

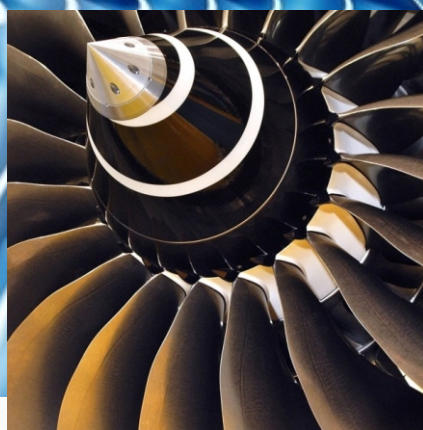
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A design and stand tests of real-time vehicle active suspension

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Abstract: The paper deals with innovations in vehicle suspension technology developed in the Josef Bozek's Research Center of Combustion Engines and Automobiles at CTU in Prague, Czech Republic. A unique innovative suspension system that uses a linear electric motor as a controlled actuator has been designed. Many experiments on the energy management in the system have been accomplished. In order to verify various control strategies and to test different ways of energy consumption optimization we designed and constructed a unique one-quarter-car test stand. To realize simulation and practical experiments at the test stand it is necessary to find a proper experimental road disturbance signal to excite the active suspension system. The disturbance signal is applied on one more linear motor that is placed under a wheel of the one-quarter-car test stand to excite the active suspension system. The paper deals with the way and results of experimental verification of vehicle active suspension behavior when robust control is applied and also with energy management strategy that is used in the system. A modified H-infinity controller that enables to set energy management strategy is mentioned in the paper. At the close of the paper, some experiments taken on the one quarter-car model and their evaluation are discussed.

Keywords: ACTIVE SUSPENSION, VEHICLE, ONE-QUARTER-CAR MODEL, ROBUST CONTROL, EXPERIMENTS

1. Introduction

The suspension system is an important aspect of car design because it influences both the comfort and safety of passengers. Two major performance requirements of any automotive suspension system are to provide a comfortable ride and good handling when random disturbances from road unevenness and variable cargo act upon the running vehicle. Passenger comfort can be understood as an attenuation of sprung mass acceleration or as sprung mass vertical displacement minimization, while good handling can be characterized as attenuation of unsprung mass acceleration.

The effort devoted to passive suspension design is ineffective because improvements to ride comfort are achieved at the expense of handling and vice versa. Instead, the best result can be achieved by active suspension [1], [2], ie. by an additional active force F_a (Fig.1) that can act on the system and simultaneously improve both of these conflicting requirements. Another important goal of the control design is to maintain stability and robustness of the closed loop system [2].

In most active suspension systems, the biggest disadvantage consists of energy demands. Regarding linear electric motors, this drawback can be minimized or even eliminated because under certain circumstances there is a possibility to recuperate energy, accumulate it and use it later for the active suspension when necessary. This way, it is possible to reduce the posted claims on an external power source as much as possible. In next paragraphs, the proposed strategy how to control the energy distribution in the suspension system is described. In order to regenerate electric power from the vibrations excited by road unevenness a new energy-regenerated active suspension system has been designed. The research team modelled and simulated the active system to show the performance improvement and performed many experiments with the actuator prototype on a new test stand the team designed.

All suspension systems are designed to meet various specific requirements. In suspension systems, mainly two most important points are supposed to be improved – vibrations absorbing (videlicet to reach maximal passenger comfort) and attenuation of the disturbance transfer to the road (videlicet car handling). The first requirement could be understood as an attenuation of the sprung mass acceleration or as a peak minimization of the sprung mass vertical displacement. The second one is characterized as an attenuation of the force acting on the road or – in simple car models – as an attenuation of the unsprung mass acceleration. The goal is to satisfy both these contradictory requirements. Satisfactory results can be achieved when an active suspension system generating variable mechanical force acting between the sprung and unsprung masses is used. Such an actuator can be a linear electric motor [1]. In comparison with traditional actuators that use revolving electro-

motors and a lead screw or toothed belt, the direct drive linear motor enables contactless transfer of electrical power according to the laws of magnetic induction. The gained electromagnetic force is applied directly without the intervention of mechanical transmission. Linear electric motors are easily controllable and for features like low friction, high accuracy, high acceleration and velocity, high values of generated forces, high reliability and long lifetime, their usage as shock absorbers seems to be ideal.

2. Problem Solution

2.1. One-Quarter-Car Model

The traditional one-quarter-car model (Fig.1) is used to design a suspension controller and to simulate the system behavior.

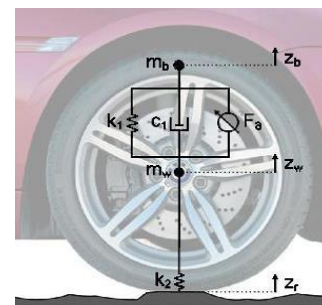


Fig. 1 One-quarter-car model.

In Fig.1:

- F_a active suspension force [N]
- m_w unsprung (wheel) mass [kg]
- m_b sprung mass supported by each wheel and taken as equal to the one quarter of the total body mass [kg]
- k_2 stiffness of the tire [N/m]
- $z_r(t)$ road displacement (road disturbance) [m]
- $z_b(t)$... displacement of the sprung mass [m]
- $z_w(t)$... displacement of the unsprung mass [m]
- k_1 stiffness of the passive suspension [N/m]
- b_1 damping quotient of the passive suspension [Ns/m]

The model involves unsprung (wheel mass) and sprung (taken as one ideal quarter of the car body mass) masses, a conventional passive suspension (a spring and a damper), stiffness of the tire, and linear electric motor as an actuator placed in parallel to the traditional passive suspension (Fig.1).

2.2. Test Stand

The same configuration is used for real experiments as well as verification. Mechanical construction of the test stand is obvious from Fig. 2. Under the wheel there is placed another linear electric motor that uses an experimental input signal described in next

paragraphs to generate road displacement (road deviations) under the running wheel. The modified H-infinity controller mentioned below has been developed in Matlab, implemented into dSpace, and connected to the test stand system. For more details see [4].



Fig.2 Test stand

The basic principle and structure of the linear motor used as an actuator in the designed active suspension system is described in [3]. The appreciable feature of linear motors is that they directly translate electrical energy into usable mechanical force and motion and back. They are linear shaped. Linear motor translator movements reach high velocities (up to approximately 4 m/s), accelerations (up to g [m/s²] multiples) and forces (up to 8 kN). The electromagnetic force can be applied directly to the payload without an intervention of mechanical transmission.

2.3. Linear Motor Model

In order to verify control algorithms a linear motor model including a power amplifier in Matlab Simulink has been created. The model enables to demonstrate the conversion of electrical energy to mechanical energy. In the model, it is assumed that the magnetic field of the secondary part with permanent magnets is sinusoidal, the phases of the primary part coils are star-connected, and a vector control method is used to control the phase current. Here, PWM voltage signal is substituted by its mean value to shorten (about 10 times) the simulation period (inaccuracies caused by such a substitution can be neglected).

The linear motor model is shown in [1]. In the model, an input vector is given (see Fig. 3) by the instantaneous position [m] (necessary to compute the commutation current of the motor coils), instantaneous velocity [m/s] (the voltage induced in the coils depends on the position [m] and velocity [m/s]) and desired force [N].

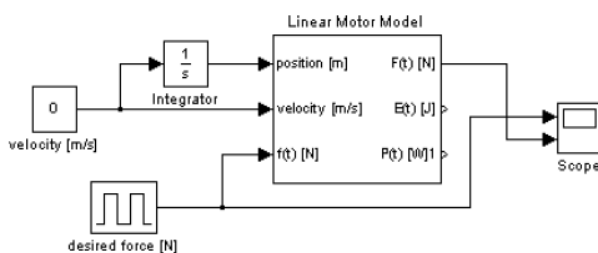


Fig.3 Linear motor input-output model

The designed model function, we verified comparing dynamics on the simulation model and the real linear electric motor, respectively. The simulation parameters correspond to catalogue parameters of TBX3810 linear motor by Thrust-tube.

For example, responses caused by changes of the desired force in the form of a right-angular signal and corresponding real time responses are compared in Fig.4. and b, respectively. The upper signals in both figures represent desired force and the lower ones real output forces.

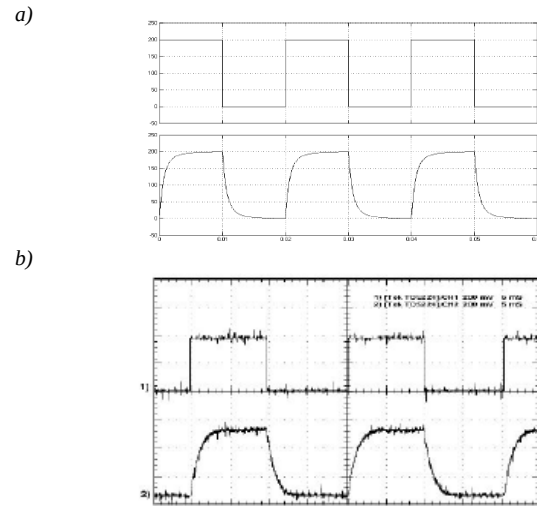


Fig.4 a) Simulated response, b) Real time response

Figs. 4a) and 4b) represent simulated and real time responses, respectively (rightangular force signal : 0→200 [N], power supply of 150 [V], velocity: 0 [m/s]).

For the automotive suspension system, the application of the synchronous three-phase linear motor TBX 3810 produced by Copley Controls Cooperation (technical parameters: peak force 2027N, peak current 21.8A, continuous stall force 293.2N, electrical time constant 1.26ms, continuous working voltage 320Vac) has been designed by the research team. Comparing the time responses in Fig.4a) and Fig.4b), it can be seen a very good matching level of the model and real motor behavior.

It results from many experiments we made in [4] with TBX3810 linear motor that the designed model describes the real linear motor equipped with necessary auxiliary circuits very authentically and enables to verify control algorithms developed to control the linear motor as an actuator in the active suspension system, credibly.

2.4. Energy Balance

In fact, there is some non-linearity in the recuperation process and that is why the energy management control is fairly difficult. The 3D plot in Fig. 6 represents a force-velocity profile of the recuperated energy. It shows how much recuperated (and only recuperated) energy can be obtained under the given forces and velocities. In the plot, when the recuperated energy is equal to zero or bigger it is necessary to supply energy into the system.

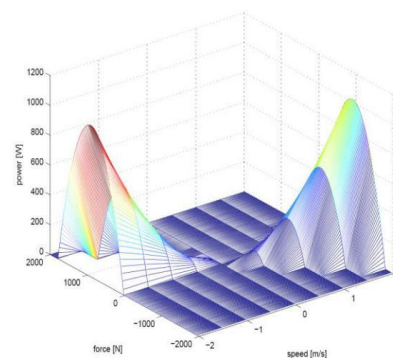


Fig.5 Force-velocity profile of the recuperated energy in the used linear motor

Regarding to this characteristic surface this gives important information of the requirements on the control system. Optimization objectives are equal to maximization of the recuperated energy (with necessary trade-offs).

2.5. Road Displacement Simulation

In order to realize simulation and practical experiments at the test stand it is necessary to find a proper experimental signal to excite the active suspension system by generated road displacement. Although the simplified suspension model seems to be linear there are many nonlinear parts in the system. Now the question is what signal to generate for experimental testing in order to reach a true model of the uneven road under the wheel. We can define two types of input signals regarding objectives:

- to prove results of simulations and pre-calculations
- to test real behavior on the road

Let us start with the first objective ie. to verify simulation results. White noise signal is supposed to be the best disturbance signal mainly for of its full frequency spectrum. But it should be noted that the whole system is nonlinear and that is why white noise cannot be used for testing. Moreover, it is not possible to generate easily white noise on the test stand.

Unfortunately, neither step input signal simulating road bump up or bump down is not realizable by the test stand for the right-angular slopes of the signal.

To simulate road the profile a random signal approximation (see Fig.6) has been used. Such a signal is described by the following equation:

$$z_r = \sum_{i=1}^n \sqrt{\frac{\dot{\omega}_i}{\pi \cdot v_x}} \left\{ \operatorname{Re} \left(\frac{b_o}{-\omega_i^2 + a_1 j \omega_i + a_o} \right) \cdot \cos(\omega_i t + \alpha) + \operatorname{Im} \left(\frac{b_o}{-\omega_i^2 + a_1 j \omega_i + a_o} \right) \cdot \sin(\omega_i t + \alpha) \right\}$$

where: (1)

$$b_o = 0.121 \cdot v_x \quad (2)$$

$$a_o = 2.249 \cdot v_x$$

and v_x represents the car velocity.

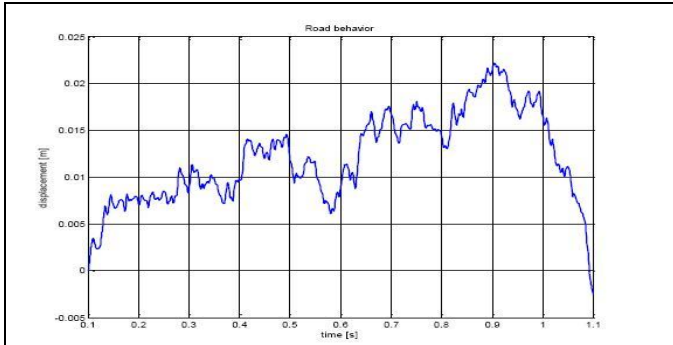


Fig.6 Random signal approximation used to simulate road displacement

2.6. Controller

Design of an appropriate controller is a complex problem. The research team tested commonly used high authority control concepts, such as Linear Quadratic Gaussian control, feedforward control concept, fuzzy control as well as H-infinity robust control. Most of the proposed concepts do not consider robustness of the designed controller, although this aspect is fairly important and well-founded. For example, changes in ambient conditions can lead to changes in the dynamics of the system which can result in substantial deterioration of the feedback controller performance.

A robust controller is necessary for the suspension system because many system parameters often vary in a wide range. Especially cargo mass changes occur for every single drive. For this

reason the H-infinity theory has been chosen for robust controller design [4], [6] via Matlab toolbox procedures.

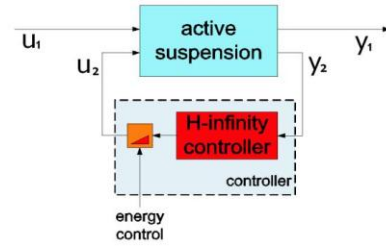


Fig.7 Modified controller structure

Nevertheless, the standard H-infinity controller cannot handle energy consumption. Some significant modifications of the controller on the base of the realized experiments were designed. An additional input to control energy demands is supposed to be connected to the controller. Then master controller can use this input to keep energy balance. The general modified controller structure is shown in Fig. 7. Energy management is controlled by an external signal depending on car and road parameters, ie. on the energy accumulator (super-capacitors) current capacity and the road surface, respectively [2].

First way to control energy consumption in the suspension system is analysis of the driving conditions and cyclic re-computing of the control signal in real time. For necessary high sampling frequency (over 1 kHz) and controller performance, this approach has been rejected.

The second possibility of energy consumption control is control via controller deterioration. Then the designed controller is reliably robust and the active suspension system relatively stable.

Two types of driving conditions are assumed:

- the terrain (surface) the car is going on is very rough and uneven and there is enough energy stored in the accumulator (supercapacitors). Then the controller works in “comfort setting” mode, the linear electric motor consumes energy from the accumulator and the suspension performance is preserved.
- the terrain (surface) under the car wheels is relatively smooth and there is not enough energy stored in the accumulator systems (super-capacitors) because of the situation described above. The external signal provides this information to the controller in order to deteriorate its performance and to reduce the linear motor energy consumption. The deterioration is stated by the desired force attenuation. In this case the controller works in “energy setting” mode.

If the force is attenuated too much the active suspension system works only as the passive suspension (connected in parallel to the active suspension) while the linear electric motor works as a generator generating electrical energy to be stored in supercapacitors. Of course, in such a situation the suspension performance is deteriorated (down to the passive suspension level in the worst case).

2.7. Quantification

2.7.1. Car Stability

The first requirement in the active suspension system is to improve car stability and reach “road friendliness” that can be characterized as the attenuation of the tire pressure, or more precisely, the attenuation of the unsprung mass force acting on the road. To gain a measurable parameter, the following RMS function has been introduced.

$$I_{stab} = \sqrt{\int_0^T (z_w - z_r)^2 dt} \quad (3)$$

where z_w represents wheel displacement and z_r road displacement.

2.7.1. Passenger comfort

Another important requirement in the active suspension system is to improve passenger comfort. This requirement can be formulated as the sprung mass acceleration attenuation when the RMS function is defined as:

$$I_{comf} = \sqrt{\int_0^T (G_w - (\ddot{z}_b)^2) dt} \quad (4)$$

Where z_b represents the body displacement, G_w is a weighting function for human sensitivity to vibrations and $*$ denotes convolution.

3. Results

The random signal approximation stated in and plotted in Fig. 6 has been taken as an input signal (road profile) for experiments taken on the active suspension test stand. Two main objectives must be taken into account - passenger comfort improvement and energy consumption (see Fig. 8). In Fig.8, the corresponding body displacement for “energy” and “comfort” controller settings to the road profile input are displayed. Body (sprung mass) displacement can be taken as an indicator of the passenger comfort.

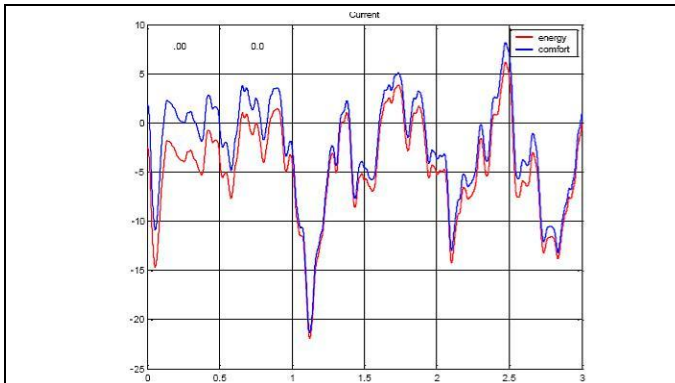


Fig.8 Body displacement for “energy” and “comfort” settings

Fig. 9 shows two curves – energy demand for standard energy consumption (called “comfort setting”) and energy demand for lower consumption (called “energy setting”). Actually, negative values of energy represent the recuperated energy.

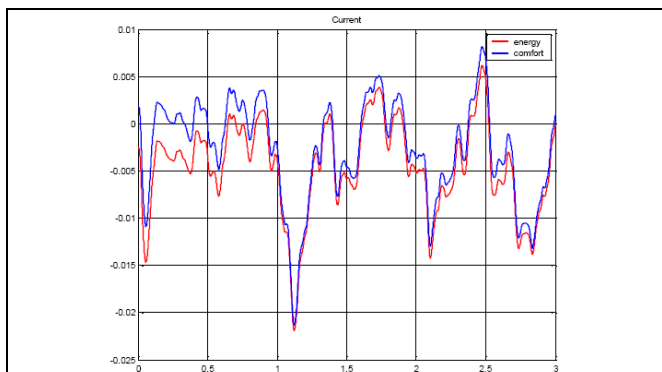


Fig.9 Demands on electric current as an indicator of energy demand for “energy” and “comfort” settings

For “comfort” controller setting, passenger comfort is maximized with no respect to energy consumption while for “energy” controller setting the controller performance is deteriorated and energy recuperated with no respect to passenger comfort.

Let us show the results as mean values of comfort and energy indicators stated in the previous paragraph. Table I involves mean values for the body displacement as absolute values of the defined

body displacement indicator and also as a percentage of its improvement. In Table I, the first table row shows that for “comfort” controller setting the comfort indicator, i.e. body displacement mean value (0,0386m) is taken as 100 %. In the second row, when the controller was deteriorated, the comfort was devaluated up to 0,0474 m, i.e. to 123 %. Table II contains mean values of power indicator i.e. electric current mean values. Lower value corresponds to lower energy demands. It is sufficient to express power values by values of electric current because the voltage supply of the motor remains constant. Similarly, the first line shows that for standard controller setting the “comfort” indicator (2,698 A) is taken as 100 %. In the second line, when the controller was deteriorated the energy indicator is devaluated down to 1,598 A, i.e. to 59 %. Briefly, controller deterioration causes comfort devaluation to 123 % while energy consumption decreases to 59 %.

Table 1: Body displacement mean values

	Body displacement mean value [m]	Percentage
For “comfort” setting	0,0386	100%
For “energy” setting	0,474	123 %

Table 2: Power mean values

	El. Current [A]	Percentage
For “comfort” setting	2,689	100%
For “energy” setting	1,598	59 %

3. Conclusion

A new method for direct real-time energy control in the car suspension system has been developed with respect to the reduction of energy consumption. Experiments that we took on the designed test stand verified validity of simulations and showed that it is possible to change energy demands according to the road surface mode of the energy storage in the car supercapacitors. The method can be extended to general plants with considerable energy demands in which the decreasing actuator signal in a given range can preserve system stability.

