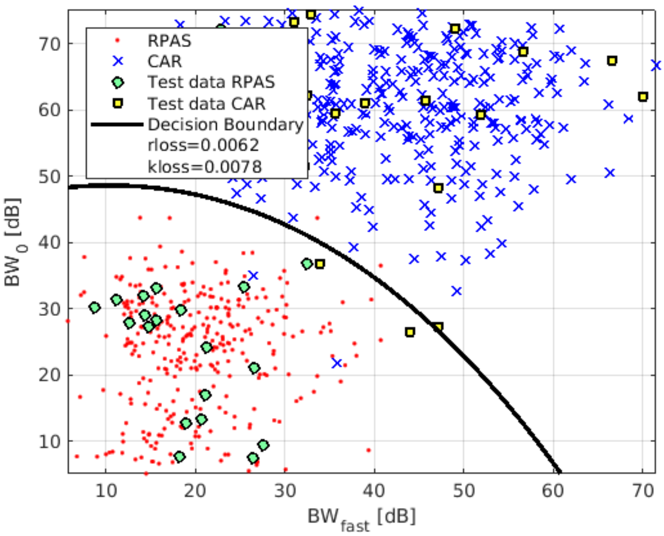

Fig. 3 Recognition RPAS and car targets by QDA

6 CONCLUSION

The article presents a way to recognition the different targets detected by the primary radar and thus to distinguish the target from other objects in the monitored area e.g. the drone in the area of the airport and adjacent surroundings. The basic idea is to get maximum information from a radar signal about a particular target using a new approach in signal processing. This information is central to solving a class problem using machine learning methods. Target recognition can be applied, for example, to protect different areas from espionage, to increase security against terrorist attacks, or to improve the features of existing radar systems in general.

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INNOVATIVE SOLUTIONS OF RAILWAY INDUSTRY FOR SUSTAINABLE MOBILITY

Marie Vopálenská[1]

Abstract
Innovative solutions of railway industry for sustainable mobility are presented in this document together with overview of present situation on sustainable mobility in railway sector.

Keywords
sustainable mobility, innovative, railway industry, interoperability, ERTMS, ETCS

1 INTRODUCTION

World Commission on Environment and Development, established under United Nations, defines sustainable transport as satisfaction of mobility needs present generations without restrictions of mobility needs future generations. Sustainable transport should meet a certain quality of life, which includes the clean air, quiet residential areas and economic prosperity without the harmful impacts on health and the environment and the depletion of limited natural resources [1].

The problem of sustainable transport is not only the technical (the provision of high quality transport infrastructure and the development of vehicles), but also it concerns the socio-economic issues (public expenditure in transport, congestions, pollutions and mobility) [2].

With growing freight and passenger transport, the risk of pollution and congestion is increasing. It is fundamental to design such a mobility that is sustainable, energy-efficient and respectful of the environment. Technical innovations and a shift towards the least polluting and most energy efficient modes of transport — especially in the case of long distance and urban travel — will also contribute to more sustainable mobility.

The target of the paper is to evaluate the situation with CO_2 emissions and its reduction ant the role of railway and the contribution of railway industry.

2 SUSTAINABLE MOBILITY

2.1 Present situation

Transport plays a key role for development of any society and economy, today and in the past. Transport systems are important for the competitiveness of any nation or regional economy as well as for the mobility of its citizens. On one sides there are benefits, on the other sides substantial costs.

Transport is currently responsible for 22.7% of global CO_2 emissions. European Commission at its European Strategy for low-emission mobility documents shows, that transport emissions are

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increasing at an alarming rate with a 53% increase between 1990 and 2011 making it clear that in the fight against climate change, a strategy to reduce transport sector emissions is crucial [3]. The significant transport sector contribution to overall CO_2 emissions is due to the reliance of the majority of transport on fossil fuels. Within the nearly 23% share of transport in overall CO_2 emissions, rail clearly stands out as the most carbon-conscious transport mode, contributing just over 3.3% to overall global transport emissions (or less than 1% of overall emissions) while transporting 9% of world passenger and freight-tonne kilometres.

Rail contributes to reducing the transport users' environmental burden to society with its exceptionally low total external costs.

Fig. 1 Picture on Specific CO_2 emissions per transport mode [4]

Furthermore, despite overall emissions of transport increasing, the emissions of the rail sector have decreased significantly in the past three decades and continue to do so. Following graph shows CO_2 emissions from passenger transport.

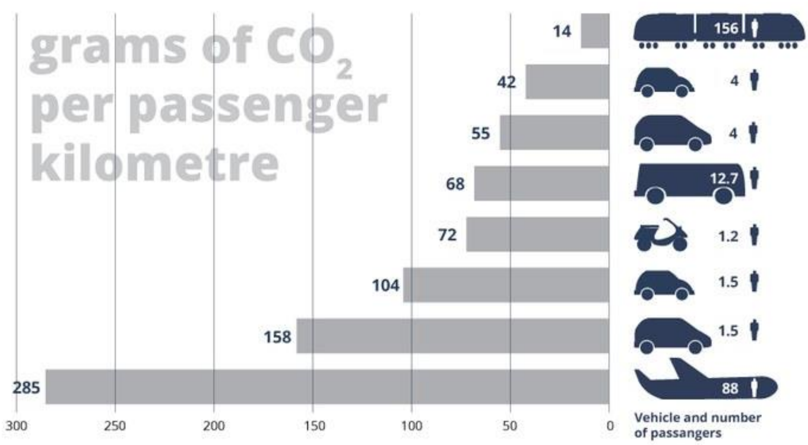

Fig. 2 Graph CO_2 emissions [5]

2.2 Paris Agreement

One of the aim of the agreement is to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change [6]. The agreement also promotes the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production.

Comprising about a quarter of energy-related CO_2 emissions, transport is a major culprit in climate change, and as such, there is a great onus on transport leaders and stakeholders to propose and deploy solutions that reduce their environmental impact despite a growing demand for mobility. Rail transport meets 9% of the passenger kilometre/freight tonne kilometre demand worldwide while only emitting 0.7% of global energy-related CO_2 emissions, while the other modes (notably road, aviation, and maritime) emit 22% of global energy-related CO_2 emissions. It is obvious that rail is the most carbon-conscious and environmentally friendly mode of transport.

Transportation emissions account for roughly 1/4 of emissions worldwide, and are even more important in terms of impact in developed nations. Modes of mass transportation such as light rail and long-distance rail are the most energy efficient means of transport for passengers. Modern energy efficient technologies, such as plug-in hybrid electric vehicles help to reduce the consumption of petroleum, land use changes and CO_2 emissions. Utilisation of rail transport, especially electric rail, over the far less efficient air transport and truck transport, significantly reduces emissions.

2.3 CO2 emissions reduction target

Environmental issues receive increased attention of policy makers at both national and European levels. To achieve the ambitious objective of a 60% reduction in CO_2 emissions in the transport sector by 2050 set out in the 2011 Transport White Paper, the European transport system must undergo step changes [3]. For instance, it has to use less and cleaner energy and make efforts to reduce its negative impact on the environment and key natural assets. The railway sector can significantly contribute to this effort through cutting-edge low-carbon solutions that tackle climate change and urbanisation-related challenges. It is important to enable the sustainable growth of mobility based on rail as the backbone of an intermodal transport system.

Notably, the Trans-European Transport Network (TEN-T) is a major tool to foster economic competitiveness and sustainable development of the European Union. According to the European Commission, the completion of the TEN-T Core Network by 2030 will have positive effect for the European economy in terms of GDP level increase, fostering employment, time savings on travelling and a reduction in greenhouse gases emissions.

Although rail technologies are already 3 to 4 times cleaner than road or air transport in terms of CO_2 emissions, efforts need to be intensified to tackle climate change in the upcoming decades. The rail supply industry is therefore committed to further progress over the whole life cycle of our products – from production to operation to end of life – such as emissions reduction, increases in energy efficiency and material recyclability, and noise and vibrations reduction, among others.

Moreover, the European Rail Traffic Management System (ERTMS) is a key technical solution to achieve interoperability on the European railway network, but also to respond to a growing transport demand. Not only does ERTMS will enable full interoperability along the European railway network, but it will also help to improve capacity on railway lines as a high-performance signalling system.

2.4 Modal shift barriers

Rail systems have to face several obstacles before reaching full interoperability. Railways have greater or lesser interoperability depending on their conformity to standards of track gauge, couplings, brakes, signalling, communications, loading gauge, operating rules, etc. Furthermore, there is a persistence of redundant national rules or in conflict with EU TSIs, as well as a heterogeneous level of competence of conformity assessment bodies. In order to overcome these interoperability challenges, the full implementation of the Technical Pillar of the Fourth Railway Package it is vital.

The different modes of transport have often been developed independently in the Member States, often without taking into account inter-modal competition. As a result, the current situation of the transport market is characterized by severe distortions of competition and a high taxation burden on rail transport. The removal of the present taxation inequalities would favour the establishment of a level-playing field between the different modes of transport and therefore a modal shift towards the least polluting modes of transport.

The current situation displays an unequal treatment of infrastructure charging, being rail transport indeed the only mode to be heavily regulated at EU level for charging of infrastructure. The currently ongoing revision of the Eurovignette Directive could be an opportunity to create a fairer level playing field applied to all modes introducing the principle of distance-based charging in road transport and taking into account the costs of all externalities.

Rail infrastructure is facing a twofold challenge. On the one hand, ageing rail infrastructure needs to be modernised and upgraded in order to meet the demands of growing transport flows. On the other hand, new infrastructure will have to be constructed in order to meet capacity demand in certain regions as well as to better link up European Member States. Rail will only be able to compete with other modes of transport and unfold its environmental benefits if a modern infrastructure is provided.

2.5 The role of the rail supply industry

Even with a past environmental performance record better than any other major mode, the rail sector is committed to further reducing its GHG emissions. In particular, the European rail industry, representing 46% of the global market for rail supplies, is actively focused on continual innovation of rail system technology in order to further improve energy efficiency and reduce GHG emissions while at the same time boosting the attractiveness of rail transport and thus eliciting a modal shift from more polluting transport modes to rail.

Over the past two decades, the European rail industry has provided considerably more energy efficient products to its customers. In 2010, an estimated 20% energy reduction had already been obtained compared to 1990 vehicles. On certain types of vehicles, the savings could represent as much as 50%. Regenerative braking or energy storage technologies have contributed to these results. Nevertheless, further gains in energy efficiency are still possible to reduce the energy consumption and carbon footprint of the railway system, and the industry is committed to achieving this long term goal.

Over the past two decades, the Czech rail industry has significantly improved the environmental performances of its products, be it on energy efficiency, noise and vibrations or recyclability of materials. Regenerative braking, energy storage or lighter materials are already game changers – and more work is being carried out to mitigate the impact of climate change.

3 CONSIDERABLE INOVATIVIE PROJECTS

3.1 VEHICLES

What will be the future products? It will be dual-mode vehicles with traction batteries powered by a trolley and high-energy or high-power electric buses. Optimised hybrid locomotives and train sets enable the provision of seamless services between electrified and non-electrified parts of the network both for freight and regional passenger services. The support of efficient last mile services will improve the competitiveness of rail freight services, especially in the intermodal industry as well as for private sidings.

An automatic coupling together with continuous electric wire, facilitate efficient shunting operations and new production schemes. Electronically controlled braking and automated brake tests are innovations which are creating step changes especially in rail freight services. Instant electronic braking reduces derailment risks and improves the general safety and security of the train operation. This is especially important for longer, heavier, commercially faster trains which will be an important pillar of future rail freight services.

The development also focuses on enhancing effective utilization of applied materials, eg. fiber composites or aluminium alloys. Advanced technologies also include laser welding, a higher use of extracts and castings thanks to the latest production methods or improved methods of material bonding. These approaches deliver primarily lower weight of vehicles which leads in its turn to more efficient transport from the point of view of energy consumption.

In accordance with requirements for the sustainable development, Škoda Transportation develops systems which cause less pollution and noise, show higher energy efficiency and have lower operating costs. One of the many examples is the use of electric traction or energy recovery technology. The Škoda Electric company made use of an electric drive employing the possibility of an integrated diesel generator and supercapacitators in 45 trolleybuses in the Italian city of Rome, and this ranks it again among the technological leaders in the field of trolleybus supply.

Hybrid cars represent an important intermediate step on the way to an electric bus. Škoda Electric works on this technology with the aim to take full advantage of the current leading-edge technology in electrical engineering (the most advanced semiconductors, a traction motor with high efficiency and a high-capacity traction battery) and to optimize the properties of a thus powered bus (range of vehicles, seating capacity, weight per axle) [7].

3.2 COMPONENTS

BON*AXLE*® is innovative induction-hardened axle. It is solution to the requirements of increased safety and reliability. It also brings significant decrease of life-cycle costs (LCC). BON*AXLE*® is likely to bring paradigmatic change in railways across Europe and beyond. GHH-BONATRANS achieved to improve the technology already well established in Japan by adapting it to the conventional European geometry and steel grades.

BONA*STAR*® is a family of new wheel materials for all types of passenger, locomotive and freight wheelsets. In comparison with the wheels made of standard EN grades, BONA*STAR*® ensures 30% greater life in mileage by increasing the fatigue limit in the wheel web significantly and by providing greater hardness and strength of the rim (while preserving its high-level plastic properties). BONA*STAR*® also ultimately reduces the wheelset LCC [8].

3.3 ERTMS

The European Rail Traffic Management System (ERTMS) is a key technical solution to achieve interoperability on the European railway network, but also to respond to a growing transport demand. Not only does ERTMS will enable full interoperability along the European railway network, but it will also help to improve capacity on railway lines as a high-performance signaling system. More specifically, ERTMS will bring the following benefits to the rail system making modal shift considerably more attractive:

- Increased capacity on existing lines and a greater ability to respond to growing transport demands: ERTMS reduces the headway between trains enabling up to 40% more capacity on currently existing infrastructure;
- Higher speeds: ERTMS allows for a maximum speed up to 500 km/h;
- Higher reliability rates: ERTMS may significantly increase reliability and punctuality, which are crucial for both passenger and freight transport;
- Lower production costs: one proven, harmonised system is easier to install, maintain and manufacture, making railway systems more competitive;
- Reduced maintenance costs: With ERTMS level 2, trackside signalling is no longer required, which considerably reduces maintenance costs;

- An opened supply market: customers will be able to purchase equipment for installation anywhere in Europe and all suppliers will be able to bid for any opportunity;
- Reduced contract lead time due to the reduction of process engineering;
- Improved safety for passengers

The ETCS L2 has been piloted within the Czech Republic in the section Kolín – Poříčany. Based on the experience of the application of the ETCS L2 on the pilot section, the technical specifications for the implementation were defined. The main characteristic of these specifications is the implementation of the ETCS L2 respecting mixed, it means operation of rail vehicles equipped and not equipped with OBU ETCS.

Presently has been completed the first commercial project of installation the ETCS L2 on a section Kolin - Břeclav – state border of the Czech Republic with Slovak Republic and Austria. Under the realization is a project ETCS L2 on a section Petrovice u Karviné – Břeclav, and the newly launched work is the realization of the section Čecká Třebová – Přerov. The further development of the ERTMS system, which includes ETCS is defined by an ERTMS national implementation. This plan defines the basic parameters for the development of the ETCS in the framework of the railway infrastructure of the Czech Republic [9].

3.4 RESEARCH PROJECT

The FINE 1 project aims to reduce operational costs of railways by a reduction of energy use and noise related to rail traffic. The project results are expected to enable an increase of traffic in Europe and to enhance the attractiveness of railway in relation to other modes of transport.

The project activities will support the innovation process within the S2R Technical Demonstrators (TDs) by providing methodology and know-how to enable development of low noise and low energy TDs. The project is fully in line with the EU objectives with eight technical work packages (WPs) addressing technologies to support these objectives. The reduction of energy use for rail vehicles is as addressed in WP 3 and WP4 and will indirectly lead to reduced green-house gas emissions, also with most rail transport powered with electricity. Further, reducing energy use will lower the life cycle cost and the costs of vehicle operation. The project also aims at development of practical methods for predicting noise and vibration performance on system level including both rolling stock, infrastructure and its environment. Prediction of interior vehicle noise is addressed in WP 7 and source modelling for interior and exterior noise in WP 8. With an accurate characterization of each contributing source, it will be possible to optimize cost benefit scenarios, as addressed in WP 6, as well as take exposure and comfort into account. Finally, the auralisation and visualisation techniques of traffic noise scenarios and the noise control techniques developed in WP 9, support the reduction of noise exposure for residents by efficient traffic planning and novel mitigation techniques.

In summary, the expected FINE 1 advances of the state-of-the-art in noise modelling and control as well as in energy management and control methodology, will improve the competitiveness of the European railway system compared to other modes of transportation and thus promoting a modal shift to rail.

4 CONCLUSION

Rail is the most environmentally-friendly transport mode contributing to only 0.7% of global energy-related CO_2 emissions while meeting 9% of the global mobility demand compared to 22% of global energy-related emissions emitted by all other transport modes: road, aviation and maritime [10].

A modal shift to rail (as the most sustainable mode of transport) should be at the backbone of any transport sector strategy to reduce CO_2 emissions [11].

The European rail industry is fully committed to developing technology for rail that is even more energy efficient and environmentally-friendly which will continue the decades-long trend of declining rail transport emissions [12].

Much of rail transport relies on electric energy which allows for even further CO_2 emissions reductions as the energy sector shifts to renewable, low-carbon energy generation. This technology and infrastructure has already been deployed in many parts of the world, whereas the other major transport modes are almost entirely reliant on fossil fuels.

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A NEW METHOD TO ESTIMATE LOAD CARRYING CAPACITY OF THIN-WALLED CONICAL SHELLS WITH CIRCUMFERENTIAL RING LOADED BY AXIAL FORCE

Haluk YILMAZ[1], Erdem ÖZYURT[2], Petr TOMEK[3]

Abstract

The conical shell with different shell thicknesses and base angles at the lower edge are investigated in the study. A new method is proposed to estimate load carrying capacity of the conical shell structures with a base angle less than 25°. The proposed method is also applicable to different radial stiffnesses of the structure. Empirical relationships are established based on the results of the numerical analysis.

Keywords

Conical shell, Circumferential ring, Load Carrying Capacity, Axial loading, FEM

1 INTRODUCTION

The load carrying capacity of a structure which is computed by merely linear buckling formulations is not a reliable way regarding safety aspects for nonstandard structures. These approaches may give higher loads than the real load carrying capacity. The additional bending effect occurs in nonstandard structural elements. For instance, a conical shell with base angle higher than 25° which is clamped on the radial direction (a standard structure) under uniform axial load has almost a clear membrane stress. However, a bending state occurs at the beginning of the loading from nature of the conical shell structure with the base angle less than 25° (nonstandard structure). For this reason, linear FEM analysis or theoretical calculations cannot be used to evaluate the load carrying capacity in nonstandard structural elements (conical shells with the base angle less than 25°, spherical cap, etc.). Thus, the loss of stability approach is a vital issue to simulate real system response under axial loading. Determining the load carrying capacity of the nonstandard structure might be infeasible by referring to the procedures within the context of the standards and recommendations because it is difficult to estimate the nonlinearity of the structure. Likewise, the recommendations and standard methods are based on the linear theory of the shells.