Various active suspension controllers were developed via Matlab implemented into dSpace and connected to the test stand system. As discussed in [3] and [4], the most satisfactory responses of the suspension system have been reached using H-infinity robust control.

4. Acknowledgement

This research has been supported by project INTER-VECTOR 17019 of the Ministry of Education, Youth and Sports.

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Creation of cars with improved technical and economic parameters

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Abstract: Modern trends in the movement of freight rail cars are associated with improved technical and economic movement of rolling stock. GSKBV (Mariupol, Ukraine) in collaboration with the branch institutes of Ukraine and the Ukrainian Railways are developing promising models of freight cars. One of these cars is a thermos car. The technical solutions used made it possible to create a thermos car with improved technical and economic capabilities. The obtained scientific and technical groundwork for the creation of this car allows us to carry out further work on the creation on the basis of the presented design - a car with an autonomous cooling system.

KEYWORDS: freight cars; innovative design; thermos car; spring suspension, structural strength

1. Introduction

Modern trends in the development of cargo transportation by rail are associated with an increase in the technical and economic characteristics of rolling stock. Therefore, the direction of research is relevant, which involves the improvement of the designs of freight cars. There are several ways to solve this scientific and technical problem [1],[2]. One of these ways is the creation of innovative designs of freight cars. This implies the use of more durable materials and advanced engineering technologies, which allows us to create designs of freight cars with better quality characteristics.

2. Problem discussion

The deterioration of rolling stock is currently one of the acute problems of the railways of Ukraine. The wear and tear of the fleet of freight cars intended for the carriage of perishable goods and other goods requiring compliance with the temperature regime during their transportation is no exception. In addition, enterprises that previously produced isothermal rolling stock ceased to exist, or ceased to produce rolling stock of this type.

3. Objective and research methodologies

GSKBV (Mariupol, Ukraine) in collaboration with the branch institutes of Ukraine and the Ukrainian Railways are developing promising models of freight cars. One of these cars is a thermos car model 16-1807-04 (Fig. 1). In this car, steels of increased strength are used, which made it possible to create a structure with a relatively low ratio of the car's tare weight and carrying capacity (tare ratio). In addition, a number of technical solutions were used in the car design, which made it possible to maximally break the cold bridges and obtain a car design with a lower heat transfer coefficient of the body guard. The design of the car allows extensive use of mechanization and automation of technological processes in its manufacture. The same applies to the main layer of thermal insulation material applied in the body structure, applied by spraying (Fig. 2). Bogies with bilinear spring suspension, polymer linings in friction units were used as running parts, which made it possible to improve the dynamics of the car, remove the impact on the track and increase the turnaround time and service life in general for this type of cars from 22 to 32 years [3], [4],[5]. A number of technical solutions used in this car are protected by the patents of Ukraine and the Russian Federation.



Fig.1. Thermos car model 16-1807-04

The car was created using modern design tools and assessment of the stress-strain state. At the same time, the key point was a preliminary assessment of the thermal properties of the body.

The calculation is based on the determination of the total heat transfer coefficient of the body guard [6]. The heat transfer coefficient of individual zones of the fence is determined as for a multilayer wall by the formula:

$$K = \frac{1}{\frac{1}{\alpha_B} + \sum \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_H}}$$

where: δ_i and λ_i - are the thickness and thermal conductivity of the i-th element;

α_B - heat transfer coefficient from product to metal sheathing;

α_H - heat transfer coefficient from metal sheathing to outside air.

The average heat transfer coefficient of the body guard is determined by the formula:

$$K_C = \frac{\sum K_i F_i}{\sum F_i}$$

where: K_i - heat transfer coefficient of the i-th element;

F_i - surface area of the i-th element.

As a result, in order to improve the accuracy of the calculation, the body structure was divided into 18 zones (elements), different in their heat-conducting characteristics.

At the same time, the overall heat transfer coefficient of the body guard was 0.25 W/(m²K). At the same time, thermal engineering tests of a full-scale sample showed an exact coincidence with the results of theoretical studies.

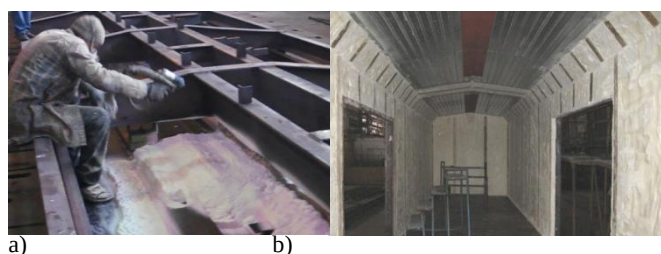


Fig.2. Car frame (a) and Car body (b) spray-applied insulation

The assessment of the structural strength of the car body was carried out by the finite element method. For this, its design model was used, created in the program of three-dimensional parametric modeling SolidWorks, which is an approximate representation of a real structure. The calculation was performed using the ANSYS software package. As an example, Fig. 3 shows the result of calculating the strength of the end wall and frame of a car upon impact.

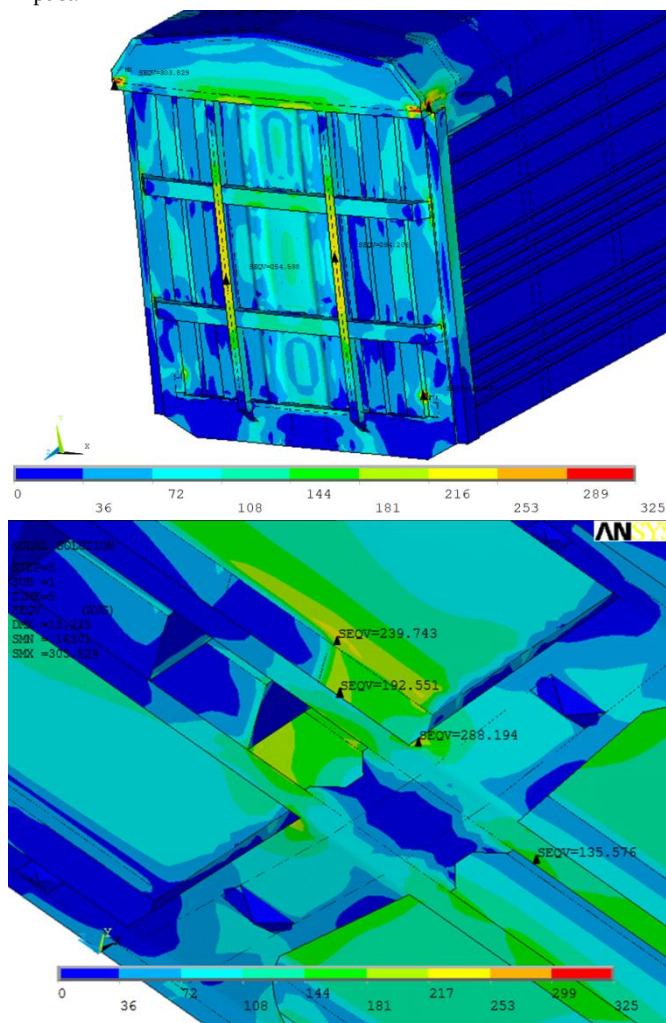


Fig.3. Stress-strain state body elements in the design mode impact.

The key task in the creation of the car was to confirm the declared service life of the car - 32 years. For this, a theoretical and experimental assessment of the fatigue strength of the car body was carried out. According to the calculation performed, on the basis of the obtained stresses from the action on the structure of the car of the vertical (from the load and its own weight) and longitudinal tensile and compressive forces. Taking into account the effective body vibration frequency of 2.6 Hz, car frame deflection in the middle part (Fig.4.) 5.0 mm and the statistical distribution of the

amplitudes of the longitudinal forces for one year, the minimum fatigue safety factor for the service life of a carriage of 32 years was 2.1 with its allowable value according to the accepted assessment method of 1.8.

When conducting fatigue tests, to create vertical vibrations of the body, pneumatic pulsators were used (Fig. 5, a) installed in the cantilever part of the car, one on each side. In this case, the friction wedges of the spring suspension of the bogies were dismantled. The vertical load was created by loading the body with sandbags (Fig. 4, b)



a)



b)

Fig.4. Car tests to determine the fatigue safety factor

The overall size of the car allows this car to be operated along the entire 1520 mm rail network and along the main and a number of other railways - members of the Organization for Cooperation between Railways (OSJD) with a gauge of 1435 mm used for international traffic.

According to the Unified Tariff Statistical Nomenclature of cargo, this car can carry almost 500 different types of cargo. Currently, more than one hundred cars of this model are in operation. In comparison with analogues, this car allowed to increase the transportation time for perishable goods from 3-6 to 10 days.

Some of them have already undergone scheduled repairs. At the same time, there were no complaints from the car owners. Taking into account the high (more than 90%) deterioration of the fleet of isothermal cars, the presented model, in terms of its technical and economic parameters, is one of the most promising models for replacing cars of this type retired due to the end of their service life.

4. Conclusion

The technical solutions used made it possible to create a thermos car with improved technical and economic parameters. The car allows you to transport a wide range of perishable food cargo in the required temperature range for a longer distance.

Thus, the problem of creating a car with improved technical and economic parameters that meets the needs of the freight transport market has been solved.

The obtained scientific and technical groundwork for the creation of this car allows further work to be carried out on the basis of the presented design - a car with an autonomous cooling system, which will further expand the capabilities of carriers.

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Analysis of ship construction designed for restricted production facilities at SME

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Abstract: The paper presents the design and construction process of a series of four multipurpose ships for SME shipyard with some restrictions in production facilities. This process is based on software that is available free or the some tasks could be subcontracted by SME. The main dimensions are optimized by the system “Expert” and hull forms are generated by PolyCAD. Due to the restriction in the production facilities the ships are with the same breadth and for additional unification the depth is also equal. Three different hull structure topologies are evaluated by MARS2000 software and modeled by AVEVA Marine design software. The analysis includes evaluation of man-hours for construction of parallel mid-body of the all variants. The analysis takes into account the restricted preassembly space and human recourse, lifting capacity of building crane, geometry of building slipway etc. Some conclusions for labor intensity and influence of series function are made based on the presented data.

Keywords: CONCEPTUAL DESIGN, MULTIPURPOSE SHIP, MIDSHIP SECTION, PARALLEL MID-BODY PART, SME, RESTRICTED PRODUCTION FACILITIES

1. Introduction

Restricted production facilities are mainly characteristic of small and medium sized shipyards (SME). The restrictions can be geometrical and functional. The geometrical are connected with dimensions of production hall, length and breadth of slipway while functional production restriction are mainly connected with lifting capacity of assembly and building cranes, lifting capacity of floating docks service slipways. The authors in [1] analyzed possibilities of shipbuilding in restricted production facilities. The authors presented two option of building technology. Option 1- ship hull will be performed on the building berth of the floating dock and option 2 ship hull will be performed on building berth which is part of launching complex. Additional analyses [2] of ship performance accounting for SME shipyard building limitations shown that the designed ships with a constrained breadth, due to shipyard building limitations, don't lead to a considerable reduction of the ship performance, and in some cases the ship performance may be even better than the one of the ships with unrestricted breadth. The recently finished study [3] analyzes the influence of the equal depth and breadth of a series of four multipurpose ships on the ship features and how this changes the productivity of the SME. The positive and negative effects of additional steel weight, increased cargo volume and gross tonnage and improved intact stability are in the range of less than 5%.

The present study evaluates the series effect at construction of a series of ships with the same midship section and different length of the parallel mid-body (PMB) that could lead to a more significant increase in the productivity of SMEs. The study is presented as a part of the overall ship design and construction process in conditions of SME.

2. Conceptual design

The ship design process together with the used software is presented on Fig. 1. During the conceptual design two free available computer programs could be used. The “Expert” system [4] is designed to determine the main dimensions and main characteristics of the ship after optimization of CAPEX, OPEX or RFR. The PolyCAD (<https://www.polycad.co.uk/>) provides surface modelling capability for hull forms using mathematical curve and surface entities and parametric hull generation.

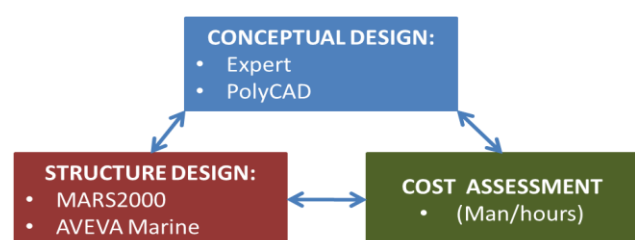


Fig. 1. Scheme of the design process

The “Expert” system was used to determine the main dimensions of a series of multipurpose ships with deadweight 5000 – 8000 tDW. The ships are with restricted breadth (B) equal to 16 m due to limitation of production facility of SME. Table 1 presents the main dimensions of the ships.

Table 1. Main dimensions of series of multipurpose ships

DW, t	5000	6000	7000	8000
L, m	88.63	106.6	120.62	135.06
B, m	16	16	16	16
d, m	7.08	6.88	6.67	6.57
D, m	8.81	8.93	9.03	9.17
L/B	5.54	6.66	7.54	8.44
B/d	2.26	2.33	2.4	2.44
L/D	10.06	11.93	13.36	14.73
Cb	0.69	0.721	0.772	0.812
Lp, m	3.0	7.7	33.0	61.7

The hull forms are generated by the parametric hull generation module of PolyCAD with the same depth (D) equal to 9.17 m. The PMB of the ship is adjusted to obtain the volume displacement of the ship. The values of PMB (Lp) are shown in the Table 1 and hull forms in Fig. 2.

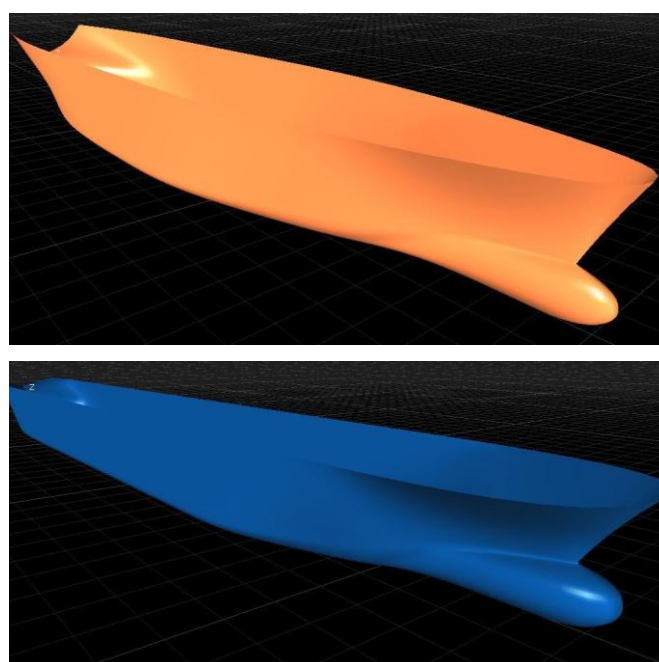


Fig. 2. Generated hull form o50000 tDW (up) and 8000 tDW (down)

3. Steel structure

The structural assessment is carried out by MARS2000 software (also free available from BV¹) and based on [5]. Design characteristics of ship construction are related with providing of ship strength throughout ship life cycle. The software offers calculation of geometric properties, evaluation of hull girder strength, ultimate strength and local strength and assessment of transverse cross-sections and transverse bulkheads throughout ship length.

Three ships are so-called “box shaped” ship type with double side. Three different structures scheme are developed and evaluates by MARS 2000:

- Scheme 1: girder frame system in double bottom and flat strip in side sections (Scheme 1 of midship section in MARS2000Fig. 3);
- Scheme 2: bulb frame system in double bottom and flat strip in side section
- Scheme 3: bulb frame system in double bottom and side section

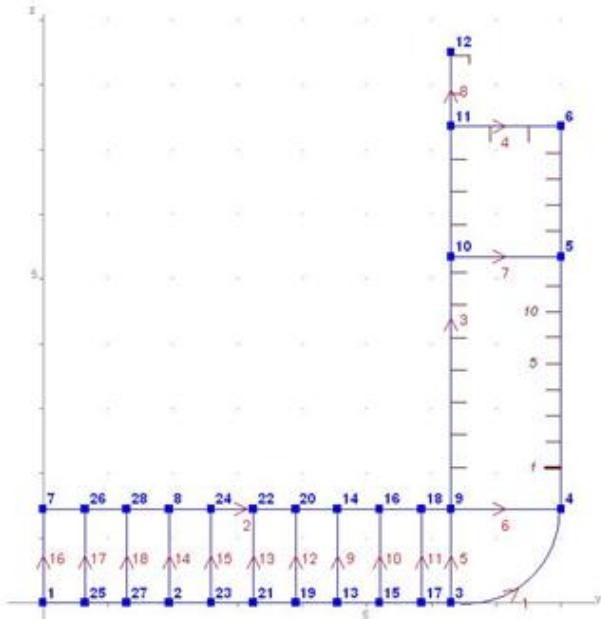


Fig. 3. Scheme 1 of midship section in MARS2000

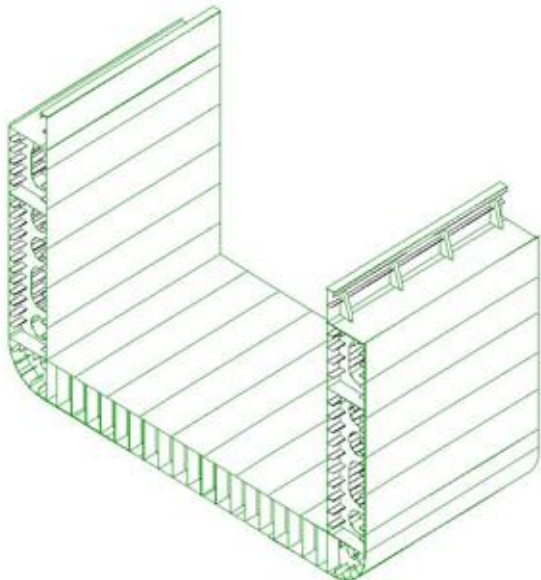


Fig. 4. Midship section with girder frame system in double bottom and flat strip in side section

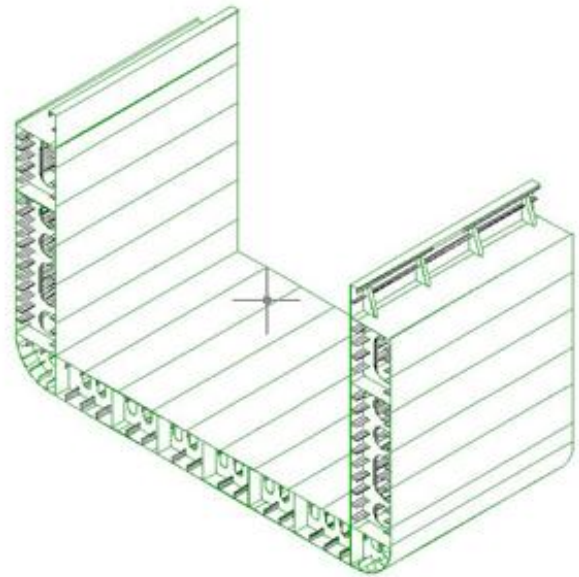


Fig. 5. Midship section with bulb frame system in double bottom and flat strip in side section

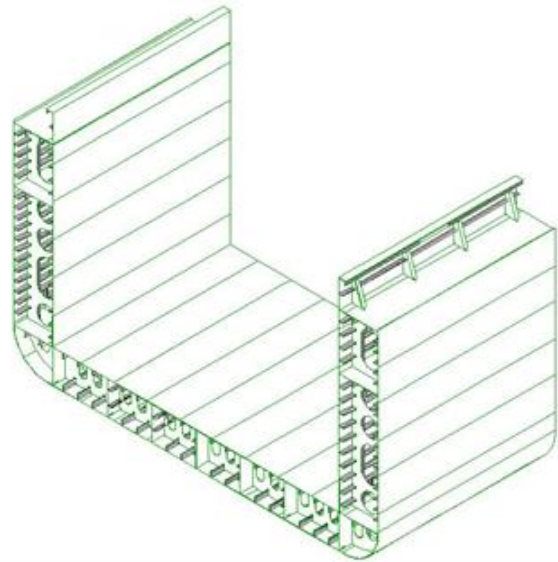


Fig. 6. Midship section with bulb frame system in double bottom and side section

The detailed design of ship structure is carried out by AVEVA Marine. Fig. 4 to Fig. 6 present a part of PMB with three of the considered schemes.