In present days, updated standards and recommendations provide useful approaches. They solve the stability of the conical shells with the base angle, $\propto_c$ (see Figure 1) which is higher than 25° and clamped lower end [1,2]. Nevertheless, the standard methods are not applicable to the shells which have the base angle less than 25°. Besides, the rules which are included in the

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recommendations can be applied only to conical shells which have clamped edges or edge with the very stiff ring. In other words, if a conical shell has either base angle less than 25° or free/flexible radial stiffness at the edges, these rules cannot be applied.

Stability of the thin-walled shell structures has been studied by many prominent authors. Results of their studies are embedded in standards, regulations, and recommendations. In one of the earliest research in the area, *Lackman and Penzien* experimentally investigated the buckling of conical shells under axial loading [3]. The conclusions were drawn on the suitability of the proposed equation, which includes a proper correction factor, to predict the critical buckling load of axially loaded conical shells. As one of the pioneers in the field, *Weingarten et al.* studied and discussed the stability of cylindrical and conical shells under axial loading. Both steel and Mylar polyester sheet materials were used for an extensive experimental programme [4]. *Singer* investigated the buckling of circular conical shells under uniform axial loading by setting Poisson's ratio equal to zero [5]. Two different solution methods to analyze asymmetric elastic buckling of axially compressed conical shells available in the literature were extensively compared by *Pariatmono and Chryssanthopoulos* [6]. *Tavares* expressed the mathematical approach to identify the stresses, strains, and displacements of complete or thin conical shells loaded along the meridian [7]. *Thinvongpituk and El-Sobky* examined the buckling behavior of aluminum conical shell under axial loading using the experimental setup and numerical model [8].

Differently from the current literature, this study focuses on the load carrying capacity of the conical shells with a base angle less than 25° which have flexible boundary ring under axial loading. This area has a lack of knowledge in the literature. Therefore, the main goal of the study is assigned to propose of a new method to estimate load carrying capacity of the conical shell structure with a base angle less than 25° for different radial stiffnesses under axial loading. Thus, the load carrying capacity of the conical shells which stay in the non-linear area, that is mentioned above, can be estimated without any need of numerical analysis. The study also proposes two dimensionless similarity parameters. These parameters allow for evaluation of the load carrying capacity of the conical shell for numerous configuration of geometrical dimensions in a wide range.

2 DEFINITION OF THE MODEL

The base angle is appointed as $10° \leq \propto_c \leq 20°$. According to these values, the equivalent radius of the conical shell, r_e, (it is also curvature radius at the botom of the shell, see Eq. 1) is set between 730 and $1440\,\mathrm{mm}$. The width of the circumferential ring b_{ring} is chosen as a constant value which is 15 mm. In the presented case, the stiff pipe on top of the shell also characterizes an adjacent part to simulate real condition more precisely. The height of the relatively stiff pipe h is assigned as $10\,\mathrm{mm}$. Cross section area of the circumferential ring is evaluated between $6 \leq A_{ring} \leq 300\,\mathrm{mm}^2$.

The thickness of the shell t_{shell} is set $0.5 \leq t_{shell} \leq 4\,mm$ interval. r_e/t_{shell} dimensionless parameter is assigned depending on the equivalent radius and the thickness of the shell between $240 \leq r_e/t_{shell} \leq 2880$. Additionally, the model is performed without ring (no radial stiffness) and with infinite stiff ring (fixed supported) in order to determine extremities of the limit load. The problem is simplified with a constant upper radius value as r_1=50 mm. On the other hand, the value of r_2 is selected 250 mm, initially. But, it is also used in similarity parameters as a variable. Equivalent radius of the conical shell is considered in the study as Eq. 1 [1].

$$r_e = \frac{r_2}{cos\beta_c} \qquad [1]$$

3 MATERIAL AND METHOD

In this study, geometrically nonlinear analysis (GNA) is performed, and the elastic limit load is carried out. At the first step of the study, the two limit conditions, which are fixed and simple supported conical shells, are evaluated. It is important to see the extremities of the load carrying capacity. In further studies, the limit load of the conical shell for various radial stiffnesses, which is represented by a circumferential ring, is investigated. Schematic representation of the conical shell with the dimensions and the numerical model are illustrated in Figure 1 and 2. Numerical models and non-linear static analyses have been performed using the FEM program COSMOS/M with arc length control procedure. For the numerical analysis, large displacement module and Quadrilateral thick Shell element (SHELL4T) are assigned. Models are generated for three base angles α_c (10°, 15°, and 20°).

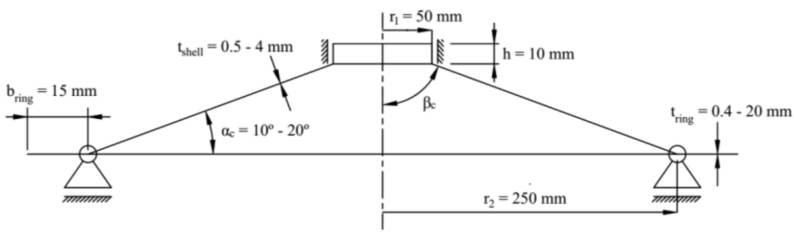


Fig. 1 Schematic representation of the conical shell with the circumferential ring.

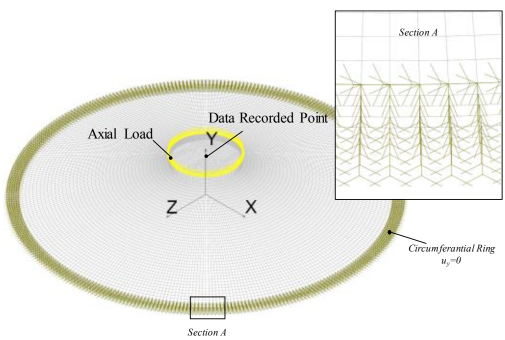


Fig. 2 Simplified numerical model.

4 RESULTS AND DISCUSSION

Figure 3 exhibits the displacement curve of the selected node number 21, which located at the top of the conical shell, depending on the axial load.

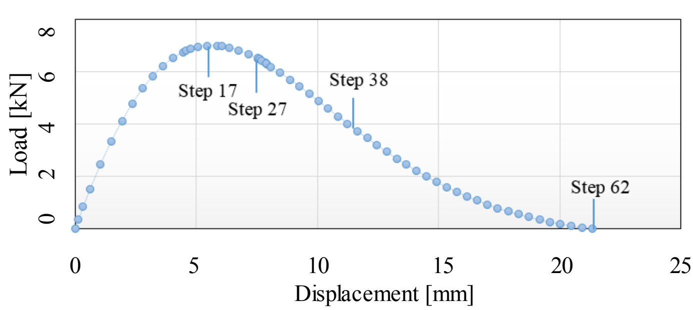
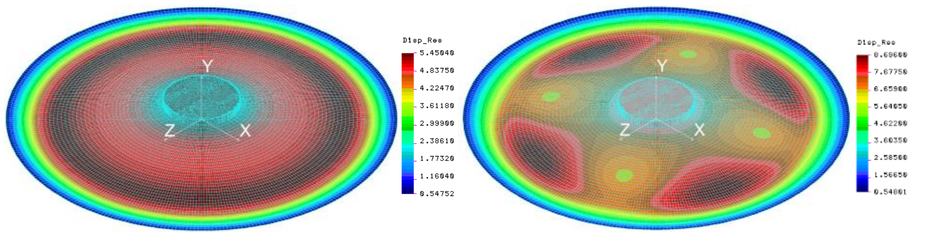
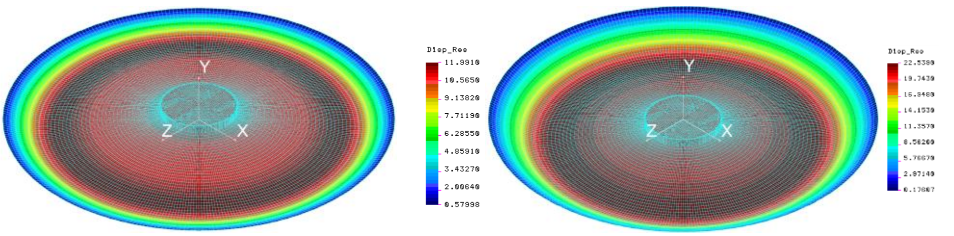


Fig. 3 Load-displacement characteristic for nodal point 21.

During the axial load increase, the structure reaches the limit state and loses its stability gradually. The load carrying capacity of the structure in parallel with geometrical stiffness decreases after this point.



a. Resultant displacement – step number 17 **b.** Resultant displacement – step number 27



c. Resultant displacement – step number 38 **d.** Resultant displacement – step number 62

Fig. 4 Resultant displacement of the simple supported conical shell for α_c=10°, t_{shell}=1.2 mm.

The shape of the deformed structure is plotted in Figure 4. At step 17, axially symmetric deformation and nonlinear collapse occur, in this case, the top of the conical shell has 5.45 mm vertical displacement under an axial load of 6.58 kN. At step 27, the possible bifurcation point occurs and it leads to the formation of four axially symmetric waves. During the subsequent process such as step 38, the load carrying capacity of the conical shell still decreases in the post-buckling process. The structure has axially symmetric deformation. Finally, at step 62, deformation propagation needs nearly zero load value. The structure gets invert shape when it is compared to initial shape at this point.

4.1 Influence of Boundary Conditions

The limit load is substantially dependent on selected boundary conditions (Figure 5). Possible displacement at radial direction causes a reduction in load carrying capacity of the structure. The significance of the boundary condition against the load carrying capacity of the conical shell increases, especially at the lower r_e/t_{shell} values.

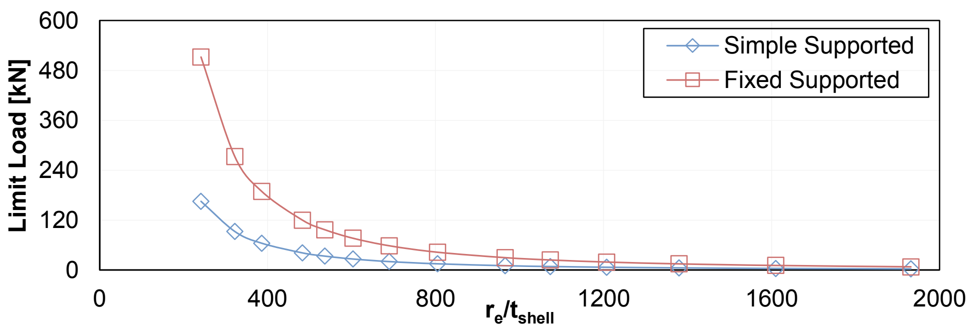


Fig. 5 Influence of the boundary conditions on the load carrying capacity for base angle 15°.

The results of the fixed supported conical shell (wholly restricted radial displacement) suggest that the circumferential ring stiffness is quite efficacious on the limit load of the structure. The relation between the limit load and r_e/t_{shell} parameter of the conical shell with base angle 15° is illustrated in Figure 5.

4.2 Influence of Base Angle

The influence of the base angle on the load carrying capacity at the various shell thicknesses is illustrated in Figure 6. From the curves, it is obviously seen that the conical shell with a higher base angle for the same shell thickness has a relatively larger amount of load carrying capacity. The strength of the structure against axial loading increases with both the shell thickness and the base angle. The limit load of the structure is nearly related to the square of the shell thickness. Data are well matched with a second order power function of the shell thickness. On the other hand, the increment of the base angle, even just one degree, gives a serious contribution to the limit load, positively. Since the increment of the base angle provides reducing the bending state effect which is caused by the nature of the structure. The proportion of the radial component of the force at the lower edge also decreases as base angle increasing.

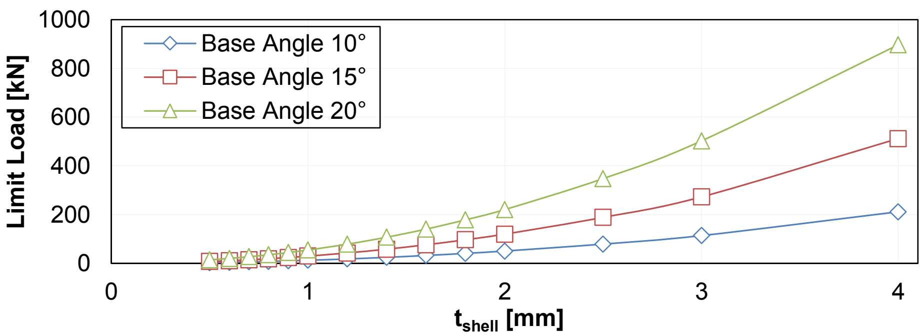


Fig. 6 Effect of the base angle on the load carrying capacity for the fixed supported conical shell.

4.3 Conical Shell with Circumferential Ring

In the previous sections, the load carrying capacity of the simple supported and fixed supported conical shells is mentioned. These boundary conditions at the lower edge are the representations of the extremities. However, in the practical applications, the conical shell is used with the boundary conditions which are located between two extremities (with a circumferential ring). This part of the study aims to derive simple relationships corresponding to geometrical parameters

The following figure is exhibited the limit load depending on r_e/t_{shell} for different circumferential ring stiffnesses. As expected, the curves which belong to various ring cross-sectional areas (different radial stiffness) are positioned between two extremities. It is interesting that the ring area even $A_{ring} = 6\ \mathrm{mm}^2$ contributes significantly positive effect to the load carrying capacity of the conical shell. On the other hand, $A_{ring} = 300\ \mathrm{mm}^2$ provides nearly same contribution with the infinite stiff case.

It is apparently seen that the importance of the radial stiffness on the conical shell structures which have a base angle less than 25°, in Figure 7. The capability of load carrying can reach three times higher in the comparison between the structures which have a cross-sectional area of the circumferential ring of $A_{ring} = 300\ \mathrm{mm}^2$ and $A_{ring} = 6\ \mathrm{mm}^2$ in the lower r_e/t_{shell} ratios. However, this difference decreases in higher r_e/t_{shell} ratios. This situation is related to the slenderness of the structure. In higher r_e/t_{shell} ratios, the expected limit load is relatively low. Therefore, the circumferential ring with $A_{ring} = 6\ \mathrm{mm}^2$ also behaves stiff enough against the radial displacement until the nonlinear collapse occurs. Hence, the limit loads of the structures with $A_{ring} = 6\ \mathrm{mm}^2$ and $A_{ring} = 300\ \mathrm{mm}^2$ become nearly same in case of quite high amount of r_e/t_{shell} values.

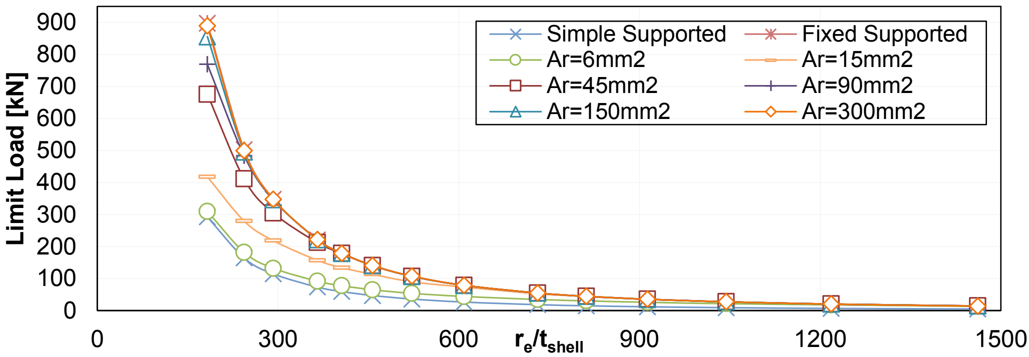


Fig. 7 Limit loads of the conical shell with different radial stiffnesses for base angle 20°.

4.4 Similarity Criteria

The load carrying capacity of the conical shell which has r_1=50 mm and r_2=250 mm was investigated up to now in the present study. But, this section mentions about the derived similarity parameter. Thus, the load carrying capacity of many different configurations of the conical shells can be estimated. For instance, a large conical shell which is used under operation can be simulated with a simple model using similarity parameters. In addition to this, the load carrying capacity of the structure can be calculated via Eq. 4 non-dimensionally without any need to a numerical analysis.

According to the results, a similarity between the load carrying capacities of the conical shells regarding geometrical parameters is tried to derive. To achieve this purpose, the load is normalized by a constitutive relation with respect to the cross-section area of the lower edge. Therefore, normalized axial load (Eq. 2) is adapted to the results as exhibited in the literature before [9]. It is a function of limit load and geometrical parameters of the structure; besides, it represents the limit load in nondimensional form.

$$F_{Normalized} = \frac{F_{lim}}{2\pi r_2 t_{shell} E} \quad [2]$$

In this study, dimensionless Γ rigidity parameter of the circumferential ring depends on the radius of the lower edge of the conical shell, the thickness of the shell and the cross-sectional area of the ring. The parameter is represented in Eq. 3.

$$\Gamma = \frac{r_2 t_{shell}}{A_{ring}} \quad [3]$$

The function that is seen in Eq. 4 gives results in maximum 15% variation when it is compared to FEM. The normalized load can calculate with this equation using a and b from Table 2 corresponding to base angle and rigidity parameter Γ.

$$F_{Normalized} = a\left({}^{r_e}/_{t_{shell}}\right)^{-b} \quad [4]$$

The aforementioned non-dimensional similarity parameters are r_e/t_{shell} and Γ. If these parameters are identical for the same base angle, the normalized load of these structures is expected to be equal. The numerical analyses results and obtained values from Eq. 4 for randomly selected conical shell structures are seen in Table 1. The structures which are expected to operate in real applications have different upper and bottom radii. It is seen that Eq. 4 has good agreement with the FEM results. Besides, the similarity parameters are well matched. The structures with various geometrical dimensions but same similarity parameters have a similar normalized load. In addition to this, if the rigidity parameter of the structure is not found in Table 2, linear interpolation is used to get coefficients.

Tab. 1 FEM and analytical results for the conical shells with base angle 10°

	$r_1[mm]$	$r_2\ [mm]$	$t_{shell}\ [mm]$	r_e/t_{shell}	Γ	${F_{Normalized}}^{*}$ 10^6 [-](FEM)	${F_{Normalized}}^{*}$ 10^6 [-](Eq. 4)
A_1	100	500	5	575.88	20	83.54	85.8
A_2	250	500	5	575.88	20	82.80	85.8
A_3	300	2000	20	575.88	20	86.81	85.8
A_4	800	2000	20	575.88	20	87.53	85.8
A_5	700	5000	50	575.88	20	86.95	85.8
A_6	2000	5000	50	575.88	20	88.04	85.8

Tab. 2 Coefficients of the conical shell for parameter Γ.