The most important operations for steel structures are cutting and welding. Comparison of the characteristics of a block length of 7.8m according to the three schemes of structure are shown in Table 2.

Table 2. Cutting and welding length and total weight

Item	Scheme 1	Scheme 2	Scheme 3
Cutting length, m	1505.56	1067.8	1041.41
Welding length, m	2041.02	1552.59	1087.52
Weight, t	108.68	105.14	97.67

At Scheme 1 the floors are located every three spacing in double bottom stopped at each one girder. In this system is absolutely necessary girders plate to be cutted in small pieces and fitted in appropriate place in ship construction. This is the reason for high value of cutting and welding length respectively. In other two schemes of construction the cutting is applied to the bulb profile cut-out and openings in bottom and double side. The welding length is about 35-45% longer than the cutting length. The reason is

¹ <https://marine-offshore.bureauveritas.com/mars-2000-2d-ship-structural-assessment-software>

obvious, the welding in ship construction is done on both side of construction elements.

Comparing the all mentioned characteristics the most suitable one is presented in Scheme 3. This scheme is considered in the next analysis.

4. Estimation of man-hours for parallel mid-body for series of ships

Taking into account the Scheme 3 of midship hull structure the man-hours for construction of PMB of the series of four MPV in the above mentioned range are estimated. The unit mass of the hull structure is 12.209/t.m, calculated by AVEVA model.

The length (L_p) and weight (W_p) of PMB as man-hours for its construction (MHp) for four ships (variants) are presented in Table 3. The value of MHp is calculated taking into account coefficient of productivity (k) that depends on technological level of shipyard, and it is adopted to be 0.12 mh/t.

Table 3. Characteristics of parallel mid-body for the ships

Var	DW, t	L_p , m	W_p , t	MHp, mh
1	5000	3.00	36.626	4.395
2	6000	7.70	94.007	11.281
3	7000	33.00	402.889	48.347
4	8000	61.70	753.280	90.394

Construction of PMB with the same breadth, depth and geometry of structure elements (although the sheets can be of different thicknesses) could be considered as can be considered as high-volume production and for it to apply the series function (f_s) defined in the shipbuilding [6]. The function is defined as:

$$(1) \quad f_s = -0.1483 \ln(n) + 0.9995,$$

where: n = number of the ship in the series.

The man-hours for ship series are reduced by function f_s .

For estimation of man-hours for construction of PMB of a ship from the analyzed series MPV, we propose the following formulas:

$$(2) \quad \Delta L_p = L_p - L_p^{(0)}$$

where: L_p = length of PMB of the ship under the estimation; $L_p^{(0)}$ = the length of the PMB of the first ship in the series;

$$(3) \quad \text{if } \Delta L_p \leq 0 \text{ then } MH_p^{(s)} = MH_p^{(i)} * f_s(r) \quad r > 1$$

where: $MH_p^{(s)}$ = man-hours for construction of PMB for the ship considered as a series ship; $MH_p^{(i)}$ = man-hours for construction as individual ship (last column of Table 3); $f_s(r)$ = series function with serial number r .

$$(4) \quad \text{if } \Delta L_p > 0 : MH_p^{(s)} = MH_p^{(0)} * f_s(r) + k (W_p - W_p^{(0)}), \quad r > 1$$

where: $MH_p^{(0)}$ = man-hours for construction of PMB for the first ship in the series; $W_p, W_p^{(0)}$ = weight of PMB for actual and the first ship in the series.

Formulas (1) to (4) are used to calculate the reduction of man-hours for construction of PMB for different ships and different scenarios. The scenarios differ in who is the first ship in the series.

The reduction in the man-hours for construction of PMB for all ships depending of the first ship in the series and corresponding serial number is presented on Fig. 7 to Fig. 10. As one can expected the biggest reduction is for the ship with 5000 tDW that has the shortest PMB. Independent of the first ship in the series, for the ship the original series function is applicable. For the biggest ship, the reduction is smaller and once again depends on which is the first ship in the series.

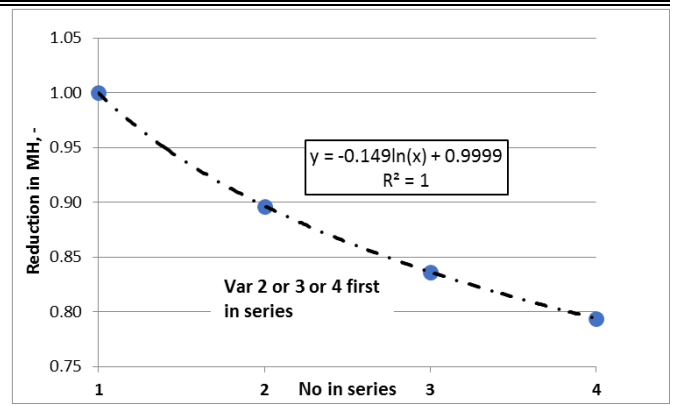


Fig. 7. Reduction in MH for construction of PMD of 5000 tDW ship

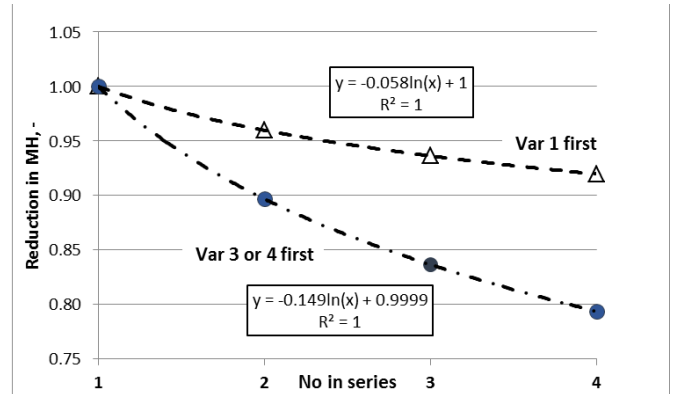


Fig. 8. Reduction in MH for construction of PMD of 6000 tDW ship

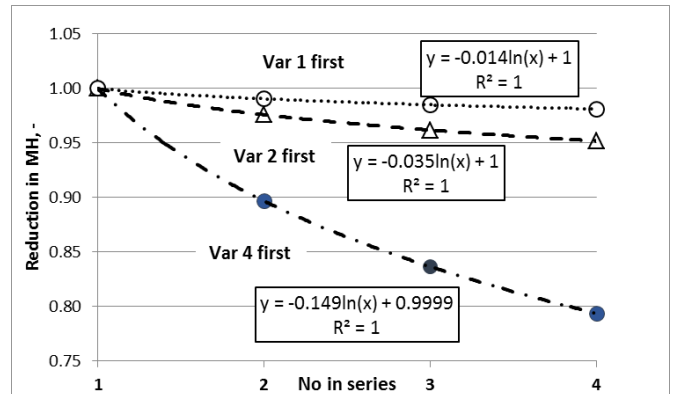


Fig. 9. Reduction in MH for construction of PMD of 7000 tDW ship

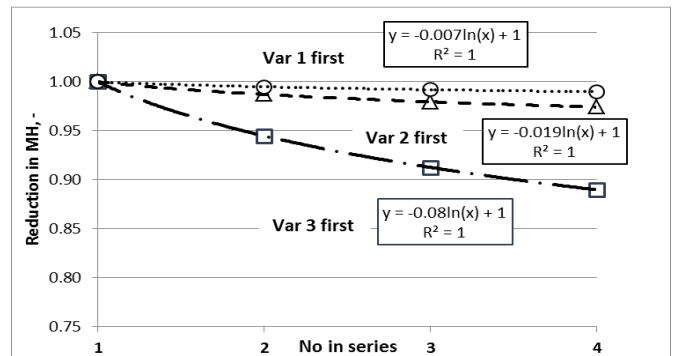


Fig. 10. Reduction in MH for construction of PMD of 8000 tDW ship

All relations are very well approximated by logarithmic regression type.

The m -permutations of n elements is calculated by $n!/(n-m)!$. In our case $m = n = 4$ that gives 24 permutations. For all of them, the relation between the minimum and maximum value of MH is 0.79 for the first 3 ships and 0.89 for the last one.

5. Conclusions

The paper deals with restricted production facilities in the shipyard which is mainly characteristic of small and medium sized enterprises. Taking into account such limitation a conceptual design and detail structure design of PMB of a series of four MPV in the range of 5000 – 8000 tDW is presented. The ships are with the same breadth and depth, transversal section, internal arrangement transverse and longitudinal frame spacing.

Based on developed hull form three schemes of hull structures were analysed. The most competitive concerning weight, cutting and welding length is the third scheme i.e. bulb frame system in double bottom and side section.

The accepted unification in main dimensions and hull structures permits implementation of series function for reduction of man-hours in construction of PMB of the ship taking into account the first ship in the series and serial number of the next ships.

The reduction of man-hours for construction of PMB varies between 11% and 21%. The results can be more accurate if in (4) the value of $MH_p^{(0)}$ and k is taken from the real construction in the SME.

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Fixed joints applied in car construction

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Abstract: The paper deals with the problem of joints of car parts of the car construction. The construction of the car must meet the emission standards, in order to meet them it is necessary to reduce the weight of the car while maintaining strength and durability. Therefore, different materials are used in the design of car construction, such as different types of steels, aluminum alloys, composites and plastics. This increases the demands on the car construction and on the type of sheet metal joining technology used. The paper deals mainly with glued and welded joints in the design of car construction. The suitability of individual types of joints is solved using the finite element method.

Keywords: FIXED JOINTS, FEM, AUTOMOTIVE INDUSTRY, CONSTRUCTION

1. Introduction

Reducing car body weight is one of the main goals in car body design. Demands for CO₂ emissions are constantly increasing, and more expensive fossil fuels require a reduction in fuel consumption. The effort of designers in the automotive industry is to use a material that would meet the lowest possible weight without compromising the safety of the crew, ideally with the lowest possible production costs [1]. We do not encounter such a variety of materials used for car body construction anywhere else in any mass-produced engineering product.

The construction of a car is made up mostly by steel of various qualities and properties. Steel makes up more than 80% of a car's construction. Thanks to its properties, steel is a suitable material for car bodies construction, and thanks to its low price (compared to other suitable materials), it is also the most used material. Recently, extremely strong steel is also used - this type of steel differs from the others in that it is not made to achieve a specific chemical composition, but to achieve certain properties [2].

The average weight of road motor vehicles has been declining since the 1970s. The average European vehicle weighs almost 1,100 kg, with ferrous metals (60%), non-ferrous metals in particular aluminum (7%), plastics (10%), rubber (4.5%), glass (3%), textiles and anti-noise mass (4%), paint and putty (1.5%), liquids and other materials (7%). The material currently represents 30% of the production cost, so there is a great effort by manufacturers to reduce its consumption. A favorable argument for the use of plastics in car production is the recyclability of all thermoplastics.

The use of plastics is also associated with innovations that are intended to increase safety, comfort and increase environmental friendliness. At present and also in the near future, the use of special composite reinforcement materials in car bumpers is expected, which show three times higher rigidity and energy absorption than ordinary plastic. Plastic headrests contribute to greater passenger safety. In the event of a kickback, the front half of the headrest moves forward as a result of activation, reducing the risk of personal injury in the car. The main use of new materials or existing materials by replacing e.g., metals require a number of tests and experiments of their effective and efficient use. New trends in car development are focused on the use of new, lightweight or composite materials, for special surface treatments of car bodies, the use of light metal structures as well as for increasing the share of plastics for the assembly of modern types of cars. From the production-technical point of view, plastic composites filled with natural fibers of flax, cotton or sisal proved to be the best. By using these composites, great profile stability of the manufactured parts, their good impact safety, minimal emissions in the interior and high dimensional freedom are achieved.

Time plays an important role in car construction. Therefore, the aim is to use the most effective - the fastest ways of joining materials in the production of automotive parts, or in the construction of the entire car body [3]. However, the speed of joining materials and welding must not increase at the expense of the quality of joints and welds.

2. Joining materials in the automotive industry

In the automotive industry, it is necessary to combine materials of various qualities and thicknesses, whether plated or unplated, but also ferrous and non-ferrous metals. Thus, in addition to traditional steel, wider use is given to aluminum, carbon, magnesium, high-strength steel and also plastics. With conventional methods of connecting materials, such as spot resistance welding or laser welding, it is not always possible to ensure the required quality of joints. That is why companies are exploring alternative methods of joining materials.

Conventional methods of joining materials in the automotive industry include welding, laser welding, soldering, and gluing.

Welding technology is mainly associated with metallic materials. However, there are also polymeric composite materials (thermoplastic matrix composites) that can be connected by this technology. The advantages of welding are good mechanical properties and resistance of joints, short processing time and minimal need to prepare connected surfaces. The main disadvantages of this type of connection for composite materials are the restriction exclusively to thermoplastic materials, problems with the disassembly of connected parts and the presence of foreign substances in the structures of materials needed for individual types of welding (induction, resistance, ultrasonic). Laser welding is also increasingly used in the automotive industry (Fig. 1).

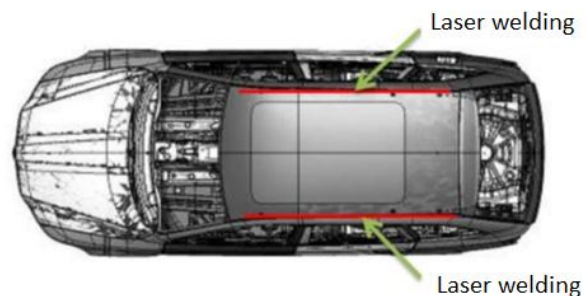


Fig. 1 Laser connection on the roof of the car.

At present, car body plates are most often joined by resistance (spot, seam and projection) welding technology. This technology has several disadvantages. These disadvantages include, for example, problematic joining of sheets of different thicknesses and qualities, or thermal influencing of the welded area. Other specific problems are caused by the zinc coating, which serves as a corrosion protection in cars [4]. Zinc adheres to the electrodes and there is a problem at the weld seams to maintain the protective function of the coating.

Mechanical connecting is the most widely used method of connecting materials. However, it has many disadvantages. These disadvantages are, for example, the increase in the weight of the structures due to the need to enlarge the joints, the stress concentration at the joints, the risk of galvanic corrosion (especially in the case of CFRP), the possibility of delamination in the production of holes, differences in thermal expansion of different

types of joined materials. The main advantages of this type of material connections include the possibility of disassembly of the connected parts.

Glued joints appear in the automotive industry in many types, both in terms of functional stress and in terms of design. It can be said that the bonding either acts as a complementary and sealing function (bonding and cementing of bodies for sealing, vibration damping, corrosion protection, application of reinforcements) or, in specific cases, can generally represent welding technology in structural strength joints [5]. Some applications of glued joints can be seen in Figure 2.

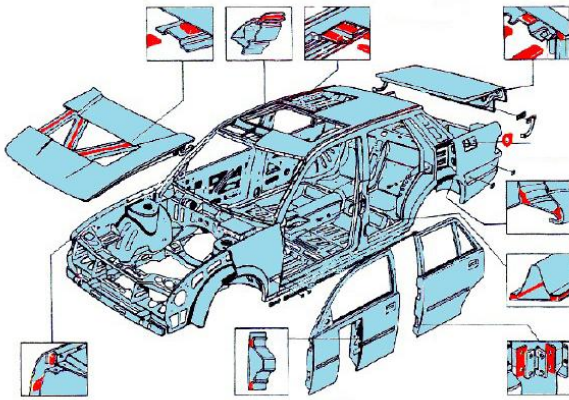


Fig. 2 Glued joints of the car body [6].

By using the bonding technology we avoid these problems and we can take advantage of the many advantages it offers in the automotive industry. Such as the possibility of new assembly procedures, reduction of the resulting weight of the car, preservation of the protective layer of zinc, higher strength and rigidity of the body, high quality of appearance of the parts to be joined and substantial reduction of noise in the car body.

It also has number of complications with the use of bonding technology in car body construction. For example, the adhesive must be overpainted, due to production, short time intervals to cure the joint, the adhesive life must be longer than that of a car, the adhesive must have sufficient strength, the shrinkage of the adhesive during curing on the car body surface.

The nature and composition of the adhesives used to build the car body is always firmly linked to the desired function of the joint. In this way, the adhesives can be divided into strength, reinforcement and sealing. Strength adhesives cure together with body paint. The edge adhesives are partially cured by induction heating during assembly, but full hardness is achieved only during the curing of the varnish by high temperatures in the furnace. The designer currently has a choice of many types of adhesives with different mechanical properties, ranging from tensile to brittle behavior. In the automotive industry, we are particularly interested in strength adhesives.

3. Use of FEM in the calculation of glued joints

Recently, at ever faster evolving computer technology and available literature, we can encounter modern numerical methods, such as finite element method (FEM). It is one of the most widespread numerical mathematical methods used to solve the problems of elasticity and strength, the dynamics of pliable bodies, heat transfer, fluid flow, electromagnetism, and many other problems in engineering.

Knowledge of the behavior of glued joints is essential for their subsequent application in practice. For effective prediction of the properties of glued joints it is necessary to use suitable tools allowing to accurately model various modes of failure that may occur in the structure. The failure of glued joints includes the area

from the beginning of loading to the initiation of the crack, followed by the area of development of the failure.

The possibility of numerical simulation of the glued joint is the main requirement for its successful design. If a suitable numerical method was found, it would be possible to replace a large part of the glued joint experiments with this simulation. This would lead to a reduction in the times involved in the development, production and production cost of the product. The simpler tools offered by FEM analysis allow you to model only the area from the beginning of the load to the initiation of damage. The principles of linear elastic fracture mechanics apply in this area. The behavior in this area is described by the cohesive stiffness of the adhesive layer. The failure initiation state occurs at a critical value of the stress at the crack front. In the FEM model, this state describes the tension between the nodes of an idealized adhesive layer caused by their critical displacement and critical load.

In addition to the strength approach, advanced analyzes can also be based on the elasto-plastic fracture mechanics approach to describe the area of failure development. These principles apply especially in a situation where the adhesive layer is very thin between two parts to be glued and its behavior cannot be described by macroscopic properties, such as tensile modulus or Poisson's constant (E , ν) [5]. In these cases, the behavior of the bonded joint by the energy required for crack propagation, or the rate of release of the strain energy G , is described. These approaches make it possible to predict the onset and spread of failure without prior knowledge of the location of the crack and the direction of crack propagation in the structure. The quality of the calculation and the accuracy of the results are directly dependent on how ideally the adhesive layer can be idealized using conventional and advanced tools offered by FEM analysis [7]. In addition to the accuracy of the results, the duration of the calculation, these can also differ in the user-friendliness of the results.

Elements commonly available in FEM analyzes can be used to idealize the adhesive layer. Their behavior is described in terms of material parameters, which in some cases can be obtained from glue producers, but more often it is necessary to find out more difficult by means of experiments. Specifically, the adhesive layer can be replaced by contact, 3D elements, 2D elements, a linear spring system, or simply replacing the adhesive, such as the SSG element in Siemens NX or the TIE element in Abaqus.

The first step is to create a CAD model. This model is then converted into a preprocessor, which converts the geometric model into the form necessary for the calculation itself. In this phase, the main task is to create an adequate computer network and to define the initial conditions correctly. The preparation of the whole calculation model follows the rules that each company creates itself and must be strictly observed. The rules are set to achieve a compromise between computational complexity and result accuracy.

The next step is to load the file into the solver and start the calculation itself. The calculation is started using the command line and follows the mathematical operations described above. The results are written to files during the calculation.

The last step is to load and process the results in the postprocessor. The postprocessor allows viewing the simulated process, plotting acceleration, stress, strain and many other variables depending on the selected variable.

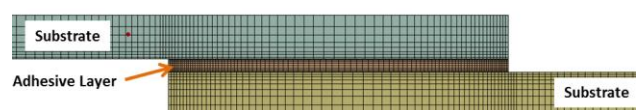


Fig. 3 2D plain strain finite element model of bonded joint.

In recent years, models using the so-called cohesive joint model have been used in the research of glued joints. The cohesive Model can be used to model adhesives, bonded surfaces, seal models, patches, or delamination processes (Fig. 3). The cohesive model exploits some of the advantages of common FEM elements and is based on Griffith's refraction theory. The aforementioned common elements included in the FEM creation tools are characterized by the absence of a criterion for predicting the evolution of violations for any violation mode. The cohesive model is innovative and used approach for the calculation and prediction of the evolution of bonding failure, specifically this model includes, compared to the previously mentioned models, the area of crack initiation in the structure.