Base Angle $\propto_c$ [°]	**Range of** r_e/t_{shell} **parameter**	**Rigidity Parameter** $\Gamma = \frac{r_2 t_{shell}}{A_{ring}}$	**Coefficients** a	b
10	480 - 2880	Fixed Supported	0.0696	0.995
		Simple Supported	0.0190	1.001
		1	0.1652	1.067
		5	0.1173	1.066
		10	0.0569	0.987
		20	0.0286	0.913
		40	0.0371	0.957
		60	0.0508	1.015
		80	0.0546	1.044
		100	0.0417	1.015
15	320 - 1930	Fixed Supported	0.1141	0.999
		Simple Supported	0.0289	0.998
		1	0.1697	1.032
		5	0.1320	1.028
		10	0.0814	0.979
		20	0.0424	0.899
		40	0.0515	0.948
		60	0.0700	1.008
		80	0.0730	1.032
		100	0.0614	1.025
20	240 - 1460	Fixed Supported	0.1526	0.991
		Simple Supported	0.0375	0.996
		1	0.2634	1.038
		5	0.2036	1.033
		10	0.1230	0.984
		20	0.0566	0.880
		40	0.0730	0.946
		60	0.0936	1.006
		80	0.0937	1.023
		100	0.0650	0.992

5 CONCLUSION

In this study, the load carrying capacity of the conical shell structures which have different radial stiffnesses is examined. The base angle of the conical shell structures is kept less than 25° to contribute to filling the deficiency in the literature. A new method is proposed to estimate the load carrying capacity for mentioned conical shell structures. Results which are obtained from the nonlinear FEM analyses are stated below.

In order to predict load carrying capacity of the conical shell structures under the axial load with lower base angles (i.e. 10, 15 and 20°), nondimensional design parameters (Γ and r_e/t_{shell}) are derived. Based on these parameters, a similarity approach is proposed which estimates load carrying capacity of the shells of different shell geometry configurations at the same base angle. This similarity approach tells that the two different shell configurations having the same Γ, r_e/t_{shell} and base angle have the same normalized loads. Practically, this provides an enormous advantage of estimating load carrying capacity of the conical shells from small to large structures. Therefore, there is no need to perform some series of the experiments to determine the load carrying capacity of the structures. The sensitivity on imperfection is less dominant on these type non-standard structures. However, the influence of the imperfections on the carrying capacity of the structure should be investigated in detail at further works to accomplish the research fully.

A simple expression is proposed to calculate the normalized load of the conical shell structure as a function of the dimensionless geometrical shell parameters and two constant coefficients of “a” and “b” which are selected considering the base angle, rigidity parameter. In this way, it enables an appropriate prediction of the load carrying capacity of the conical shell structures under the axial load for a variety of the shell configurations without performing some complex non-linear FEM analysis or numerical solutions. Furthermore, the discrepancy of the proposed new method and FEM results of the normalized load is found out to be the maximum 15%, which can be considered in the acceptable limits for a highly nonlinear shell behavior of the lower base angles.

Implementation of the linear theory in the load carrying capacity calculations concludes with the high amount of deviations due to the presence of the circumferential ring and highly nonlinear shell response of the shell structures, which is encountered at low base angles such as 10, 15 and 20º. The proposed expression for the normalized load minimizes this aforementioned deviation and keeps the results within the acceptable limits. Since particular equation coefficients of “a” and “b” are selected in order to characterize the non-linear response of the corresponded shell geometry.

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THE POSSIBLE CONTRIBUTION OF POSTAL SERVICE SECTOR TO CITY LOGISTICS

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Abstract
The use of traditional postal services is constantly decreasing, prompting the management of postal service providers to look for new opportunities for utilization of available resources and developing the postal service sector. Simultaneously the city logistics experts are looking for a way to ensure sustainable development of the urban areas and fulfill increasing delivery requirements within the city. In Czech and European literature, there is no publication focusing on the interconnection of these two sectors, i.e. postal service sector and the city logistics. Foreign literature provides a number of papers related to the possibility of cooperation between the postal service sector and the city logistics. The analysis of these papers and the proposal of possible solutions respecting local conditions in the Czech Republic is the aim of the paper.

Keywords
postal services, city logistics, reverse logistics, urban consolidation centre

1 INTRODUCTION

The problems of city logistics, which has been designed to ensure sustainable urban development in the city, are the object of experts', politicians' and public attention. The main cause of such interest is the deterioration of the state of the cities around the world, especially in the ecological, economic and social aspects. One of the main cause of urban unsustainability is the development of e-commerce, which results in higher demand for parcel delivery and larger numbers of trucks in cities. Changes in the transport market, wherein the current post-liberalization era is a considerable competitive pressure, lead transport companies to offer more frequent and smaller supplies for the maintenance of the competitive position of the company. It causes a higher number of journeys and the inefficient use of the cargo space. The lack of interest of large shipping companies in the problems of city logistics and urban sustainability causes a permanent deterioration of the whole situation, especially in large cities. Another reason of unsustainable cities is the increase in individual car traffic in cities, mainly due to the rising trend of urbanization. According to the United Nations 54 percent of the population currently lives in urban agglomerations and according to the prediction about 66 percent of the population will live in cities by 2050 [2]. Besides the growth of the urban population, the trend of growing goods' flows is continuing, which leads to the increasing activities of the road freight and light commercial vehicles [2]. Negative impacts of growing trend of road transport are related to the economy (prices

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increase), society (damage to human health, accidents, noise and lower quality of life in the city) and environment (emissions and consumption of non-renewable energy) [3]. A lot of authors (Tadič, Taniguchi, Witkowski) outlined sustainability as a way to ensure economic, ecologic and social prosperity in city logistics. Sustainability can be characterized as a development that provides the needs of present and does not compromise the ability of futures generation to ensure their own needs [4]. In term of city logistics, it can be characterized as an urban development and ensure the consumers' needs for goods' flows in a way that not damages the liveability of a city for the future generation. There is a need to create a balance between smart economic growth and cleaner, safer and quitter agglomerations and a risk of disaster due to global climate change, so urban transport should work in a way where the cities are more sustainable and liveable [5]. The efficient city logistics system can be a way how to achieve this balance. City logistics could be characterized as a process of planning, implementation and monitoring effectiveness of people, freight transport and information flows in urban areas in order to improve quality of life in the city [6].

The postal service sector in Europe has changed since the end of 2012 year, when there was complete liberalization of the postal service sector. National postal providers in Europe have thus lost their monopoly position within their territory and are now facing a great competitive pressure especially from the global courier, express and postal service providers. The development of digital technology has changed the way of communication and has reduced the use of basic postal services. At the same time, the volume of parcel delivery grows mainly due to the development of e-commerce. Currently, the national postal providers are looking for a possibility to maintain its market position and develop new services and direction to satisfy the growing demand. However, due to licensing mode for the basic postal service, the national postal operators continue to provide services just like before liberalization, on the other hand, competing companies mostly apply the strategy of cream-skimming and offers just profitable services such as bulk mail or parcel delivery. The situation has led to the fact that a large number of trucks from different companies are currently daily circulating in Czech and European cities, which returns us to the city logistics problems.

The research of Czech and European literature shows a lack of publication focusing on the city logistics and postal service sector problems and a possible sustainable solution. Foreign literature (mostly from the USA) provides a number of papers related to the possibility of cooperation between the postal service sector and the city logistics. The analysis of these papers and the proposal of possible solutions respecting local conditions in the Czech Republic is the aim of the paper.

2 THE CURRENT STATE OF CITY LOGISTICS AND POSTAL SERVICE

As was pointed out before a huge demographic shift has a global trend: people leave rural areas and move to large cities. Cities, that are already trying to provide adequate services to residents, will be exposed to more pressure with the growth of their population. That's why cities are focusing on extensive data, analytical and digital technologies in order to improve the management of their territory. In an effort to solve the main city logistics problems, for example, traffic congestion, poor air quality, and infrastructure maintenance, the government of the cities seeking for a new smart solution. The postal operators could support the cities initiatives in the city logistics efforts, due to the extensive network, the postal operator could be a platform for collecting important data [7]. On the other hand, it is difficult for cities to begin a cooperation with postal provider due to several factors, for example, money, technology expertise and data collection and storage.

The historical position of postal service providers is changing in all countries in Europe and in the world. Until recently the postal service has been fundamental for many businesses like banks, logistics, retails, communication and the other. On the other hand, the growth of alternative communication channels has affected the role of postal service and changed the traditional postal value chain. With the aim to adapt to new circumstances, postal service providers (providers of postal services need to find a way to ensure the added value services to customers) use the benefits of the digital and paper world. Nowadays the consumer has become the central point of the parcel value chain, due to it the receiver requires to choose from the different options of delivery, for example, speed of delivery, reliability and convenience. While the customer requires to have an option to redirect or postpone the delivery, postal services providers stuck in the past with traditional postal value chain (the items are collected, sorted, shipped and delivered to recipients) [8].

The main problem of future cooperation is the city governments need to invest in city logistics projects and on the other hand postal services providers need to invest in information technology. The willingness of the governments of the cities to invest the limited recourses to the unproved city logistics project varies from one city to another. Often, pilot projects are funded by the private sector or the state grant, but in the long run, the question of funding is still undetermined. Due to similar financial problems and some similar initiatives like to cut down carbon emissions, the idea of cooperation between the city governments and the postal service sector can be useful. The postal service sector can represent the opportunity for the cities to start city logistics projects. Interviews with cities governments show that all participators saw postal service operators as valuable partners, mostly thanks to the ubiquity infrastructure that crisscrosses almost every town daily and postal vehicles that travel down almost every road every day [7]. Cities in Europe and around the world can benefit from the cooperation with the postal service sector. Increasing the effectiveness of postal service providers in any city would mean reducing trucks from private logistics providers in the city center, which would lead to the fulfillment of the goal of city logistics, such as an improvement of traffic, emission and noise situation in cities. Thanks to it postal service provider could better manage the logistics, keep costs under control and invest the money saved form the cooperation with cities to meet the customer expectations and retain the leader position in a highly competitive market.

However not just the cities could be benefited from such cooperation, collaborative city logistics projects could also have a positive impact on postal service providers. For example, cost saving and efficiency gains (as materially benefits from improved pavement conditions and as a result a decreasing of vehicle deterioration, less frequent repairs and reduced fuel consumption). Furthermore, the appropriate city logistics system in the city is aiming to improve traffic flow, so the postal provider’s drivers would spend less time in traffic congestions and by that improve the service of delivery on time for customers [7]. In case of saving time to ensure last mile delivery, postal service providers could also provide effective reverse logistics. At the present time, reverse logistics is taken as a big challenge and costly ineffective area for logistics providers as well for society as a whole, because of externalities. Logistics companies, that have to ensure the flow of goods from the customer to the place of origin, are losing incomes and time. Some posts around the world already offering a reverse logistics services to the customer, but the efficient reverse logistics system as a part of sustainable city logistics is still missing.

Another benefit from cooperation for postal service provider could be, as was pointed out before, in similar initiatives like to cut down carbon emissions. Helping cities meet their emissions goals would help posts meet their own emissions goals, for example updating the over 20-year old fleet of delivery vehicles, which are becoming costly to maintain and out-of-date with the current technology. Increasing of a goodwill among customers and stakeholders, including legislators and revenue generation as the city logistics project could also be taken as a benefit and a business opportunity the postal operators services [7].

3 THE USE OF POSTAL SERVICE IN CITY LOGISTICS

In cooperation between postal service and city logistics some of the postal assets are very valuable for cities. To this category belong vehicles, letter carriers and stationary assets. The vehicles could be used mainly for placing sensors or cameras, which can collect information about air quality, traffic patterns, road and bridge integrity. Putting the sensor on the postal vehicle would improve its function by giving the sensors mobility. Carrier could be used for putting the data, which couldn't be collected passively. For example, data about fallen trees, damaged public property or streets and snow-covered sidewalks in winter. Daily presence of carries around the town can guarantee quick detection of a problem. The last category of valuable assets could be stationary objects of postal services providers. This includes collection boxes, home mailboxes and post offices. They could be used more in the smart city project, like facilities for community engagement [7].

Postal offices, on the other hand, could be used for the purpose of city logistics needs. The importance of warehousing and order fulfilment is rising in response to the growth of e-commerce, due to some indicators, the speed of order's delivery is a major factor in e-commerce retail supply chain. [9]. The quickest way to satisfy times requirements of the customers is to use the inventory stores near the towns or more effective in the city center. Thanks to the warehouses in city center, retails have an opportunity to compete with tigers like Amazon and also reduce transport costs and time and improve inventory turnover. The warehouse needs are rising due to the rising logistics requirements, which is a result of an increasing variety of products of different value, weight, and size. It seems like the appropriate warehouses' location could determine not just the competitive position of the company, but also the effectiveness of the whole system of city logistics. A suitable warehouse means an efficient way of using supplying trucks in the city, which can lead to the reducing of urban traffics in cities and all the benefits follow from it. Due to an increasing demand for warehouse space in the cities, it is on the lowest level since 2001 and at the same time, the retail demand causes building of new warehouses near and into the cites to providing ultra-fast delivery, which does not exactly match the goals of city logistics. A vast network and an available space can be the key to resolve the warehousing problem [9]. In order to create functional city logistics system in cooperation with the postal service sector, the use of the available space should be done with understanding all details and, above all, in order to create a functioning system of city logistics, not to meet the needs of individual retails companies, for which the only aim is to increase revenues. That is why renting the places of the postal service sector in highly ineffective. Those places should be used for supplying cities in an efficient way, for example with vehicles, that use alternative fuels. The creation of urban consolidation centers in the available spaces, where the postal service provider could be the largest and most important provider of supply to the city could be the biggest contribution of the postal service sector to the city logistics situation. It may be against the rules of fair trade and competition, but as was found out, the system, with a lot of delivery companies just makes the city logistics situation worth and unsustainable for the future.

Nowadays another city logistics problem is an effective reverse logistics, which at the present time is complicated and costly due to the lack of an efficient reverse logistics system. The process of returning goods or reverse logistics have more and more considerable impact on city logistics due to the rapid growth of return goods as a result of e-commerce rising volumes. The biggest issue is that developing and growing industry like reverse logistics still don't have a set standard solution or best practices. The lack in this can represent another area of contribution of postal service to city logistics system. Postal service provider in Amerika (USPS) already provides return logistics. The biggest competitive advantages are that USPS deliver to nearly every address in Amerika six days a week and by that, it is the least expensive provider of last mile delivery and first mile pick up. Again, postal offices and boxes are very useful and serve as a collection point across the country. Reverse logistics is generally more complicated process than forward logistics process. During the last one, retailer knows exactly how much inventory they have, its status and locations.

In reverse logistics the customer is the one who decided if the product will be returned or not, how it is going to be pack and when the return stars. Also, the friendly return is considered as a quality standard, the return should be fast, free and easy for consumer [10]. Simplifying such a complicated process as pickup goods, deciding about the destination of returned goods and their subsequent processing, can help reduce costs and achieve goals of city logistics. As was pointed out before, use of postal service provider for reverse logistics seems to be the most effective way of returning good. But the postal providers' role doesn't have to be done by that. The postal service provider could provide added services to both sides of the return market by collecting unboxed returned goods in post offices. The process of returning goods can starts with evaluation unboxed goods by a postal services worker or authorized person, who can analyze goods condition, decided where returned goods should go and sort the items into large polybags or boxes going to the same destination [10].

3.1 Already existing cooperation between postal service sector and the city logistics

As tab. 1 shows some countries and cities that are already using the postal service providers in order to achieve city logistics goals. Most of the cities used postal service vehicles as a moveable base for different sensors or cameras. The collected data could contribute to the knowledge about city logistics problems as bad air quality, traffic congestions or pavement conditions, but they are not directly contributing to the solution of that problems. More important cooperation, as the creation of parcel locker or consolidated delivery to the city center, has a bigger impact on city logistics situation in the city, but, on the other hand, is costlier and requires a different level of cooperation between cities and postal service providers.

Tab. 1 Cooperation between postal service sector and the city logistics

Country	**Cooperation of postal service sector and the city logistics**
Spain	Air quality monitoring sensors placed on postal vehicles
France	La Poste plays the role of the data collector and analytics services
USA	Digital cameras on postal vehicles monitor a pavement condition
USA	Air quality monitoring sensors placed on postal vehicles
Singapore	Three-story facility with warehousing space, reverse logistics solutions, automated parcel sorting and loading docks for customers across Southeast Asia
Belgium	City logistics program runs by that reduces the number of separate deliveries in the center by consolidating packages at facilities nearby prior to delivery
Finland	500 parcel lockers terminals in stores and malls, where a customer can receive online orders, try them in store and return it back to the locker if they are not satisfied

Source: USPS, 2016

4 CONCLUSION

Nowadays the situation of city logistics is very similar in all European Union countries. Efforts to create a functioning city logistics system have lasted for several years, but only a small number of cities have succeeded in an achieving a sustainable system of city logistics. Meanwhile, most cities are still unable to solve old problems such as congestion, air pollution and security. The situation of the post-liberalized postal sector is also very similar in the states of Europe. Maintaining a competitive position and finding new opportunities are the main tasks of postal operators across Europe. Some states (Belgium, Spain, Finland) have already found a possible joint solution for both situations, such as cooperation with the postal service sector and the city logistics. While in the United States there are several studies about possible cooperation and its outcome, and in the above-mentioned European states the first steps have been taken to establish co-operation, there are no references in the Czech Republic about this topic.

It follows from the above that the first step in further possible cooperation is to create the corresponding studies in order to determine the possibilities of the postal service sector (especially Czech national postal service provider - Czech Post) to provide its resources for the purposes of city logistics. Possible cooperation can be started gradually, for example, by creating an efficient reverse logistics system in some cities through postal service sector. As was pointed out before, reverse logistics can be a big opportunity for logistics provider, who can ensure it efficiency, with the required level of costs. Creating an efficient reverse chain within the city can be quite a challenge, but fast, free and friendly reverse logistics can earn customers' loyalty. In some countries, postal services providers already ensure some reverse logistics activities, but the general and efficient system is still missing. However, researches have shown that a good system of logistics returns can make a significant contribution to an improvement of the city logistics situation, especially in the future. Reverse logistics is seen as a result of growing e-commerce, which will raise in the next few years. This means the need to create not only an efficient system of last mile delivery in the city, but also an effective system of reverse logistics. Just as in the case of creating a functioning logistics system, to create appropriate reverse logistics system, it is necessary to find suitable and main partner of the city. Last mile delivery and return logistics represent the main field of cooperation of city logistics and postal sector. The creation of the last mile delivery system and the reverse logistics system in cooperation with the Czech Post could be the first step towards the creation of urban consolidation centers, the creation of which in the Czech cities would be a major step forward and the achievement of the basic goals of city logistics.