The cohesive model must be implemented in the numerical model of FEM analysis. All elements making it possible to apply the principles of the cohesive model are generally referred to in the literature as decohesive elements. These elements can be one-dimensional, two-dimensional, and three-dimensional elements and include commonly available solver for FEM analysis. Cohesive elements are used for modeling an adhesive layer with a certain final thickness compared to a cohesive surface contact. The adhesive behavior of these elements is defined by the material properties. Cohesive elements are defined by the thickness, stiffness and strength of the adhesive. It is advisable to apply cohesive elements especially in places where crack development can be expected. It is assumed that at the beginning of loading there are no cracks in the adhesive layer, otherwise this phenomenon can be modeled by the absence of elements at the crack site. The relative displacements between the upper and lower surfaces, which are measured in the thickness direction and in the directions perpendicular, represent the opening of the crack face between the glued surfaces.

4. Use of FEM in the calculation of welding joints

Welding analysis is an important topic in engineering research and it is widely employed in the fabrication due to their advantage of improved structures performance, cost savings and easy implementation. However, welding application cause undesirable permanent distortion and residual stress in the material. Welding has about 26 imperfections e.g. cracks, porosity, worm hole, inclusions, lack of penetration, lack of fusion, lack of fit, undercut, excessive weld overfill, insufficient weld throat, root overfill, misalignment, weld sag, incomplete root, cold lap, arc strike, sputter etc. [8]. With all this imperfection simulation parameter will be in challenge. Material modelling is, together with the uncertain net heat input, one of the major problems in welding simulation.

FEM analysis was carried out in Solid Works software. The first step contained of modeling solid bodies of sheet metal plates. The dimensions of the metal plates are 25 mm width, 100 mm length and 0.8 mm thick. Despite the spatial volume, the modeled metal plate is defined in Solid Works as a sheet metal, which will make it in FEM evaluation a 2D object. Modeling of assembly (Fig. 4) was carried out, in a manner that two metal sheet bodies share the line of weld. Materials for the examined were set in FEM environment, but first they had to be defined in a library using properties specified by manufacturer.



Fig. 4 Computer model of weld.

A finite element model comprises a system of points, called "nodes", which form the shape of the design. Connected to these nodes are the finite elements themselves which form the finite element mesh and contain the material and structural properties of the model, defining how it will react to certain conditions. The density of the finite element mesh may vary throughout the

material, depending on the anticipated change in stress levels of a particular area. Regions that experience high changes in stress usually require a higher mesh density than those that experience little or no stress variation.

Next step was to perform the tests for the yield strength. Each assembly had its sheet metal plates materials chosen accordingly to the test. Then the weld method was chosen as edge weld, specifically one side groove weld. Reason for this weld is that Solid Works did not offer laser weld function. But principle of welding method is that it melts the materials in weld spot, which makes them unite after cooling. In this manner the groove weld was the only one which can be put on a weld line, making connection between welded metals, and is easy to work with i.e., changing properties. For simulating tearing process, one side of the assembly (one sheet metal plate) has to be fixed, by fixing any linear movement or rotational, while the other side (second sheet metal plate) have defined linear force. The linear force changes between computed force for weld for first and second sheet metal plate material. One of the last things before results is to define appropriate size of the mesh, so that no local maximum appears in the results.

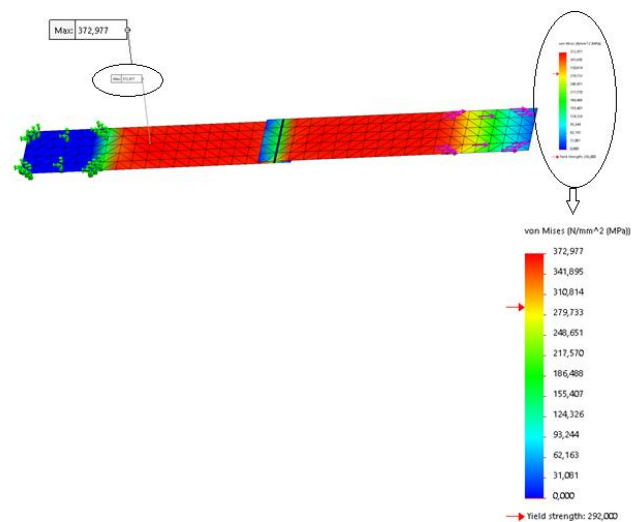


Fig. 5 Example of FEM analysis for a pair of TI-TL materials.

The ultimate stress is gained in a same manner as for the yield strength, but with the different changing forces. Biggest challenge is to determine force value for which, examined weld will break. The Solid Works does not dispose a function where the FEM will determine how much force breaks examined weld. Therefore some calculation through coefficients were adopted. First step is to run study with any force value. The bigger the better. This gives first coefficient, which is factory of safety coefficient. If this coefficient has determined value of safety to 1, then it will make a range of coefficients smaller than 1. Multiplicating of the force and the lowest coefficient gives a value of the force for the yield strength for the weakest material. Further multiplication of this force with coefficient for the weakest material of the ultimate strength to yield strength, rises this force to the values, when weld breaks.

Welds were examined for the following materials:

- HX340LAD+Z (Re=414MPa, Rm=473MPa, Zn layer 111 g.m⁻²),
- TL1550-220+Z (Re=292MPa, Rm=373MPa), Zn layer 104 g.m⁻²,
- HCT600X+Z (Re=346MPa, Rm=654MPa), Zn layer 105 g.m⁻²,
- DC04 (Re=197MPa, Rm=327MPa), without Zn layer.

R_m is ultimate strength (stress) for material and R_e is Yield strength. Table 1 shows some results of the FEM analysis. There are FEM weld analysis results for different material combinations in this table.

Table 1: Results of the FEM weld analysis.

Combination of materials (fixed – pulled sheet)	Loaded by F_m for pulled sheet [MPa]	Loaded by F_m for fixed sheet [MPa]	Force when weld breaks max F [N]
DC-DC	331.443	331.443	6452.6495
TL-TL	378.068	378.068	7359.5429
TL-DC	331.443	378.068	6492.8157
TL-HX	479.427	378.068	7360.4713
HX-DC	331.443	479.427	6492.8157
HX-HCT	662.886	479.427	9332.8498
HCT-DC	331.443	662.886	6492.8157

5. Conclusions

The production of cars with lower weight and thus with lower fuel consumption, follows the ecological requirements of reducing materials of various thicknesses and qualities, whether plated or unplated, but also the connecting of ferrous and non-ferrous metals. Their application in the automotive industry opens new opportunities for designers. These consist in the optimal use of the properties of different types of sheets, which can be combined into one unit and thus affect the strength, stiffness or resistance to corrosion and resistance to chemical aging in different parts of the mold.

Glued joints appear in the automotive industry in many types, both in terms of functional stress and in terms of design. It can be said that the bonding is either complementary and sealing (bonding and cementing of bodies for sealing, vibration damping, corrosion protection, application of reinforcements) or can, in specific cases, represent welding technology in structural strength joints.

Welding is the most commonly used process for permanent joining of machine parts and structures. Welding is an expedient by which metals may be joined by increasing the temperature of the work pieces to their fusion point and allowing the molten metal formed to flow together and solidify.

Due to the influence of the welding residual stress, residual plastic deformation, heat affected zone and stress concentration effect the fatigue life of welded components is far lower than the parent metal.

To calculate strength of welded structure and to find behaviour under cyclic load, it is very important to do analysis according to real life problems, so that analysis results can be used to predict the life of structures. After welding of structures there are many factor involve defining parameter in the finite element analysis.

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Problems of world and Ukraine international airports in a pandemic condition

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Annotation. Features of activity of the international airports of the world in the conditions of a pandemic are considered. The losses of the world's airlines are given. The condition of aircraft manufacturers is assessed. The activity of the main international airports of Ukraine in recent years is analyzed. The programs of development of the international airports of Ukraine for the near future are considered.

KEYWORDS: AIRPORT, AIRLINE, PASSENGER TRAFFIC, PANDEMIC.

1. Introduction

To ensure the stable and efficient functioning of international air transport, it is necessary to have a global network of airports that will ensure the regularity of flights, their safety, the quality of passenger service at the airport. Airports are strategically and socially important government facilities [8, 9].

The world airport market is well developed. The best airports in Europe include: Charles de Gaulle International Airport; Heathrow International Airport; Frankfurt am Main International Airport; Madrid Barajas Airport; Schiphol International Airport.

The global transport and logistics system has been one of the worst hit by the COVID-19 pandemic. Today, countries are in transition: the transport sector is adapting to new operating conditions and is gradually beginning to recover from the crisis, in particular, the resumption of travel to individual countries.

Due to the actively progressing processes of globalization and internationalization of the world's economies, the share of the air transport industry is becoming increasingly important every year. The proper functioning of flights, the provision of an appropriate level of ground handling and the attraction of more tourists are performed by airports. It is worth noting that the situation with the COVID-19 pandemic has negatively affected the development of this industry, but gradually destinations and flights are being restored.

2. Features of the international airports in the world in a pandemic

The global transport and logistics system has been one of the worst hit by the COVID-19 pandemic. Today, countries are in transition: the transport sector is adapting to new operating conditions and is gradually beginning to recover from the crisis, in particular, the resumption of travel to individual countries.

With the cancellation of most passenger flights, airlines in the pandemic have begun to pay more and more attention to the transportation of commercial goods by air. In fact, these shipments have traditionally been less common due to the high cost of air tickets. The total number of flights in 2020 decreased by 62% compared to 2019 [4].

According to the Joint Research Center of the European Commission, the economic costs of airlines and airports due to the inability to intensify activities during the pandemic will lead to a significant reduction in world GDP, not taking into account the consequences for each economy.

In contrast to the transportation of commercial cargo, air transport accounts for the bulk of international passenger traffic. The closure of borders and the imposition of restrictive measures by governments have had a very negative economic effect on the operation and development of airports and airlines. There have been large-scale job cuts.

According to the analysis of the International Air Transport Association (IATA), the total revenue loss of the global aviation industry in 2020 amounted to almost 400 billion US dollars.

According to economists, the air transport industry will no longer be the same as before the coronavirus. In order to adapt to modern realities, carriers are remodeling business models, introducing innovative approaches and changing technologies. It is assumed that the average passenger traffic will be reached no earlier than 2024.

After the onset of coronavirus on aircraft, the crew was forced to wear masks, at airports and on board passengers, the temperature is measured, passengers are given antibacterial wipes, and aircraft cabins and airports are additionally disinfected. Companies that continue to operate during the pandemic have begun to block seats so that there is at least 1 empty seat between passengers.

To prevent the virus from spreading, airlines have stopped cooking hot meals and are offering packaged snacks and sandwiches to passengers instead.

Losses on the example of airlines [5]:

1. Aeroflot: in 2020 carried almost 35% fewer passengers.
2. All Nippon Airways and Japan Airlines have canceled about 90% of international flights, although domestic flights are scheduled.
3. American Airlines canceled about 60% of flights.
4. British Airways has prepared a restructuring program with 12,000 jobs.
5. Air Canada canceled about 80% of flights, 15,200 employees went home.
6. Condor Airlines proved to be unprofitable during the coronavirus crisis and the Polish company LOT withdrew from the agreement (estimated amount of EUR 300 million).
7. Delta AirLines canceled 80% of its flights.
8. "EasyJet" completely stopped flying for a while, hoping to overcome the consequences with a loan from the National Bank of England.
9. "Flybe" experienced difficulties in 2019, but the pandemic completely exacerbated the situation.
10. Air France-KLM is gradually resuming flights.
11. Gol canceled orders for 34 Boeing aircraft.

The European branch of the International Airport Council has estimated the effects of the coronavirus to be 14 times greater than the global financial crisis of 2008-2009. But now the number of flights is gradually increasing.

However, freight traffic did not suffer as much as passenger traffic. In general, without loans or state aid, it will be difficult for airlines and aircraft companies to overcome the crisis caused by the pandemic.

Small carriers that are not established in the market or serve only seasonal summer flights are in danger of extinction. Less crisis will affect government-backed companies or large airlines as they raise additional funds.

The International Air Transport Association (IATA) predicted that the financial losses would be very significant. At risk of layoffs of 25 million workers. CEO Alexander de Junyak predicts that airlines that have used the "free space" strategy will have to raise prices by 50% to operate with at least a minimum profit.

As for aircraft manufacturers, the situation is as follows:

1. Airbus plans to reduce aircraft production by a third, the company's share price has halved.
2. Boeing has abandoned an agreement to buy 80% of the Brazilian manufacturer Embraer, which will be prepared in 2018. The company also plans to cut 10% of its 160,000 staff.
3. Bombardier sent 2/3 of its employees on unpaid leave. The company's share price has tripled.
4. Embraer sued Boeing for the purchase of 80% of the Brazilian manufacturer. From January 2020 to April, the company's share price fell twice.

Regarding the situation in some countries:

1. USA: Donald Trump has signed a law to provide assistance to the economy in the amount of about 3 trillion dollars, of which 61 billion is intended for the aviation industry. Due to declining demand for air travel, the country's eight leading airlines have laid off about 100,000 workers and reduced the number of aircraft by 900.
2. United Arab Emirates: Authorities have suspended flights for some time.
3. Norway: The least restricted air service among all European countries.
4. People's Republic of China: China's air passenger traffic has decreased by almost 80%. Local low-cost carriers offer even lower ticket prices. This is not very critical for Chinese airlines, as some airlines receive government subsidies to serve the most popular destinations. The Chinese Civil Aviation Authority has decided that Chinese airlines can fly to each country once a week.

3. Activities of international airports in Ukraine in recent years

Beginning in 1999, the structure of enterprises in the airport industry of Ukraine began to change dramatically due to the introduction of the program of division of the state airline into separate - the airport and the airline. Today, most airports have an independent status.

According to the plan of the State Department of Air Transport of Ukraine, all buildings and structures, as well as most of the movable land property and equipment, were included in the airport infrastructure. Priority for distribution was given to airports, which led to losses for airlines and aggravation of relations between airlines and airports, as well as weakening of airlines, stratification of airports in terms of congestion and profitability.

The number of flights operated by airlines dropped significantly during the pandemic. For example, in 2020, Sky UP operated 8,745 flights, in 2019 - 12,198 flights, despite the fact that in 2019 there were 5 aircraft, and in 2020 - 11. In 2020, the number of passengers carried by UIA fell more than 4 times, the company's fleet includes 35 aircraft.

Boryspil International Airport served 5.16 million passengers, which is 66% less than in 2019. But against the background of a decrease in passenger flights, the airport recorded an increase in freight traffic.

Consider the passenger traffic of 3 international airports (IA) of Ukraine for 2009-2019: IA "Boryspil", IA "Lviv" them. Danylo Halytsky, IA "Dnipro".

From fig. 1. we see that the passenger traffic of IA "Boryspil" from 2009 to 2012 increased, from 2012 to 2014 slept, from 2015 to 2019 increased.



Figure 1. Passenger traffic of IA "Boryspil" from 2009 to 2019 [2]

From fig. 2. we see that the passenger traffic MA "Lviv" them. Danylo Halytsky grew from 2009 to 2010, slept from 2010 to 2011, grew from 2011 to 2013, slept from 2013 to 2015, grew from 2015 to 2019, slept in 2020.

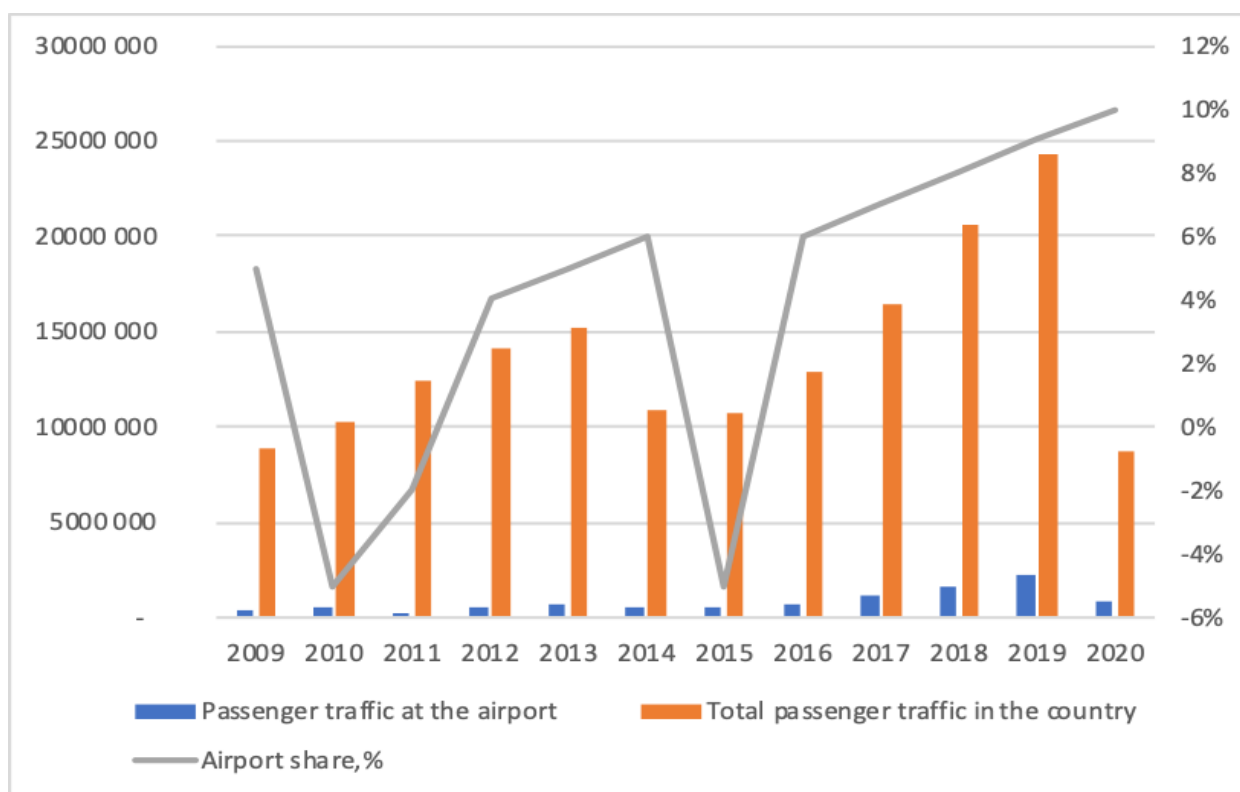


Figure 2. Passenger traffic MA "Lviv" them. Danylo Halytsky from 2009 to 2020 [1]

From fig. 3. we see that the passenger traffic of IA "Dnipro" from 2010 to 2013 increased, from 2013 to 2017 slept, from 2017 to 2019 increases.



Figure 3. Passenger traffic MA "Dnipro" from 2010 to 2019 [3]

The decline in 2013-2014 at all international airports is due to the military conflict in eastern Ukraine, and in 2020 due to the global pandemic COVID-19.

4. Development programs of international airports of Ukraine

The main airport of Ukraine, IA Boryspil, is actively involved in the development of domestic infrastructure. Today, the transfer zone is being created, the gallery is being expanded, and the parking lot near Terminal D is being completed. In May 2019, the Concept for the Development of Boryspil International Airport for the period up to 2045 was approved. According to the document, the purpose of the concept is:

1. Improving the level of flight safety and aviation security [6].
2. Increasing the level of passenger service.
3. Ensuring sustainable development of the Airport as an international hub.
4. Creating a favorable investment climate to ensure the development of airport infrastructure.
5. Overcoming growing competition from European airports.
6. Taking into account the possibility of servicing low-cost airlines in the coverage area.
7. Differentiation of passenger and cargo flows to and from the Airport.
8. Ensuring the possibility of building an underground railway track to the central terminal.

Regarding the main tasks for 2020-2021, among them are the following: reconstruction of the runway №2, improvement of Terminal D, development of a detailed plan of the airport, expansion of the transfer area for transfer passengers, reconstruction of the baggage claim area for domestic passengers.

Also in 2016, the State Target Program for the Development of Airports for the period up to 2023 was approved. The purpose of this program is to meet the needs of the state in ensuring the stable development of the aviation industry, bringing air transport infrastructure in line with international standards, ensuring Ukraine's transit status, taking into account its unique geographical location, improving the management of state property.

As a result of this Program, the following is envisaged [7]:

1. Reduction of time for ground maintenance of each aircraft to 35-40 minutes.
2. Doubling the transit potential of the main international aviation transport hub of the state.
3. Development of non-aviation activities of airports up to 40% of total revenues of airports.
4. Intensification of public-private partnership for maintenance and operation of airports and creation of a favorable investment climate for the development of the aviation industry.
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5. Increasing the share of low-cost airlines.
6. Increasing the total passenger flow to the level of 24, 3 million passengers by 2023 [2].
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Zaporizhzhya International Airport is an international airport that operates around the clock and uses two runways (ground and artificial). Created on October 15, 1943. The situation regarding the development of the airport changed in 2013, when the Zaporizhia

airport changed its form of ownership and was transferred to the ownership of the local community.

Since 2015, the airport has been cooperating with such carriers as: Turkish Airlines, Pegasus Airlines, Atlasglobal. In 2016, measures were developed to develop the airport and ensure its operation. The terminals were overhauled, the runway lighting equipment was reconstructed, and several units of necessary equipment were purchased. In 2017, contracts were signed with AndaAir and Bravo. In 2018, the company began working with one of the largest European carriers Polish Airlines LOT. And in 2020, the airport took the first flight from Budapest (direct). Also in 2020, a new terminal was opened to serve passengers. In the future, the airport plans to deepen cooperation with other global airlines and improve the airport's infrastructure.

Danylo Halytskyi Lviv International Airport is the largest international airport in Western Ukraine in terms of passenger traffic and route network. The airport serves the following airlines: Ukraine International Airlines, LOT, Azur Air Ukraine, Pegasus Airlines, Atlasjet Ukraine, Austrian Airlines, Turkish Airlines, Deutsche Lufthansa AG, Wind Rose, "Azerbaijan Airlines", "Belavia", "Dniproavia", "Motor Sich", "Bravo Airways", "Jan Air", "Ellinair", "Sprint Air SA".

The strengths of the SWOT analysis of the airport include:

1. Convenient slots.
2. Extensive work experience.
3. High quality of services.
4. The system of work is adjusted.
5. Modern passenger terminal with reserve capacity.
6. Availability of modern RESA software.
7. Tourist attractiveness of the city of Lviv.
8. Powerful recreational potential of the surrounding areas.
9. Possibility to accept wide-body aircraft (CAT - D) on the runway.

Features:

1. The open sky.
2. Growth of air mobility of passengers.
3. The potential for the development of air cargo.
4. Development of airlines in the business aviation segment.
5. Changes in the formation of policy in the field of air transport.
6. Announcement of the open sky with the United States of America.
7. Attracting new traditional and low-cost airlines.
8. Investments in the development of aviation and non-aviation activities and infrastructure.
9. Improving the sphere of tourist services in the region.

Weak sides:

1. A small number of air cargo.
2. Lack of a perfect procedure for regulatory regulation of air carriers' bases.
3. Seasonality of the airport.
4. Development of non-aviation activities.
5. Insufficient ground connection with regional centers of the service area.
6. Lack of basic low-cost airlines.
7. Excessive bandwidth for current demand.
8. Non-optimal organizational structure of the airport and number of staff.

Threats:

1. More dynamic development of competing airports.
2. Competition with other modes of transport.
3. Low purchasing power of citizens.
4. Social and political instability.
5. Polish airports with low-cost airlines.
6. Intensification of the armed conflict in eastern Ukraine.

In 2021, it is planned to install electric boilers to provide thermal energy to the airport for the heating season. In 2022, the replacement of external water supply networks with plastic polyethylene pipes.

Airport Dnipro International Airport is owned by Dniproavia, a member of the Privat group. It can serve up to 3,000 passengers daily.

In 2021, the name changed from "Dnipropetrovsk" to "Dnipro". About \$ 3 billion has been invested to address the airport's pressing issues. Today began a large-scale reconstruction, which involves the construction of a new terminal, runway, modernization of airfield infrastructure. Also, production processes are constantly being improved, continuous training and advanced training of staff is underway.

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5. Conclusions

The main feature of the airport is that, despite the need to make a profit, you need to remember to solve government problems for the development of transport infrastructure. Therefore, the state controls the operation and development of airports. This feature complicates the solution of commercial problems facing owners and managers.

The main feature of the airport is that it cannot change the type of activity, its location, limited in the ability to diversify production. This situation limits the range of strategies chosen and further raises the importance of the stage of implementation of the chosen strategy.

Today we are witnessing the processes of globalization and internationalization, which are deepening and expanding their borders. Airports play a significant role as they expand foreign cooperation. Unfortunately, today, due to the events of the COVID-19 pandemic, many airports have suffered losses and the number of passenger and cargo flows has decreased significantly.

The value of airports for each specific region of Ukraine is much higher than that of airlines. They act as commercial enterprises. Airports are also large investors in infrastructure, as they provide new jobs, provide tax revenues, investments, and initiate tourism. Airports without tourist orientation are the initiators of business or business trips.

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Creation of safe and secure parking areas network for trucks in georgia for systematization of road freight flow

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Abstract: Road freight is the key element of the land freight system in Georgia and the main component of the South Caucasian transport corridor connection Black Sea port with Azerbaijan, Armenia, Iran and middle Asian countries. The creation of effective road system and appropriate infrastructure, based on the best European experience is the most important logistical goal has to be achieved in Georgia today. One of the main elements of this infrastructure are the safe and secure areas for trucks, yet to be created in Georgia.

Keywords: TRUCK, PARKING PLACE, ROAD FREIGHT

1. Introduction

Georgia is located at the crossroads of Europe and Asia, serving such countries as Armenia, Azerbaijan, Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan, Kirgizstan and Afghanistan where strategic cargo transportation takes place. Every day, goods worth millions of dollars are transported through the south-Caucasian transport corridor and its vital part - Georgia.



Fig.1. South Caucasian region

Despite sectors quite successful performance in case of volumes, it faces a considerable range of issues, amongst which can be included unsystematic road haulage, road accidents, traffic, number of problems related to security including cargo and equipment theft. Currently in Georgia there are no facilities that enable safe and secure parking of trucks and that also provide a minimum level of services to cater for the social well-being of the drivers.

By establishing of network of safe and secure parking areas in Georgia all mentioned above problems might be solved. Drivers, transport companies, forwarders, shippers, insurers and the society as a whole will benefit from an adequate supply of these facilities via protection of drivers, cargo and transport equipment. Furthermore, road safety, through well rested and stress-free drivers, is also an area in which such facilities can have a considerable positive impact. [1]

2. Benefits of creation of safe and secure parking areas for trucks in Georgia

Based on a best European experience we can presume that creation of mentioned above areas will solve number of problems which are topical issues for Georgia at the moment. Safe and secure parking area for trucks should be a protected territory where drivers would be able to accommodate vehicles safely. As per existing statistics almost all facts of cargo theft happen while trucks are parked at unappropriated areas without video monitoring or supervising due to lack of appropriate infrastructure. Creation of safe parking areas will definitely solve this problem.

Another serious problem we face now in Georgia is a big number of road accidents caused by driver's fatigue. Parking areas should be equipped with appropriate infrastructure for driver's recreation. The minimum comfort services at parking area should include:

- Toilets (Male and female)
- Showers (Male and female)
- Waste bins
- Snacks and drinks available to purchase for 24/7
- Internet connection
- Electricity connection for personal use

As a best alternative a motel for night stay should be a part of parking area or located next to it. Adequate rest for the drivers for sure will significantly reduce a number of road accidents caused by fatigue.

Other common reason of road accident is technical malfunction of trucks. For the driver who is a part of international cargo handling is very difficult to arrange normal technical maintenance in a foreign country, especially for the laden and heavy vehicle. Safe and secure parking area can be a solution. Aside to other infrastructure technical maintenance center can exist at each big parking area where drivers would be able to receive adequate service.



Fig. 2. Model of safe and secure parking area

Road freight in Georgia is affected by congestions due absence of general traffic control system. Road police actions are intended to prevent congestion at particular places or roads critical points, but they are reacting, not preventing. So, their efforts cannot be enough. The long convoy of trucks along the highways waiting for the permission to move is very common picture in Georgia. The situation is especially difficult near to the border checkpoints where bottleneck effect exists. Truck drivers are often forced to wait 2-3 days for the crossing of border having parked a vehicle at the side of the road, without normal possibility of rest and in mountain regions even unable to purchase food and beverage while waiting.



Fig.3. Traffic congestion at Georgian-Russian border

System of parking areas might be a solution. Each parking area can have a traffic operator service which will be a part of national road traffic control system and monitor truck movements in real-time. Being coordinated from one side with road police department and from another side with authorities at border checkpoints these operators would be able to provide to the drivers detailed information about the condition at roads and give a green light for departure from the parking area at most optimal time to prevent the possible congestions. To monitor the vehicle status in real-time also would be helpful for shippers, expeditors and transporters. They will have the possibility of better and most optimal planning of their routes, being able to cut the costs, attract extra cargoes and minimize idle staying time of equipment.

3. Optimal dislocation of safe and secure parking areas in Georgia

The dislocation of safe and secure parking areas mostly depends on road traffic flow intensity levels, but based best European experience we can presume that such an area could be created in every 120-150 km from each other, near to biggest cities in about 15-20kms and near to each border checkpoint in about 10-15 kms. Based current road freight volume it could be argued that 7 main safe and secure parking areas would be enough for Georgia.

1. Sarphi (Georgian – Turkish border)
2. City of Kutaisi suburb
3. City of Khashuri suburb
4. City of Tbilisi suburb
5. Lars (Georgian – Russian border)
6. Sadakhlo (Georgian – Armenian border)
7. Red bridge (Georgian – Azerbaijanian border)

Creation of parking areas at mentioned above points with presence of road traffic operators will make possible to establish national road traffic control system which in fact will cover whole country.

4. Financial benefits of safe and secure parking system creation

The parking areas system can generate a big income in comparison with the expenses necessary for their creation. As mentioned, such an area to be located in suburbs and less populated places where real estate costs are not high. Infrastructure also is not expensive or complicated so it will be possible generate considerable direct income from parking and other provided service from the very beginning. Indirect effect from cutting of road freight costs, optimization of road flow, deduction in number of thefts and road accidents would be even bigger.

5. Conclusion

The system of highways in Georgia is currently in the middle of the process of formation. Yet to be created many kilometers of highways, tunnels, road forks and other elements of infrastructure. Now is the best time for establishment of safe and secure parking areas system, as it can be organically implemented into the future road system without big extra expenses and efforts, being planned as it's part from the very beginning.

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Transferium Chomutov

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Abstract: This paper deals with passenger railway transport accessibility of the city of Chomutov, Czech Republic. The paper presents a conceptual study of a new transportation hub – the Transferium. Based on the unsuitable accessibility of the existing railway station, the location of a new railway station is proposed. The paper addresses the transport and transit demands of the new railway station in the context of current and future traffic. Furthermore, the urban integration of the new station and the surrounding urban space is proposed, and last but not least, the construction and technical context is presented.

Keywords: RAILWAY TRANSPORT, PASSENGER TRANSPORT, RAILWAY STATION, SUSTAINABLE TRANSPORT, URBANISM

1. Introduction

Many cities connected to rail transport do not have a well-located station with regard to current passenger transport needs. The railway station is often located at an unsuitable walking distance from most journey sources and destinations in the city, therefore the use of rail transport also means the use of another mode or system of transport (city public transport, car). Thus another transfer occurs on the entire transport chain and the total travel time is extended. The city of Chomutov in the Czech Republic is such a case.

The city of Chomutov (50,000 inhabitants) in Ústí nad Labem Region lies on the double-track electrified line Ústí n.L. - Cheb. The city is accessible by rail through two access points (Chomutov railway station, Chomutov město stop). Chomutov is currently served by both regional connections and the long-distance line R15 Prague - Ústí n.L. - Chomutov - Cheb and long-distance line R25 Most - Chomutov - Pilsen. Despite the fact that the city is connected to the railway by two access points and both of these points are served by all passenger trains, the overall accessibility of the city by rail is unsatisfactory. None of the existing access points is located in a place with suitable walking distance to the center or to the largest residential areas of the city. At the same time, neither Chomutov railway station nor Chomutov město stop can be effectively (without unnecessary detours) connected to public bus transport and city public transport, and for none of these access points a P + R car park can be built for spatial reasons.

It can be assumed that the importance of the railway transport will increase in the coming years for the city of Chomutov. The expected growth factor is not only the planned reconstruction of the arterial railroad Ústí n.L. - Chomutov - Cheb, which after completion will bring reduction in travel times along the whole axis, but especially the planned connection to the future high-speed line Prague - Most (this is a branch line of the high-speed line Prague - Dresden, which is in intensive design preparation). After the completion of both constructions, the accessibility of Chomutov and Prague by rail will be a completely full-fledged alternative to individual transport and will fundamentally change the existing Modal-Split [2].

For these transport challenges, it is necessary to have an appropriate transport terminal in Chomutov, which can only be created by modifying or rebuilding the existing railway junction. As part of the reconstruction of the railway junction, the current possibilities are very limited: the area of the Chomutov město stop cannot be further expanded, and the Chomutov railway station with possibly suitable area is contrarily located in an unsatisfactory and inappropriately accessible position.

The solution for the reconstruction of the railway junction is a new station located centrally in the city, the *Transferium Chomutov*, working title Chomutov centrum railway station, which would serve as a replacement of the existing Chomutov railway station [5].

The authors of this paper conceived a conceptual transportation-urban design study, which deals with finding a location suitable for

a "new station" with a complex function of a "transport terminal" - with better access to the city center and in an area where it will be possible to design technically and technologically functional, urbanistically and spatially functional and architecturally attractive solution of this terminal.

2. Transit and transport demands for the Chomutov railway junction

Transit demands

In the last year before the COVID-19 pandemic, the Chomutov railway station has been used by about 2,500 passengers a day, of which approximately 1,600 passengers fell into regional transport trains [7].

	2015	2016	2017	2018	2019
Departures into other regions	1734,0	1871,1	1746,2	1832,7	1944,0
Arrivals from other regions	1784,0	1841,7	1729,7	1819,0	1990,8
Transport within the region	8040,4	9869,8	10562,6	12585,5	11200,6
Total sum of rail passengers	11558,4	13582,6	14038,5	16237,2	15135,4

*Table 1: Passenger transport related to Ústecký region by rail (thous. Passengers)
Source: Transport Yearbook 2019*

The number of passengers naturally depends on the transport relations that go to / from Chomutov. Based on the 2011 census, the total commute to Chomutov for work and education from the area is 5,751 people, the total commute from Chomutov to the surrounding cities, including the capital city of Prague, is 4,561 people [4].

In Czech realities, regular commuting and rides usually accounts for about 1/3 of the daily realized trips. From the available data, it is clear that improving infrastructure parameters will lead to an increase in regular daily commuting, as was the case in other cities. Commuter data have no informative value about Modal-Split in individual sessions. It is true that more attractive public transport will mean a higher share in the overall transport relationship [1].

While in the near future it is not reasonable to expect a dramatic change in commuting, in the medium-term period it can be expected that - together with the high-quality infrastructure - commuting to Prague will dramatically strengthen.

This reinforcement can take place in 2 levels:

- 1) the number of departing from Chomutov will not change, but Prague will fundamentally dominate the departure at the expense of other centers; ie a trip to Prague can be approached by up to 1000 people
- 2) the number of commuters will increase (ie it will be more attractive for the citizens of Chomutov, with regard to the time availability, to commute to work than to look for it in the place itself); ie a trip to Prague could exceed the limit of 1000 people

At the same time, it is necessary to take into account the fact that similarly, transport relations to Chomutov may change from cities in the vicinity (typically eg. Kadaň, Klášterec), which again

partially reorient themselves to the dominance of Prague. Part of these transport flows will also be transferred to the railway and will be loaded to Chomutov junction (either by transfer passengers or in the form of P + R).

If, with a comparable travel time by individual / public transport, we estimate the division of public transport to be 50%, then after the construction of new connections we must realistically count on 500-600 regular commuters on the Chomutov - Prague rail route, which can be reflected in the level of approx. 1500 passengers on this route daily (including irregular journeys).

Compared to the current situation, the passenger load will increase by this value in the Chomutov junction. In the rush hour, in terms of boarding / alighting for a train to / from Prague, the turnover of passengers on one train in the number of 200–300 people can be considered. Both the widths of the platforms and the capacity of the escalators, etc. are dimensioned for these values in the newly designed Chomutov centrum station.

An estimate of the number of parking spaces in the P+R and K+R modes is also based on these values. Parking areas in the P+R mode are designed in the form of a multi-storey parking house so that, if necessary, it is possible to increase its projected capacity, without the need to intervene in the concept of the entire transport hub Chomutov.

In terms of transit function, the current Chomutov railway station will be replaced by the new Chomutov centrum railway station.

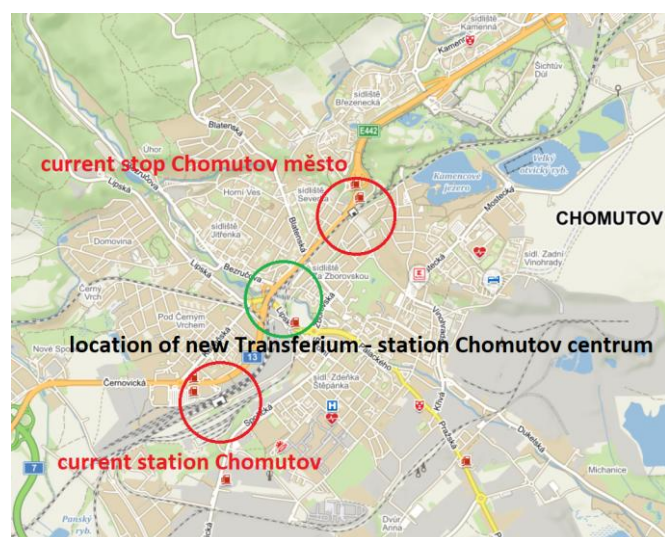


Fig. 1 Situation of Chomutov service by rail

We propose that passenger trains then pass through the current railway station unattended. At the same time, we propose the Chomutov město stop to be newly served only by regional transport trains, while long-distance trains will serve Chomutov only at one central point - at the new Chomutov centrum railway station.

Transport demands

Existing conceptual documents of the Ministry of Transport of the Czech Republic [6] and the Ústí nad Labem Region [7] were taken into account in order to specify the prospective scope of passenger transport in determining the required number of transport tracks. The proposed design of the new Chomutov centrum railway station meets both the needs of the short- and medium-term conceptual operating horizon and the strategic outlook.

There are 4 transport tracks with platforms designed in the station (in a new position on the relocated line), while the platform is also situated at the existing connecting track 90 leading to the freight station.

This number of tracks corresponds to transfer ties which can be realized in Chomutov even in the case of a complex tact group.

The maximum occupancy scheme is the following combination:

- Track 1: train direction Klášterec – Most.
- Track 2: train direction Most – Klášterec.
- Track 3: train direction Jirkov – Žatec.
- Track 4: train direction from/to Vejprty.
- Track 90: train direction Žatec – Jirkov.

All alternative ways of creating a complex tact group (without overtaking trains in the same direction) are less demanding in terms of track occupancy.

The considered track 4 is the only one from which it is possible to operate the Vejprty route (in the form of a dead end in the current Chomutov railway station) without collision train paths.

The considered platform at track 90 can generally be used either in the above mentioned case or in case of need of parallel train entries from Klášterec and Žatec to Chomutov centrum railway station and, last but not least, during construction and partial commissioning of Chomutov centrum railway station, and during emergencies.

After completion of the new Chomutov centrum station, the existing Chomutov railway station will remain unattended by passenger transport. From the point of view of the requirements on the functionality of this station [3] in the horizon of the operation of the Chomutov centrum railway station, the preservation of the following needs and functionalities can be defined:

- 1) Passing of passenger trains in the direction of Chomutov centrum - Vejprty and back (ideally a dead end track approx. 70 m long).
- 2) Reversal of trains Prague / Ústí n.L. / Most ending in Chomutov (ie an ideally overtaking track situated between the main tracks).
- 3) Parking and overnighting of trainsets (ie at least 2 tracks), or for cleaning, armament with water (or toilet).
- 4) Maintaining the connection to the district of the former depot (refueling of motor-units).
- 5) Connection of the NTM (National Technical Museum) complex
- 6) Preservation of at least one track for trains from Vejprty (special passenger trains, which would have to go around or reset at the Chomutov railway station, freight trains with the need to reset to the freight yard).

The total track requirements for the new Chomutov railway station thus represent 2 main tracks + 4 secondary tracks + 1 dead end track. The actual implementation of the Chomutov centrum railway station does not produce any additional demands on the Chomutov railway trackage. On the contrary, these demands are significantly lower than the extent of the current trackage. After the completion of the Chomutov centrum railway station, the current Chomutov railway station can either be left in its current state and used up to the end of its life, or reconstructed with a reduction of the tracks.

Connection to bus and city public transport

One of the main goals of creating a central transport hub in Chomutov is to concentrate all means of public transport at one spot in order to enable transfer connections (both to city public transport and regional bus transport). All means of public transport must be arranged in one node so that their interconnections can be efficient, short and fast.

We propose the abolition of the existing bus station and the transfer of bus and public transport stations to the new transport terminal of the Chomutov centrum railway station.