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THE SLIP CONTROL OF A TRAM-WHEEL TEST STAND MODEL WITH SINGLE NEURON PID CONTROL METHOD

Abdulkadir ZIREK[1], Bekir Tuna KAYAALP[2]

Abstract

In this study, a single neuron PID (proportional, integral, and derivative) control algorithm is proposed for longitudinal slip control of a tram-wheel test stand. Hebb learning algorithm was employed for tuning the control parameters. The main advantages of the proposed algorithm are adaptivity, self-organizing, and self-learning. The performance of the control strategy is simulated using the mathematical model of the tram-wheel test stand that is developed in MATLAB environment. The simulation results show that the proposed algorithm has better closed-loop performance compared to traditional PID control method.

Keywords

Adaptive, single neuron, slip, learning algorithm, control, adhesion, traction

1 INTRODUCTION

Slip control systems are safety and control devices that are implemented in vehicles to prevent wheel slip during low adhesion conditions, especially high wheel acceleration and deceleration cases. Advanced slip control systems are available in the current field of study [1-4]. Watanabe and Yamashita proposed a pattern method for the control of longitudinal slip [5]. The controller detects the slip through a threshold value. If the actual exceeds the threshold value, the motor torque reduces according to a specific pattern. Dankan and Ramachandra [6] proposed a control method based on bang-bang control strategy to keep the slip at an optimum value. The control principle based on error value which is obtained by difference between actual and desired slip. This value is used to keep the motor torque between defined maximum and minimum. Yamashita and Soeda [7] proposed a slip control method through the early detection of wheel slip convergence. The method uses less delayed rotational acceleration signal for slip detection. Above mentioned slip control strategies have effective results for slip control, however, they still do not guarantee re-adhesion if the low adhesion condition continues for long period. Furthermore, the excessive torque drops, and frequent torque oscillations are some of the weakness of above mentioned strategies.

In order to suppress the disadvantage of above discussed methods, in this study, a single neuron PID control method is proposed to control longitudinal wheel slip. The performance of the proposed control method is simulated using the mathematical model of tram-wheel test stand that is developed in MATLAB environment. The control algorithm is tested for two different cases. In first case, the control method is tested for variable reference slip value. For the second case, variable

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adhesion conditions are considered. The simulations results shows that the proposed control method has good adaptibility, and strong robustness. The response of the control algorithm regards to slip control had better performance compared to the conventional PID control method.

2 SIMULATION MODEL

To evaluate the performance of the single neuron PID controller, a numerical model of the Tram-wheel test stand have been built in MATLAB environment. The test stand which is located in VVCD, Doubravice, Pardubice built by VUKV. Stand has a full-scale tram wheel with diameter 695mm which is used in operation at present in public transportation in Prague. Wheel is driven by a torque controlled PMSM (Permanent Magnet Synchronous Motor) with a nominal torque of 852 Nm. Wheel is attached to the stand frame with a swinging arm allows the vertical movement and a pneumatic spring is located top of arm which supplies the normal force and the quantity of the force by pressure control. Roller rail with diameter 904 mm is mounted to bottom of stand with a base plate which is driven by an ASM (Asynchronous motor) with nominal torque 891 Nm. Rotational movements are measured by rotary encoders and a torque sensor is embed in the shaft between ASM and roller for measuring the confronting torque on roller rail. Illustration of the test stand can be seen in Fig. 1 with additional measuring and processing components.

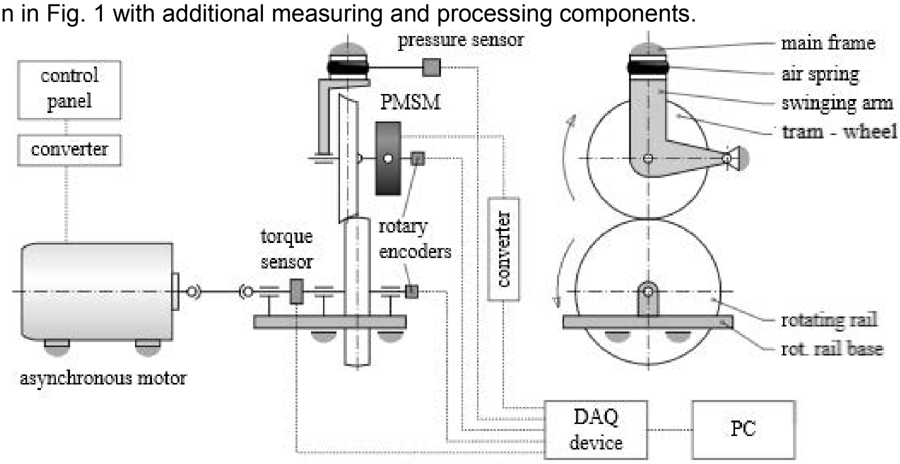

Fig. 1 An illustration of full-scale tram-wheel test stand [8]

A block diagram of the simulation model is summarized in Fig. 2. The simulation model consists of four main parts which are a PMSM, an ASM, a Polach/Freibauer contact force calculation block and a single neuron PID controller block. The former three parts of the simulation were explained in detail in previous study by Zirek et al. [9]. This paper focused on the description and performance evaluation of a single neuron PID controller. Although iterative step time for the simulations is selected as 20 μs, the response time of the controller is selected 40 μs due to limitation of the response time of the actual test stand.

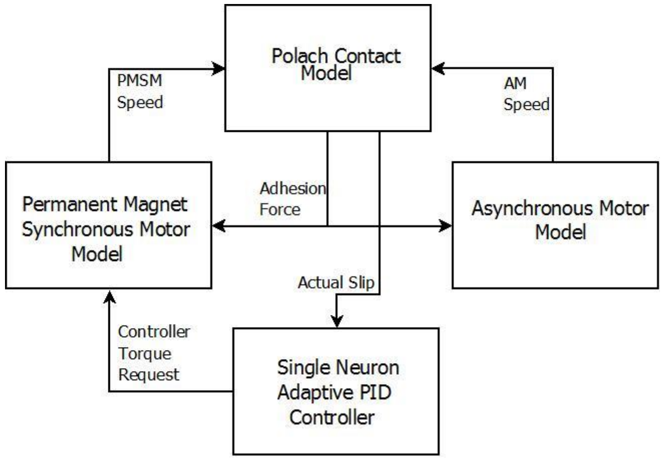

Fig. 2 Block diagram of tram-wheel test stand simulation model

3 STRUCTURE OF SINGLE NEURON PID ALGORITHM

PID is the most common control method using feedback in engineering systems. The PID controller calculates the error between the desired and actual value and applies correction based on proportional, integral, and derivative terms. The mathematical description of the controller in discrete time can be written as equation (1) [10]:

$$u(k) = u(k-1) + K_p\big(e(k) - e(k-1)\big) + K_i e(k) + K_d\big(e(k) - 2e(k-1) + e(k-2)\big) \tag{1}$$

where u is controller output, K_p, K_i and K_d are the gains of the proportional, integral and derivative terms of the PID controller, respectively, k is iterative step and T_s is sampling time. e is process tracking error and can be written as equation (2).

$$e(k) = s_{ref} - s_{act}(k) \tag{2}$$

where s_{ref} is reference slip value and $s_{act}(k)$ is actual slip.

The vital part of the PID control is the correct selection of the precise control parameters. However, this selection is not an easy process without using a special tool such as MATLAB-Simulink tuning block. Moreover, the conventional PID controller has difficulties about keeping the system stable, due to a nonlinear slip-adhesion characteristic of the tram-wheel test stand. To overcome the described issue, single neuron PID control algorithm can be used. The Single neuron control method has been implemented in numerous applications [10–13]. In this work, the single neuron PID control method will be investigated for slip control of a tram wheel-test stand. The sketch of single neuron PID controller proposed is provided in Fig.3.

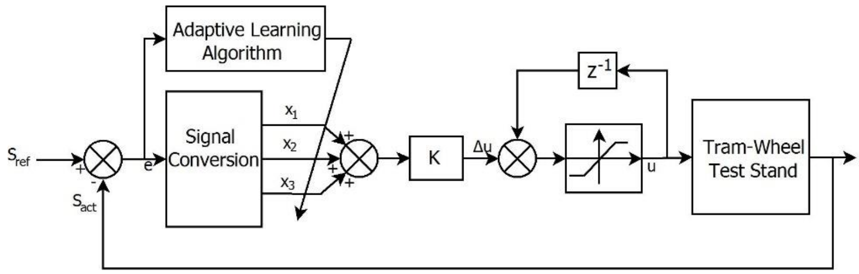

Fig. 3 Sketch of single neuron PID controller

The input of the system is error $(e(k))$ which is converted to three state variables $(x_1, x_2,\ and\ x_3)$ as can be seen in equation (3).

$$\begin{aligned} x_1(k) &= \mathrm{e(k)} \\ x_2(k) &= \mathrm{e(k)} - e(k-1) \\ x_3(k) &= \mathrm{e(k)} - 2e(k-1) + \mathrm{e(k-2)} \end{aligned} \tag{3}$$

The key element of the control the method is learning rule. Hebb learning algorithm is implemented as provide in equation (4):

$$w_i(k) = w_i(k-1) + n_i e(k) u(k-1) x_i(k) \tag{4}$$

where $n_i\ (i = 1,2,3)$ are integral, proportional and derivative learning rate, respectively. Selecting low value of learning rate will cause system to learn slowly, while excessively high value of learning rate make the controller weights diverge [11]. The weighted coefficients are calculated as follows:

$$\overline{w}_i(k) = \frac{w_i(k)}{\sum_{i=1}^{3} |w_i(k)|} \tag{5}$$

The output control torque of the single neuron PID controller is calculated as in equation (6).

$$u(k) = u(k-1) + K \sum_{i=1}^{3} \overline{w}_i(k)\, x_i(k) \tag{6}$$

where $u(k)$ is the final torque request of the controller, and K is the proportional coefficient of neuron which has to be selected bigger than zero. K affects the closed-loop gain of the systems. Choosing bigger K makes the system more robust, however, it will result overshoots in systems even may lead the system unstable. The optimum value of K is determined by trial-error method (TEM) via simulations. Moreover, the initial values of the weights are required to start the controller [10].