The current bus station has 12 stands for regular transport, 2 stands for city public transport and an exit parking space. The new proposal maintains this scope in principle (or the number of stands is increased by 1) and handling / parking stands are added. According to the Transport Service Plan of the Ústí nad Labem Region, bus transport in the Ústí nad Labem Region is stabilized and we do not anticipate any major turbulence in the order that would cause a lack of bus stops. In the proposal, the individual stands should be suitable for buses with a length of 13 m, in the case of city public transport for articulated trolleybuses with a length of 18 m. For short-term parking, the boarding stand can also be used as a handling parking; for longer shutdowns beyond the scope of the proposed 5 parking spaces, transitions to suitable premises would be necessary (eg garages of the DPCHJ transport company).

3. Urban design proposal

The basis of the urban design proposal is the transfer of the train station to the given locality and the creation of a Station square. The station building is oriented towards the city center and forms the compositional opposite of the municipality building. The station also defines the front of the Station square. The main access to the station is from the city center along a wide pedestrian / cycle promenade. On the north side, the promenade is lined with commercial spaces, which form the northern north front of the square. From the south side, the promenade is followed by the tree alley and the new bus station (transferred here from its current location). The bus station ends with a block of shops, delimiting the south side of the square. The Station square thus acquires the site plan of a rectangular horseshoe opened towards the city center. Inside the horseshoe is a bus station. The access road to the square leads from the roundabout at the intersection Lipská / Zborovská / Školní / Wolkerova. The access road serves the bus station, P+R parking house, K+R parking and shop supply road.

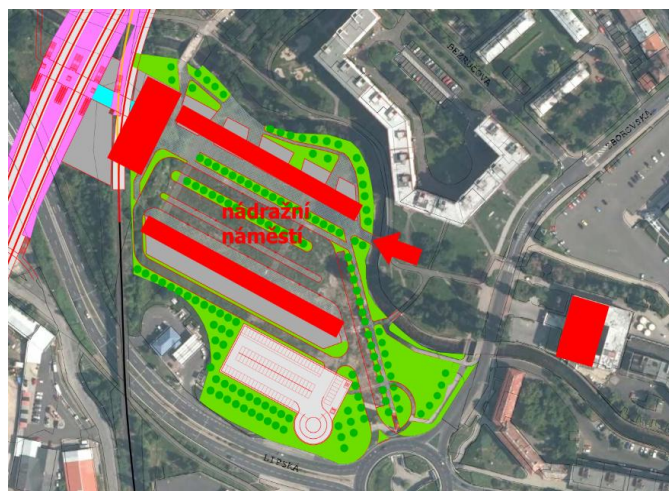


Fig. 2 Station square - delimited by the railway station and commercial buildings, opens towards the center, inside the bus station

In addition to the urban composition of the square oriented to the center, an important aspect is the connection of the station with the surrounding districts of the city. This is achieved despite the unfavorable conditions (isolation of the site by the river and the main roads) thanks to the platforms that bridge-span the area from Bezručova Street over Chomutovka river and Lipská Street.

Access to the platform is possible from three places:

- on the north side by stairs directly from Bezručova Street
- on the south side from the upper level of Lipská Street from the pedestrian underpass (platforms are here on the ground level) from the directions of Št. Kpt. Kouby and from the city center

- in the middle of the platforms access directly from the station underpass - the underpass is on the ground, the exit is stairs, escalators and barrier-free elevators. The underpass behind the station leads to the Chomutovka river.



Fig. 3 CONNECTOR – pedestrian access and permeability of the site - connecting the new station and the adjacent neighborhoods of Chomutov

3. Track construction proposal

The existing railway station is located in a historical position from 1870. The main line from the direction Ústí nad Labem approaches the station with opposite curves at a maximum speed of 60 km/h, while the station itself has a maximum speed of 80 km/h. The new passenger station is designed on the relocation of the line at km 63,350 - 64,160 (810 m) between the bridge at km 63,336 above Blatenská Street and turnout No. 6 of the Ústí nad Labem head of the existing passenger station.

The track modifications are designed without the need to rebuild the adjoining sections. The rail connectors of the Chomutov město branch can be left unmodified. The track modifications begin with a directional shift of the connecting track No. 90 to the freight yard, which frees up space for the construction of a four-track station. The connecting track will be modified by a compound curve of two radii for a speed of 60 km/h. The total length of the modification of the connecting track is 455 m.

The trackage of the new station is arranged with an island platform between the main tracks with a length of 400 m. The passing tracks are equipped with platforms with a length of 190 and 197 m. Their length is determined by the location of the stairs from Bezručova Street and on the opposite side by the bridge over Lipská Street. It is followed by a walking route to Št.kpt. Kouby. There will be stairs to these walking routes from the ends of the side platforms and from the island platform.

The cheapest possible construction solution was proposed for the mouth of the regional line from Vejprty, which is only seasonally operated today. The dead end track is assumed in the existing station and the possibility of entering the track No. 4 of the new station.

The switching of traffic to the new station does not cause any other provisional conditions in the trackage, nor the need for alternative bus transport. The construction of the new station is designed on the line relocation, so the only restriction of traffic would occur when connecting the existing line tracks to the new station tracks. Temporary single-track operations in adjacent inter-station sections should be sufficient for this technological process. The configuration of the rail couplings in the adjacent sections will currently and also in future conditions allow arriving to the two platform edges and the possibility of using the platform at the connecting track No. 90.

The new station Chomutov centrum does not cause interference with the current station. The condition of the original station can therefore be left unchanged at the very end of its service life.

The aim of the modifications is the complete removal of curved switches from the main tracks of the existing station and the elimination of the speed drop. The station will use the overtaking tracks Chomutov centrum and the arch head will be canceled. On the main tracks, from the new station Chomutov center, including the entrance to the current station, it will be possible to increase the speed to 90 km/h.

4. Implementation of the proposal

From the planning point of view, the implementation of the proposal of the new Chomutov centrum station construction encounters obstacles that need to be mentioned. It is the relationship to the valid and also new (under preparation) zoning plan of the city of Chomutov and property rights.

Although the zoning plan envisages the straightening of the railway line in the proposed section (solved by the area of the reserve for railway infrastructure), it doesn't count with the relocation of the train and bus station. The area addressed by our proposal is included in the current zoning plan as an area of trade and services, in the new plan then as an area for large commercial and administrative structures, which must be verified by a zoning study. However, placing the road and rail transport terminals is not allowed by the new zoning plan. The best solution seems to be to enter the process of elaborating a new plan and make coordinated changes that will enable the relocation of the station and the creation of a Transport Transferium. In the route of the considered relocation of the railway, some plots of land are defined as public greenery in the zoning plan - even here the prepared plan would have to be modified.

As for property rights, most of the area is owned by Chomutov invest s.r.o. It is conceivable, for example, to offer the interchange of the areas of the current (owned by the city of Chomutov) and the new bus station. In the place of the current BS, a suitable content would be, for example, residential development. Even for a commercial investor, it might be interesting to participate in the Transferium project, for example in the form of a PPP project.

In addition to state entities (ČD – Czech Railways, Správa železnic – Railways Infrastructure Manager, Povodí Ohře – Ohře Riverbasin) and the town of Chomutov, there are two private landowners in the route under consideration. It would be necessary to enter into land purchase negotiations with these owners. Here it is decisive that the land is included in the zoning plan as the railway reserve and therefore their owners had to and must take into account the possible use of this reserve.

The current development of negotiations on the purchase of land between the city and the individual owners prefigures that no agreement will be reached. However, the city of Chomutov fully supports the intention to build the Chomutov center station, and at the same time the infrastructure manager of the Railway (SŽ) took it over into its plans. The current state of project preparation thus leads to the conclusion that the new station will be built closer to the existing station than suggested by the conceptual study of the authors of this paper.

5. Conclusion

The paper presented a conceptual study of the proposed solution of the Chomutov transport hub. The authors tried to find a solution that would improve the environment of public transport and its accessibility in the city of Chomutov. The main benefits of the new solution include:

- improving the accessibility of Chomutov by rail,
- concentrating all elements of public transport in one place,

- associations of travel and transfer ties,
- significant profit for the city and the region in terms of organization of public transport,
- creation of adequate and adequately dimensioned spaces for public transport passengers,
- "cultivation" of the public transport environment in Chomutov
- the need to reconstruct vast areas and large spaces of the current Chomutov railway station, including the construction of island platforms and the like, will be eliminated
- This is a unique urban and architectural opportunity for the city of Chomutov.

Sustainable transport is a big topic today. If we focus not only on the issue of innovation in the field of operational concepts and transport telematics, then the search for new transport and urban solutions is a natural development within the Smart-Cities trend. Every journey that can be made on foot, because the service point - in our case the railway station - moves closer to a large part of the sources and destinations of the journeys, reduces the energy demands of transport and the burden of secondary transport in the cities.

The presented ideological intention served to open a public discussion in the town of Chomutov and in the Ústí nad Labem region on the topic of the new location of the railway station in Chomutov. At present, the new station is already a serious issue. The construction of a new station, albeit in a different form than the one presented in this paper, is expected around the horizon of 2030.

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Status and characteristics of passenger transport in Montenegro

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Abstract: The subject of research of this article is the review of passenger transport by all types of traffic on the territory of Montenegro in the past few years. The number of passengers transported by rail was accompanied by a constant increase in transported passengers from 2013 to 2016. After that, we have a drop in the number of passengers transported by rail in 2017. The number of passengers transported by road in Montenegro is constantly increasing from year to year. There has been a constant increase in the number of passengers transported at Montenegrin airports. As passenger transport is a very important activity of every country, in the last few years the state of Montenegro has been working on improving the transport infrastructure and the process of passenger transport.

Keywords: PASSENGER TRANSPORT, ROAD TRAFFIC, RAILWAY TRAFFIC, MARITIME TRAFFIC, AIR TRAFFIC

1. Introduction

Traffic is an organized movement of transport units on a common network and it is a consequence of applied technologies and the need for transportation (transport). Traffic is an independent economic activity that deals with the transfer of material goods, people and news from one place to another, with the aim of enabling the movement of goods and meeting social needs in transport. Traffic aims to enable the realization of the social use value of goods, to enable the process of social reproduction.

According to the mode of transport and means of transport by road, it is possible to distinguish: road traffic, rail traffic, water traffic, air traffic, and telecommunication traffic.

As far as road traffic is concerned, it can be said that in the modern period it has managed to secure a leading position in meeting the transport needs of both goods and especially passengers. [1]

2. Traffic policy in the European Union

As early as 1992, the European Commission approved the common transport policy contained in the White Paper. Based on the experience from traffic planning based on demand (unbalanced development by traffic branches, etc.), and taking into account the planning at the system level, the objectives are applied [1]:

1. Forming a trans-European network
2. Fair pricing in traffic
3. Environmental protection
4. Traffic safety
5. Social responsibility
6. Strengthening the internal market
7. Strengthening the external dimension of the single market.

The presented common transport policy of the EU serves to shape the transport system of both the EU and the candidate countries for EU membership, and thus Montenegro.

3. Passenger transport

Passenger transport performs passenger transport. In passenger transport, passengers require comfort, safety, regularity, accuracy, frequency, speed and economy. Passenger vehicles can be intended for urban, interurban and tourist transport. The technical and operational characteristics of the vehicle for each of these purposes differ significantly. Passenger transport is carried out in accordance with international and domestic legal norms. It can be: public, for own needs, domestic, international, transit, border, bilateral, line and free. Passenger transport is done individually and collectively, and the purposes of travel in all areas of travel can be very different.

4. Status and characteristics of passenger transport in Montenegro

Passenger traffic in Montenegro is realized through 4 types of transport (rail, road, water and air). The traffic infrastructure and the development of traffic in general in Montenegro are bad. Montenegro lags behind the countries of the region, but especially behind the EU countries. This situation is the result of insufficient efficiency and investments in traffic and traffic infrastructure. The results in this chapter are presented based on statistical reports [2-8].

4.1 Railway traffic

The actual length of the railway in Montenegro is 250 km. The entire line is single-track with a single-phase power supply system of 25 KV, 50 Hz. The statistical survey was conducted in accordance with Regulation (EC) no. 91/2003 and No. 2018/643. Passenger traffic (in thousands), as well as passenger kilometers (in thousands) in railway traffic in Montenegro for the period from 2013 to 2019, are shown in Table 1, and the graph in Figure 1.

Table 1: Passenger traffic and passenger kilometers in railway traffic in Montenegro for the period from 2013-2019.

	Year						
	2013	2014	2015	2016	2017	2018	2019
Passenger transport in the thousands	922	1122	1236	1284	927	992	986
Passenger kilometers in the thousands	73439	76142	80590	83897	59864	66755	66485

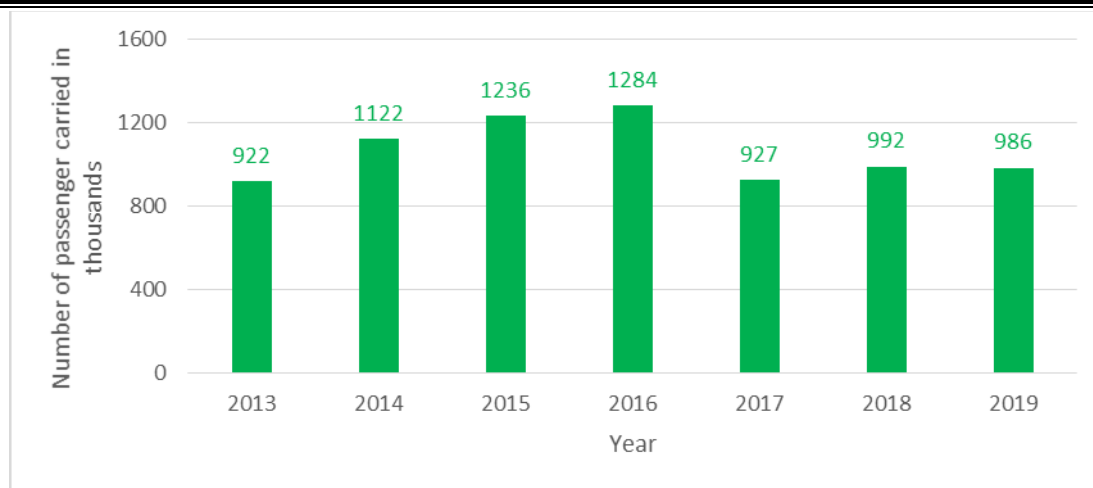


Fig. 1 Passengers transported by rail in Montenegro for the period from 2013-2019.

Figure 1 and Table 1 clearly show that in the period from 2013 to 2016 we have an increase in transported passengers. In 2017, we have a large decline in passenger transport (27.8%). The reason for the relatively large decline is that from 2013 to 2016 there were promotional tickets for a large number of routes in passenger railway traffic in Montenegro. In 2018, there was an increase in transported passengers compared to the previous year. If the number of transported passengers in Montenegro for the period from 2013 to 2019 were compared with the number of transported passengers to the EU for the same period [8], oscillations in the number of transported passengers in some EU countries would be noticed. According to the data from [8], for the period from 2013 to 2018, there was a constant increase in the number of passengers transported by rail in the following EU countries: the Czech Republic, Germany, Estonia, Ireland, Spain, Italy, Austria, Portugal and Slovakia. A constant decline in the number of passengers transported by rail for the period from 2013 to 2018, was recorded in Denmark. In other EU countries, smaller oscillations were recorded in the number of transported passengers for this period. It should be noted that data for Belgium, Cyprus, Malta, the Netherlands and Hungary are not available in the source [8].

4.2 Road traffic

The length of roads in Montenegro changed from year to year for the observed period from 2013-2019. An overview of road length depending on the type is shown in Table 2 and the number of registered and first registered road motor vehicles and trailers is shown in Table 3. From Table 2 it can be seen that in Montenegro for the period from 2013-2019 we have a constant increase in road length.

The most dominant type of road is the modern road (asphalt), which also records an increase in length from year to year for the observed period from 2013 to 2019. The number of registered vehicles also records a constant increase in Montenegro from year to year for the period from 2014-2019, which can be seen from Table 3. The number of transported passengers (in thousands) and the number of passenger kilometers of vehicles (in thousands) in road traffic in Montenegro for the period from 2013-2019 are shown in Table 4 and Figure 2. From Table 4 and Figure 2 it is clear that we have a constant increase in passengers transported by road in the observed period.

Table 2: Road lengths depending on the species in Montenegro for the period from 2013-2019

	Year						
	2013	2014	2015	2016	2017	2018	2019
Modern road (asphalt)	5 576	5 776	6 136	6147	6274	6296	6333
Gravel road	1 505	1 483	1673	1664	1654	1744	1839
Dirt uncategorized roads	884	886	805	814	822	998	1077
Total	7 965	8 145	8614	8625	8750	9038	9249

Table 3: Number of registered and first registered road motor vehicles and trailers in Montenegro for the period from 2013-2019

	Year						
	2013	2014	2015	2016	2017	2018	2019
Number of registered vehicles	203266	196059	198772	209098	219378	235385	249301
Number first registered vehicles	14654	15233	16283	18897	21878	25099	23687

Table 4: Passenger traffic and passenger kilometers in road traffic in Montenegro for the period from 2013-2019

	Year						
	2013	2014	2015	2016	2017	2018	2019
Transported passengers in the thousands	6220	6889	6987	7544	7575	7618	7680
Passenger kilometers in thousands	108802	107537	109621	113798	114196	115333	114223

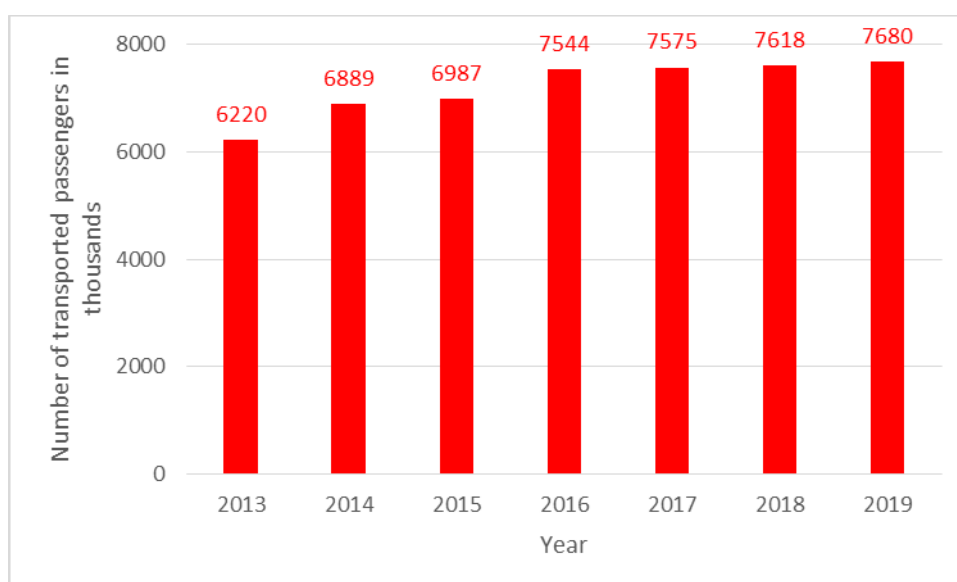


Fig. 2 Passengers transported by road in Montenegro for the period from 2013-2019

4.3 Maritime traffic

As far as maritime traffic is concerned, only data for the period from 2013 to 2016 are available, because Monstat has not been collecting this data since 2016. [8]

Montenegro does not have a developed internal maritime traffic, but the data refer only to international maritime traffic. Maritime transport is the most underrepresented type of passenger transport in Montenegro. There are two large passenger ports in Bar and Kotor. For this period, the transport of passengers by sea is shown in Table 5.

Table 5: Passengers transported by sea in Montenegro for the period from 2013-2016

	Year			
	2013	2014	2015	2016
Transported passengers	43097	42489	39198	35925

It can be clearly seen from Table 5 that the number of transported passengers decreases from year to year for the observed period.

4.4 Air traffic

The statistical survey was conducted in accordance with Regulation (EC) no. 437/2003 and from 2016 No. 437/200. [2-8]

There are only two airports in Montenegro where passengers are transported, in Podgorica and Tivat. The transport of passengers by air in Montenegro is characteristic for that reason because only international traffic is realized. Table 6 and Figure 3 show the number of passengers transported by air in Montenegro for the period from 2013 to 2019.

Table 5: Passengers transported by sea in Montenegro for the period from 2013-2016

	Year						
	2013	2014	2015	2016	2017	2018	2019
Passengers carried	1 558 940	1 612 130	1 643 905	1 855 837	2 184 859	2 454 524	2 652 801

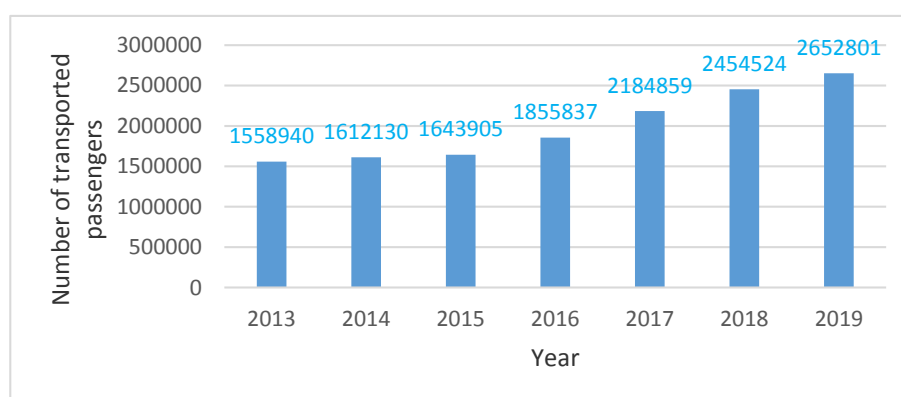


Fig. 3 Passengers transported by plain in Montenegro for the period from 2013-2019

5. Conclusion

The characteristic of passenger transport in Montenegro is that road and rail transport is used for domestic and international passenger transport. Air and sea transport is used exclusively for international passenger transport. The presented data on the number of transported passengers in railway traffic for the observed period show that the number of transported passengers increased from 2013 to 2016, and then fell sharply in 2017. In 2018 and 2019, there was a slight increase compared to 2017. Regarding road traffic, in the period from 2013 to 2019, there was a constant increase in transported passengers. Also, a constant increase in passengers at the airports of Montenegro was recorded in the entire observed period (2013-2019). The reason for this increase in the number of passengers at airports is the great growth of Montenegro as an attractive tourist destination. As far as maritime traffic is concerned, there is no data on transported passengers in the last few years, so the analysis of passenger transport by this type of traffic would not be correct. Data on the number of transported passengers by different types of traffic are necessary due to the development of the traffic planning strategy, but also the forecasting of the direction of passenger traffic in the country itself. Passenger transport is a very important activity of every country and it is necessary for each country to work on improving passenger transport.

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Application of Dijkstra algorithm to a tramway system of the ongoing expansion city of Tirana

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Abstract: The population of the city of Tirana is getting bigger. Transportation in this city has become extremely heavy. Many of its citizens choose to move using their vehicles thus causing an overcrowded traffic. It has happened to all of us to get stuck in the traffic of Tirana, to be late for our destinations and to be stressed by that chaos.

The use of public transport would be a successful way of reducing the traffic. In this paper we have treated Dijkstra Algorithm and its application in railway system of transport for the proposed Tram system for the city of Tirana. Considering the expansion(map) and relief of this city, we think that it is very favorable to build a tram system in this city. The results of this paper help to have a clear idea of the construction of the tram and a prediction of how it will work and how much it can facilitate the traffic in Tirana.

Keywords: GRAPH, OPTIMIZATION, DIJKSTRA ALGORITHM, SHORTEST PATH, TRAMWAY

1. Introduction

Tirana is the largest urban center in Albania and with the largest concentration of population. Its number and size and the daily need to move face one real challenge in transportation and another within the city. Heavy traffic, a negative effect for the movement, takes up a lot of time for the public transport, creates an uncomfortable situation for your children if you have to use the public transport to do daily necessities. Many cities in the world have applied the trams much earlier; The first electric and Tram line in the world was constructed in Sestroretsk in St. Petersburg, Russia, and it was invented by Fyodor Pirotsky in 1875. [4]

Later, using a similar technology, Pirotsky commissioned the first public electric tram in St. Petersburg. The second Tram was introduced by Siemens & Halske at the Berlin Industrial Fair in 1879. The first electric tram used for permanent public service was the Gross - Lichterfelde tram in Lichterfelde near Berlin in Germany, which was opened in 1881. It was built by Werner von Siemens. This was the first successful commercial electric tram in the world. Initially it received the current from the rails (Guarnieri, 2020). The main purpose of this paper is to assess the opportunities offered by Tirana for the construction of a Tram network that will connect with each other the key points of the city.

Nowadays, the need to move from one place to another is becoming more and more difficult. Traffic delays, buses in poor technical conditions, inaccurate bus arrival times at the station, are becoming more and more worrying for people. During the peak of people's movement, it is almost impossible to reach the station and at the same time for the bus to come on time. The bus delay increases the number of people waiting at the station, and consequently it will be filled to the first two or three stations above its capacity.

The use of Trams in many parts of the world has facilitated the travel of people within the city, being separated from the road network, which makes Trams have no delays during the journey. We think that the introduction of the tram system is a necessary condition for the city of Tirana as well.

Advantages of the usage of the Tram

Unlike buses, trams (electric) do not emit smoke during use which would affect air quality. Compared to buses, tram noise is generally perceived to be less disturbing. However, the use of solid axles with wheels fixed on them causes slippage between the wheels and the rail when cornering. This produces a characteristic loud, high-frequency noise, often referred to as a "noise".

Trams can be adapted to the number of passengers by adding more carriages during hours of high passenger flow (or removing them during hours of lower flow). For these flows adjustments no additional driver is required as it would be required for buses. In general, trams offer a higher capacity service than buses.

Multiple entrances allow trams to fill up faster than buses, which tend to have a single entrance. This, combined with faster acceleration and braking, allows trams to maintain higher speeds than buses.

Tram stops on the road are easily accessible, unlike subway and railway stations located underground (with some escalators, stairs, etc.).

Roads for trams are narrower than for buses. This saves valuable space in cities with high population densities or narrow streets.

Passenger comfort is normally higher than buses due to controlled acceleration, braking and turn service. Rail transport as used by the tram ensures a safer journey than using the road by bus.

Since the railways are visible, it is easy for pedestrians to know where the tram routes are.

Trams can run on renewable electricity without the need for very expensive and short – lived batteries.

2. Methods and Theory

Many practice problems can be solved more easily if presented through schemes of consisting of node points and joining lines having ends at these points. The study of these schemes and their properties was the driving force behind the creation of graph theory. The first work that marks the birth of this discipline of applied mathematics was published by Euler in 1736 and it is known as the problem of the seven bridges over the river in the town of Königsberg. In the park of this city crossed a river on which were built seven bridges connecting the banks of the river as in Fig. 1:

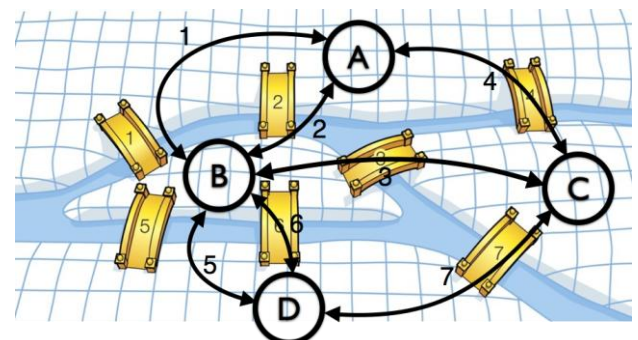


Fig. 1 [5]

The park visitors wanted to know if they could walk in this park by crossing once and only once at each of the bridges and back to the starting point. Considering the four parts of the land (shores) as nodes and the bridges as connecting lines between them, a scheme (graph) is constructed as in Fig. 1. The problem mentioned above is now formulated: Can we cross this scheme by passing only once each of its connecting lines and return to the starting point? Euler proved that such a walk is impossible because of the existence in this scheme of nodes from which a number of odd lines emerge. In practice, problems that are well reflected through such schemes, are often encountered. We can mention the scheme of transport between several centers, the scheme of water supply network,

electricity network, telegraph network in an area, the scheme of work operations in the process of carrying out a work project, etc.

3. Graphs. Key Concepts

Definition 1: An oriented graph is a pair formed by a set of elements $X = \{x_1, x_2, \dots, x_n\}$ and a family $U = \{u_1, u_2, \dots, u_m\}$ that has as elements ordered pairs of elements of X . We denote it by $G = (X, U)$.

The elements of set X are called the vertices of the graph, while the elements of U are called its arcs. The number of graph vertices is called the graph order. The element of U consisting of the ordered pair x_i, x_j of vertices is denoted by the symbol (x_i, x_j) . For the arch (x_i, x_j) the vertex x_i is called the beginning, while the vertex x_j is its end. The shape arch (x_i, x_i) is called a loop. An element (x_i, x_j) can be part of several times in U . If the element (x_i, x_j) that repeats the most, takes part p - times in U , then the graph is called p - graph. [1-3]

3.1 The Shortest Path Problem

Suppose that in a 1-graph $G = (X, U)$ to each arc $u \in U$ we have correspond a nonnegative real number $l(u)$. We call the number $l(u)$ the length of the arc u (in the graph this number will be written next to the corresponding arc). In practice the numbers $l(u)$ have different meanings depending on the real situation that is represented by the graph G and the problem that is posed for solution. Their meaning is not only that of the distance between the respective vertices as it may be in the case of studying the road network of a country, but in other cases it may be the cost or time of performing different works in a project, the amount of transport, etc.

Let $\mu = [x_i, x_{i_1}, x_{i_2}, \dots, x_{i_k}, x_j]$ be a path from vertex x_i to vertex x_j in graph G .

Definition 2: The length of the path μ in G is the sum of the lengths of the arcs that make it up. We note: $l(\mu) = l(x_i, x_{i_1}) + l(x_{i_1}, x_{i_2}) + \dots + l(x_{i_k}, x_j)$

Definition 3: The minimum distance from the vertex x_i to the vertex x_j is called the length of the shortest path from x_i to x_j on G . We denote it by l^*_{ij} . [1-3]

3.2 Dijkstra's Algorithm

In different algorithms, the process of equipping vertices with labels is also used to find the minimum distances, which facilitates the work in determining the minimum paths themselves. We give below such an algorithm that solves the problem of finding the minimum distances and shortest paths from a given vertex that we denote $s \in X$ to every other vertex of the graph with n vertices and nonnegative lengths of arcs. In this algorithm, each vertex of the graph is assigned a label with two divisions. Labels are temporary or final. At each step of the algorithm the set of graph vertices is divided into two subset S and $X - S$, where S is the set of vertices with final labels up to that moment. The temporary label of a vertex x_i is again separated into two and marked with $(\pi(x_i), x_k)$. In each step of the algorithm the last vertex that enters S plays a special role for the next step, so we denote it by $\tilde{x}$.

Dijkstra Algorithm

Initial step: We put the final label $[0, -]$ on the vertex S , and the temporary label $[\infty, -]$ on each other vertex. We get $S = \{s\}$, $\pi(s) = 0$, $\pi(x_i) = \infty$ for each $x_i \in X - \{s\}$. In the case of the vertex

S the label indicates that the minimum path length from S to S is 0. We mark it $s = \tilde{x}$.

General step: a) Examine the vertices $y \notin S$ such that the arch $(\tilde{x}, y) \in U$. For each such vertex y we compare the first indicator $\pi(y)$ of its existing label with the sum $\pi(\tilde{x}) + l(\tilde{x}, y)$ where $l(\tilde{x}, y)$ is the length of the arc $(\tilde{x}, y)$. If $\pi(\tilde{x}) + l(\tilde{x}, y) < \pi(y)$ then we put to the vertex y a new temporary label, in the first partition of which we place $\pi(\tilde{x}) + l(\tilde{x}, y)$, and in the second we put $\tilde{x}$. If $\pi(\tilde{x}) + l(\tilde{x}, y) \geq \pi(y)$, the label of the vertex y is currently unchanged. After these actions we move on to b).

b) We choose a vertex $z \notin S$ such that: $\pi(z) = \min_{y \notin S} \{\pi(y)\}$ (in case

there are several as such, one of them is considered). If $\pi(z) = \infty$, the algorithm is complete. In this situation there are no paths from S to the vertices $X - S$ in the graph and the minimum distances from S in each vertex of $X - S$ are ∞ , while the minimum distances from S in one vertex $x \in S$ are given by the first indicator of the final of the vertex x . If $\pi(z) \neq \infty$, then, we consider the label of the vertex z to be final and insert the vertex z into the set S , then we have $S = S \cup \{z\}$. If $S = X$, where the algorithm is complete, each vertex has received the final label and the indicators $\pi(x_i)$ of these labels are the minimum distances from s to x_i . If $S \neq X$, we repeat the general step taking $\tilde{x} = z$. [1-3]

4. Results and Discussion

Tirana is one of the largest cities in Albania, and meanwhile the place that offers more opportunities in many different aspects of life. Due to the opportunities it offers, it has also had a relatively high population, compared to other cities. Tirana has a population of approximately 912,190 inhabitants [7]. This figure often causes congestion and difficulty in moving around the city. One of the ways of traveling, mostly, is public transport. It has happened to all of us at least once to use this transport and we have encountered delays in stations, traffic jams, etc. One way to solve the problem for the whole society is to build tram railways. One of its main advantages is that it circulates on rails, has frequent stations, has a high capacity of passengers, passes through populated areas and most importantly does not create traffic or obstacles for citizens moving with their vehicles. So the Tram is a way of travel that has lower travel costs, less time to the destination and no delays at stations. We have built a plan for tram railways in Tirana. We have assumed 33 stations that in our case represent graph vertices scattered in the most frequented and populated areas of the city. We have drawn all 33 stations in a graph, based on the map of Tirana, and we have connected these stations (vertices) with ribs between them. We emphasize that the connection of the stations in the graph is done by means of the existing land roads that the city really has.

Fig. 2 shows the legend of public transport in Tirana.

While in Fig. 3 it is given the proposed scheme for the construction of the tram system.

We have placed each station by a number for ease of operation in the built graph. The first presumed station is Kashari with corresponding number 1, Treshi with no.2, Instituti with no.3, Paskuqani with no.4, Babrroi with no.5, Tufina with no.6, Porcelani with no.7, Shkoza with no.8, Bryli with no.9, Spitali Nënë Tereza with no.10, Bulevardi i Ri with no.11, Lapraka with no.12, Sheshi Shqiponja with no.13, Kthesa Kamzës with no.14, Yzberishti with no. 15, Sharra with no. 16, Kombinati with no.17, Fabrika e Miellit with no.18, 21 Dhjetori with no.19, Blloku Vasil Shanto with no.20, Block with no.21, Sheshi Nënë Tereza with no.22, Parku Rinia no.23, Rruga Kavajës with no.24, 9 Katëshet with no.25, Bulevardi Zogu I with no.26, Sheshi Zogu i Zi with no.27, Qyteti Studenti with no.28, Kopshti Zoologjik with no.29, Sauku i Ri with no.30, Rrethrotullimi i Saukut with no.31, Sauku i Vjetër with no.32, Qendra Tregtare TEG with no.33



Fig. 2 [6]

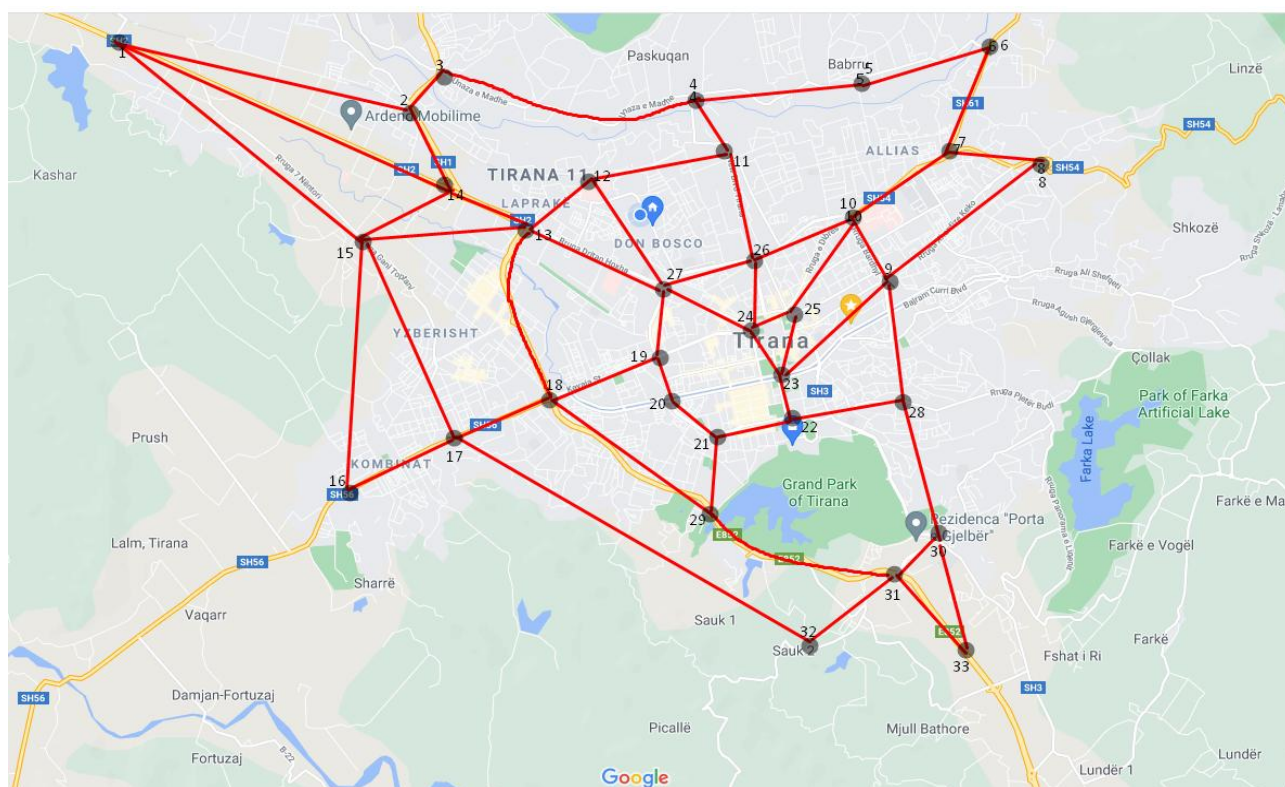


Fig. 3

The distances between the vertices of each of the two vertices (expressed in kilometers) are as below:

Kashar – Treshi (1–2)	3.5 km
Kashar – Kthesa Kamzës (1–14)	4.3 km
Kashar – Yzberisht (1–15)	3.6 km
Treshi – Instituti (2–3)	1.16 km
Treshi – Kthesa e Kamzës (2–14)	1 km
Instituti – Paskuqan (3–4)	3.66 km
Paskuqan – Babrru (4–5)	2.17 km
Paskuqan – Bulevardi i Ri (4–11)	1.7 km
Babrru – Tufinë (5–6)	1.8 km
Tufinë – Porcelan (6–7)	1.56 km
Porcelan – Shkozë (7–8)	5 km
Porcelan – Spitalet (7–10)	1.3 km
Shkozë – Brryli (8–9)	4 km
Brryli – Spitalet (9–10)	1.13 km
Brryli – Parku Rinia (9–23)	1.65 km
Brryli – Qytet Studenti (9–28)	2.18 km
Spitalet – Bulevardi Zogu I (10–26)	1.3 km
Spitalet – 9 Katëshet (10–25)	1.4 km
Bulevardi i Ri – Laprak (11–12)	3.4 km
Bulevardi i Ri – Bulevardi Zogu I (11–26)	1.18 km
Laprakë – Sheshi Shqiponja (12–13)	0.7 km
Laprakë – Bulevardi Zogu I (12–27)	2.3 km
Sheshi Shqiponja – Kthesa e Kamzës (13–14)	1 km
Sheshi Shqiponja – Yzberisht (13–15)	2.5 km
Sheshi Shqiponja – Fabrika e Miellit (13–18)	2.14 km
Sheshi Shqiponja – Bulevardi Zogu I (13–27)	3 km
Kthesa Kamzës – Yzberisht (14–15)	3 km
Yzberisht – Sharrë (15–16)	4 km
Yzberisht – Kombinat (15–17)	2.36 km
Sharrë – Kombinat (16–17)	1.3 km
Kombinat – Fabrika e Miellit (17–18)	2.22 km
Kombinat – Sauk i Vjetër (17–32)	8 km
Fabrika e Miellit – 21 Dhjetori (18–19)	1.23 km

Fabrika e Miellit – Kopshti Zoologjik (18–29)	2.66 km
21 Dhjetori – Blloku Vasil Shanto (19–20)	0.5 km
21 Dhjetori – Sheshi Zogu i Zi (19–27)	0.8 km
Blloku Vasil Shanto – Blloku (20–21)	1.18 km
Blloku – Sheshi Nënë Tereza (21–22)	0.5 km
Blloku – Kopshti Zoologjik (21–29)	1.66 km
Sheshi Nënë Tereza – Parku Rinia (22–23)	1 km
Sheshi Nënë Tereza – Qytet Studenti (22–28)	1.29 km
Parku Rinia – 9 Katëshet (23–25)	0.8 km
Parku Rinia – Rruga e Kavajës (23–24)	0.75 km
Rruga Kavajës – 9 Katëshet (24–25)	1.19 km
Rruga Kavajës – Bulevardi Zogu I (24–26)	1 km
Rruga Kavajës – Sauku i Ri (24–27)	4.5 km
Bulevardi Zogu I – Sheshi Zogu i Zi (26–27)	1 km
Qytet Studenti – Sauku i Ri (28–30)	2.27 km
Kopshti Zoologjik – Rrethrotullimi Saukut (29–31)	2.17 km
Sauku i Ri – Rrethrotullimi Saukut (30–31)	1.32 km
Sauku i Ri – Qendra Tregtare TEG (30–33)	2.3 km
Rrethrotullimi Saukut – Sauku i Vjetër (31–32)	0.5 km
Rrethrotullimi Saukut – Qendra Tregtare TEG (31–33)	3 km

Since the algorithm is being applied to a real problem, and the conditions of this problem are not known, the need arises to make some assumptions as follows:

- that the moving speed of the tram is constant all the way it will traverse
- the tram will not have delays at stations
- shorter distance means lower time cost
- the road to be traversed will be one-sided

Now applying Dijkstra Algorithm where as the initial vertex we have taken Kashar ie the vertex 1, we find the minimum distances from this vertex to all other vertices as well as the shortest path from 1 to any other vertex

In Fig. 4 it is shown the minimum distance from vertex one to any other vertex. As well as the shortest path from vertex one to thirty-three in blue ink.