4 SIMULATION RESULTS

The performance of single neuron PID control has been investigated through the numerical model of the tram-wheel test stand developed in MATLAB environment. Polach/Freibauer theory is considered for calculation of contact forces that occurs between tram-wheel and roller. The initial speed of the tram-wheel and roller is selected as 20km/h. The control parameters of the traditional PID control method are set as $K_p = 4500$, $K_i = 1800$, and $K_d = 700$ by the trial and error method (TEM). The learning rate parameters of single neuron PID method are selected as $n_1 = 0.4$, $n_2 = 2$, $n_3 = 0.05$, and $K = 7000$. After trial and error (TEM), the initial values of the weights are set as

$w_1 = 8$, $w_2 = 25$, and $w_3 = 8$. The simulations were carried out for two cases. In the first case variable reference slip and in the second one variable adhesion conditions are considered.

4.1 Results

In the first part of the simulations, the slip control ability of the proposed control method and conventional PID control are tested through variable reference slip ratios. The reference slip is varied in three steps. In the first step, the reference slip is selected as 1%, for the second step, reference slip increased to 10%, and for the third step, the reference slip is decreased to 2%. The Variation of the PID control parameters during the tuning process parameters is shown in Fig. 4. It can be observed in Fig. 5, both control methods stabilize the slip at defined reference values in very short time with small overshoots, however, the results from single neuron PID control have lower overshoots and stabilize the slip faster compared to conventional PID method.

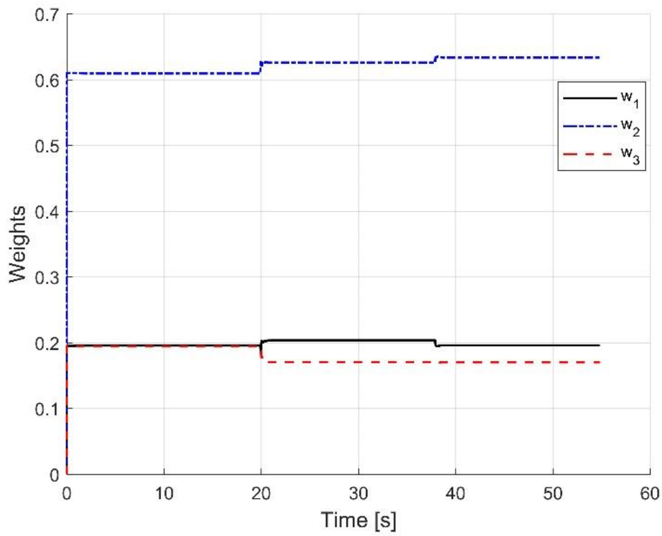

Fig. 4 Variation of the PID control parameters during the tuning process parameters

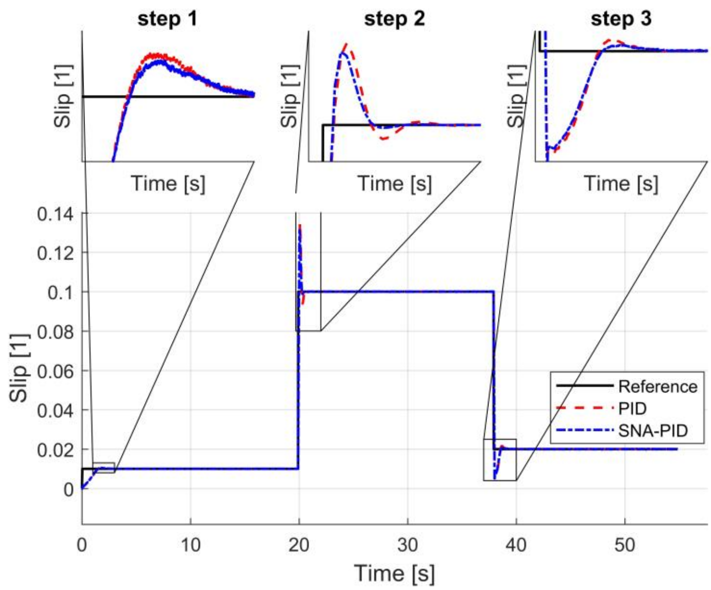

Fig. 5 Performance of conventional PID and single neuron PID controllers for variable reference slip ratio with detail of the oscillation in by particular steps

For the second part of the simulations, variable adhesion conditions are considered for the performance evaluation of the control methods. Polach/Freibauer contact parameters selection is provided as in Tab. 1. The corresponding dynamic coefficient of friction is illustrated in Fig. 6. The friction between the tram-wheel and the roller rail is suddenly dropped after 20 seconds and returned to the previous level after 38 seconds. It can be observed from the Fig. 7, both strategies have a robust reaction to sudden changes, however, there are lower overshoots in the response of the Single neuron PID control. Moreover, the single neuron PID control method stabilize slip slightly faster than the conventional PID control method.

Tab. 1 Selection of Polach/Freibauer contact parameters

	f	k_{red}	**A**	**B** (s/m)
Step 1	0.30	0.5	0.1	0.3
Step 2	0.26	0.1	0.2	0.3
Step 3	0.30	0.5	0.1	0.3

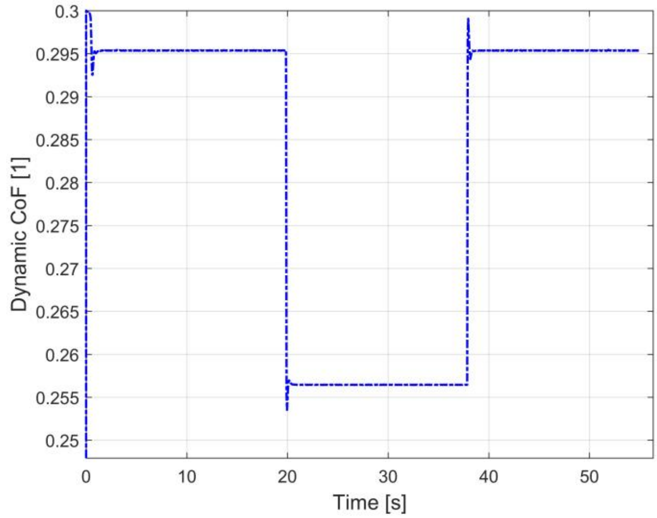

Fig. 6 The change of dynamic coefficient of friction

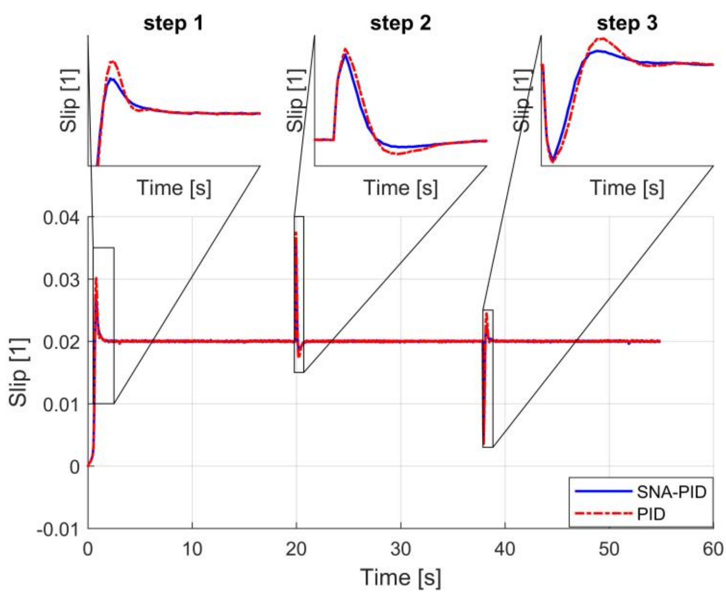

Fig. 7 Performance of conventional PID and single neuron PID controllers for variable adhesion conditions with detail of the oscillation in by particular steps

5 CONCLUSION

In this study, a single neuron PID (proportional, integral, and derivative) control algorithm is proposed for longitudinal slip control of a tram-wheel test stand. Hebb learning algorithm was employed for tuning the control parameters. The main advantages of the proposed algorithm are adaptivity, self-organizing, and self-learning. The performance of the control strategy is simulated using the mathematical model of the tram-wheel test stand that is developed in MATLAB environment. The performance of the control method was tested with variable slip ratio and variable adhesion conditions. The simulation results show that the proposed algorithm has better closed loop performance compared to traditional PID control method. The performance of the control method can be improved further by designing an adaptive proportional coefficient of neuron. Then, the single neuron PID control method can be tested with an experimentally tram-wheel test stand in the future.

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