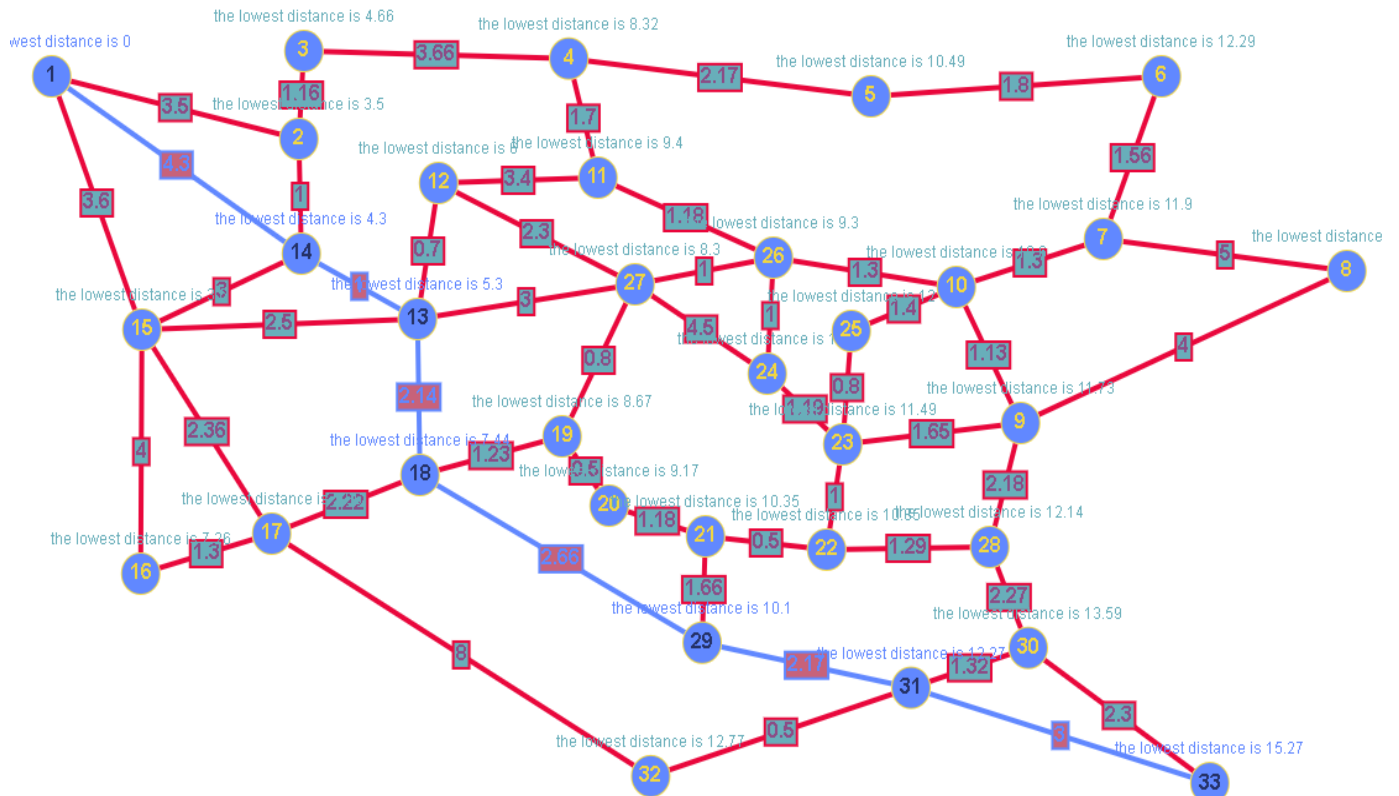


Fig. 4

Dijkstra algorithm now allows us to calculate the minimum distances from Kashar to the other stations specified in the graph and also to calculate the shortest path from Kashar to any other station as follows:

$l_{1,2}^* = 3.5 \text{ km}$	$\mu_{1,2} = [1-2]$
$l_{1,3}^* = 4.66 \text{ km}$	$\mu_{1,3} = [1-2-3]$
$l_{1,4}^* = 8.32 \text{ km}$	$\mu_{1,4} = [1-2-3-4]$
$l_{1,5}^* = 10.49 \text{ km}$	$\mu_{1,5} = [1-2-3-4-5]$
$l_{1,6}^* = 12.29 \text{ km}$	$\mu_{1,6} = [1-2-3-4-5-6]$
$l_{1,7}^* = 11.9 \text{ km}$	$\mu_{1,7} = [1-14-13-27-26-10-17]$
$l_{1,8}^* = 17.73 \text{ km}$	$\mu_{1,8} = [1-14-13-27-26-10-9-8]$
$l_{1,9}^* = 11.73 \text{ km}$	$\mu_{1,9} = [1-14-13-27-26-10-9]$
$l_{1,10}^* = 10.6 \text{ km}$	$\mu_{1,10} = [1-14-13-27-26-10]$
$l_{1,11}^* = 9.4 \text{ km}$	$\mu_{1,11} = [1-14-13-12-11]$
$l_{1,12}^* = 6 \text{ km}$	$\mu_{1,12} = [1-14-13-12]$
$l_{1,13}^* = 5.3 \text{ km}$	$\mu_{1,13} = [1-14-13]$
$l_{1,14}^* = 4.3 \text{ km}$	$\mu_{1,14} = [1-14]$
$l_{1,15}^* = 3.6 \text{ km}$	$\mu_{1,15} = [1-15]$
$l_{1,16}^* = 7.26 \text{ km}$	$\mu_{1,16} = [1-15-17-16]$
$l_{1,17}^* = 5.96 \text{ km}$	$\mu_{1,17} = [1-15-17]$
$l_{1,18}^* = 7.44 \text{ km}$	$\mu_{1,18} = [1-14-13-18]$
$l_{1,19}^* = 8.67 \text{ km}$	$\mu_{1,19} = [1-14-13-18-19]$
$l_{1,20}^* = 9.17 \text{ km}$	$\mu_{1,20} = [1-14-13-18-19-20]$
$l_{1,21}^* = 10.35 \text{ km}$	$\mu_{1,21} = [1-14-13-18-19-20-21]$
$l_{1,22}^* = 10.85 \text{ km}$	$\mu_{1,22} = [1-14-13-18-19-20-21-22]$
$l_{1,23}^* = 11.49 \text{ km}$	$\mu_{1,23} = [1-14-13-27-26-24-23]$
$l_{1,24}^* = 10.3 \text{ km}$	$\mu_{1,24} = [1-14-13-27-26-24]$
$l_{1,25}^* = 12 \text{ km}$	$\mu_{1,25} = [1-14-13-27-26-10-25]$
$l_{1,26}^* = 9.3 \text{ km}$	$\mu_{1,26} = [1-14-13-27-26]$
$l_{1,27}^* = 8.3 \text{ km}$	$\mu_{1,27} = [1-14-13-27]$
$l_{1,28}^* = 12.14 \text{ km}$	$\mu_{1,28} = [1-14-13-18-19-20-21-22-28]$
$l_{1,29}^* = 10.1 \text{ km}$	$\mu_{1,29} = [1-14-13-18-29]$
$l_{1,30}^* = 13.59 \text{ km}$	$\mu_{1,30} = [1-14-13-18-29-31-30]$
$l_{1,31}^* = 12.27 \text{ km}$	$\mu_{1,31} = [1-14-13-18-29-31]$
$l_{1,32}^* = 12.77 \text{ km}$	$\mu_{1,32} = [1-14-13-18-29-31-32]$
$l_{1,33}^* = 15.27 \text{ km}$	$\mu_{1,33} = [1-14-13-18-29-31-33]$

Now we can get the information we need for the construction of the Tram railways starting from Kashar to any other station. Today we are in the age of modern technology, where the world tends to improve and make the most of its benefits more and more. The use of trams will not only facilitate the movement of people in the capital but will positively affect the cleanliness of the environment. The biggest challenge, the most important process to be done in the city is the construction of tram infrastructure, because there is not enough space in the capital.

5. Conclusions

In this paper we reach the following conclusions:

- Graph theory finds wide application in everyday life in practical problems and especially helps designers in the field of construction and transport to determine the shortest paths between two or more

cities, centers, buildings or any designated destination as a vertex in the graph.

- The problem of shorter paths cuts the cost expressed in time or monetary value in investments.
- Finding shorter paths meets the requirements of passengers to get to the desired destination faster.
- Dijkstra algorithm turns out to be very practical in applications in everyday life, mainly in transport problems.
- In this paper we came to the conclusion that the shortest path from Kashari to TEG is Kashar – Kthesa Kamzës – Sheshi Shqiponja – Fabrika e Miellit – Kopështi Zologjik – Rrethrotullimi Saukut – TEG with the length $l_{1,33}^* = 15.27 \text{ km}$

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Traffic Accident Characteristics of Albania and their Prediction Using Bayesian Approach

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Abstract: The accident severity index of Albania has shown an increasing trend, although in 2020 there was a marked decrease of total accidents but some increase of fatal accidents. Looking at various risk factors—time, location, or speeding—this paper aims to develop a probability model that predicts accident-risk levels—flagging particularly hazardous locations or dangerous stretches of highway throughout the country—by using a Poisson model under a Bayesian Approach that can be used to predict the number of accidents occurring in a city per year from data collected. From statistical data of a year of reference, the parameters of these model are computing, with which the final distribution is considered that predicts the occurrence of car accidents in a city. The model can be very useful to those who working in the transportation and public safety sectors providing them information that could help make modifications, whether it is designs of the road or different signage, to protect drivers and citizens.

Keywords: ROAD SAFETY IN ALBANIA, PREDICTION OF ACCIDENT , HIGHWAY CRASHES, BAYESIAN TECHNIQUES

1. Introduction

Road accidents are essentially caused by improper interactions between vehicles, between vehicles and other road users and/or roadway features. The situation that leads to improper interactions could be the result of the complex interplay of a number of factors such as pavement characteristics, geometric features, traffic characteristics, road users' behavior, vehicle design, drivers' characteristics and environmental aspects. Thus, the whole system of accident occurrence is a very complex undertaking.

Engineers often have to analyze accident data to estimate the level of safety at different road infrastructure elements (segments and intersections) in order to identify hazardous (unsafe) locations and to evaluate the effectiveness of road safety countermeasures. By "safety" is meant either the true underlying accident rate or the true underlying accident frequency at a location. Statistics and applied mathematics can be very useful providing a variety of methods available to analyze road traffic accident data. As in other disciplines of statistics, the analysis of accident data is concerned with the determination of parameters and constants which has great practical importance—such as the true accident frequency/rate at a location but whose values are and cannot be precisely known.[1]

Finally, in this paper we present a distributions of Bayes Rule that predict the probability of occurrence of accidents in Albania, which is a specification of a Translated Poisson Mixture Model, which presents a weighted average of occurrence rates of observed car accidents. From statistical data of a year of reference, the parameters of the model is calibrated, with which the final distribution is considered that predicts the occurrence of car accidents in intersections for various temporary horizons.

1. Traffic accident situation in Albania

1.1.General

In Albania traffic accidents occur for various reasons. The major causes are: part of the road network is unfinished and lacks road protection and road signaling as well as supplementation with other elements of road safety, such as pedestrian crossings, metal guards, delineators, chevrons, etc; existence of black spots in the national road network; lack of lighting through roundabouts and level crossings in the national road network; non-implementation of traffic rules by road users such as: drivers, pedestrians, motorcyclists, etc.

Recently some measures regarding improvement of traffic have been undertaken in the city. Some of these measures are a one-way road system on a number of major arterials, improvement of geometrics of the intersections, and greater attention to road markings and signage. As a result there has been some improvement in the average travel speed of vehicles.[2]

1.2.Nature of accidents

According to official data, a decade ago, 322 deaths were registered annually from road accidents. While last year only 181 deaths were recorded - a decrease of 44%. In February 2021, there are 79 road accidents out of 106 accidents that occurred in February 2020, decreasing by 25.5%, compared to the same period of the previous year. In the first half of 2021, there are 204 road accidents out of 199 accidents that occurred in the first half of 2020, increasing by 2.5%, compared to the same period a year earlier. In February 2021, the number of injured (killed and injured) is 103 people from 144 a year ago, decreasing by 28.5%. In the first half of 2021, the number of injured is 268 people out of 266 people, increasing by 0.8% compared to the same period in 2020. In February 2021, the number of deaths from road accidents is 18 people out of 12 people killed in February 2020.

In February 2021, road accidents, in 81.0% of cases, occurred as a result of the driver's behavior. The highest number of accidents in this period was committed by the age group 25–34 years, accounting for 31.6% of the total number of accidents. Accidents in this age group have decreased by 10.7%, compared to the same period a year ago.[3]

1.3.Accident severity index

The Accident severity index measures the seriousness of an accident. It is defined as the number of persons killed per 100 accidents. Table below presents the Accident severity index for Albania during the period 2015-2020. It is seen that the Accident severity index has gradually increased from 10.02 in 2015 to 11.32 in 2020.[4]

Table 1: Accident severity index

Year	Number of persons killed	Total number of accidents	Accident severity index
2015	270	2692	10.02
2016	269	2778	9.68
2017	222	2611	8.50
2018	213	2291	9.29
2019	227	2044	11.10
2020	181	1598	11.32

Source:Albania Traffic Police.

Although road accidents resulting in loss of life have been declining, Albania ranks seventh in Europe for their highest number. In 2018, the ratio of accidents resulting in life in Albania was 75 per 1 million inhabitants, according to monitor calculations based on data published by INSTAT. In relation to the countries of the European Union, Albania is ranked among the countries with the highest rate, together with Macedonia, which for the past year marked an increase in fatal accidents.[5]

2. Prediction of road accident in Albania with Bayesian approach

2.1. Data Sets

The involved data for this work is referred to vehicular crashes that have happened in the road of the city of Albania. This information has been provided by the Albania traffic police and spans the period from 2015 to 2020. It is significant to consider that the quality of the information of the group of data of road accidents is little reliable, due to a series of systematic errors and inconsistencies as registry omissions, arrangement between involved parts without authority participation or other unregistered crash events. Unfortunately, this is a common situation for these records.

Table 2 shows more detailed data of accidents of the 10 location of the greatest rate of accidents for year 2020. Sites names of each of these location are shown, and the counting of number of accidents per month is listed.

Table 2: Data of monthly vehicular accidents, year 2020

Site	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Tirane	7	1	4	2	0	2	4	4	3	2	2	3
Durres	0	2	5	3	2	3	0	4	1	4	4	1
Elbasan	1	3	0	0	2	3	1	4	4	2	1	1
Fier	1	2	0	3	2	3	2	2	2	2	2	4
Vlore	0	0	0	0	0	0	1	2	4	0	0	1
Korce	0	1	0	0	0	1	0	1	1	1	1	0
Lezhe	2	0	0	1	2	1	2	1	5	2	3	1
Berat	1	0	1	0	1	0	1	1	1	1	0	0
Kukes	0	0	0	0	0	1	0	3	0	0	1	0
Diber	1	0	0	0	0	0	1	1	0	0	0	2

Source: Albania Traffic Police, author's calculations, 2021

2.2. Bayesian Approach

Bayesian methods are distinguished from “conventional” methods in that any parameter in a problem (such as the true accident frequency/rate at a location) is regarded as a random variable with a probability distribution. Whereas in ‘conventional’ methods the observed accident experience i at a site is considered to be an unbiased estimate of the true level of safety at a site, Bayesian assumes that the observed accident experience i is a variable and that it is Poisson distributed about μ —the true level of safety.

There has been considerable discussion recently on the benefits and limitations of Bayesian methods for the analysis of traffic safety data and, in particular, of crash data arising from intervention studies. The emphasis has been on the relative merits of traditional before/after studies and Bayesian approaches in various flavors including empirical (EB) and full (FB) Bayesian estimation.[6]

The Bayesian approach assumes that a probability distribution can be found before any data become available—this distribution is called the prior distribution of the parameter. According to the Al-Masaeid (1997), the Bayesian approach is a probabilistic method capable of augmenting the most recent information with the available historical data or prior knowledge to achieve better estimates.[7]

Perhaps because of its perceived complexity Bayesian methods are not often used to analyze accident data even though the general consensus is that Bayesian methods are superior to conventional methods (Abbess et al. 1981). The objective of this paper is to provide guidelines on how the Bayesian approach can be used to estimate safety (accident rate/frequency) at any location (segment or intersection) or a group of locations, and how these estimates can then be used to identify accident prone locations and to evaluate the effectiveness of remedial measures.[8]

2.3. Mixed Poisson distributions

This model for vehicular accident forecast calculates data of crashes where the number of accidents assumes that X_{it} occurs in a period of time t in the site i independently to another site, considering an initial uniform distribution and a Poisson likelihood function $P(X_{it}/\mu) \sim \text{Poisson}(\mu)$. [9]

Vehicular flow is assumed constant for all the sites, the intersections are of equal geometry and all accidents are of the same type, i.e. the observed data set $(x_1, x_2, \dots, x_n)$ has accident rates $\mu_i = (\mu_1, \mu_2, \dots, \mu_n)$, under $E(X_i/\mu) = \text{var}(x_i/\mu) = \bar{X}$. Generalized *a posteriori* expression can be written in the form:

$$P(\mu_i/X_{it}) = \frac{\mu_1^x e^{-\mu_1}}{x!} + \frac{\mu_2^x e^{-\mu_2}}{x!} + \dots + \frac{\mu_n^x e^{-\mu_n}}{x!} = \sum_{i=1}^n \frac{\mu_i^x e^{-\mu_i}}{x!} \quad (1)$$

Expression (2) represents a weighted average of Poisson distributions for different μ_i for each x_i observations, and can be re-written in a normalized fashion:

$$P(X_{it}) = P(X_{it}/x_i) = \frac{\mu_1^{x_1} e^{-\mu_1}}{x_1!} P(\mu_1 / x_i) + \frac{\mu_2^{x_2} e^{-\mu_2}}{x_1!} P(\mu_1 / x_i) + \dots + \frac{\mu_n^{x_n} e^{-\mu_n}}{x_1!} P(\mu_1 / x_i) \quad (2)$$

Initially apply expression (2) to any of the site. As an illustrative example, we are referring to the first location of table 2 (Tirana), which present 6 different monthly rates for year 2020. Considering the equal probabilities for each of them (0.166), we obtain the probability of accidents in this site. The regression of the average has been made with monthly parameters $\mu_i = (\mu_1, \mu_2, \dots, \mu_n)$ and real data using a linear regression $\mu_i = 0.425 X_{it} + 0.22$, thus, the considered annual average is $\tilde{\mu} = 1.4241$. Table 3 shows the results for each occurrence of accidents in the location we have considered.

Table 3: Mixtures of Poisson Probabilities, location Tirane

Month	Real accidents	Mixture of Poisson	Normalized	Estimated accident rates
January	7	0.0997	0.0603	3.195
February	1	0.1437	0.0870	0.645
March	4	0.1713	0.1037	1.92
April	2	0.1405	0.0851	1.07
May	0	0.0962	0.0582	0.22
June	2	0.1405	0.0851	1.07
July	4	0.1713	0.1037	1.92
August	4	0.1713	0.1037	1.92
September	3	0.1181	0.0715	1.495
October	2	0.1405	0.0851	1.07
November	2	0.1405	0.0851	1.07
December	3	0.1181	0.0715	1.495
$\bar{X} = 2.83$		...	P=1.0	$\tilde{\mu} = 1.4241$

Source: Authors.

This process is performed for each location in Table 2, in order to identify the locations with high degree of danger, also estimates monthly about the probability of having a determined number of accidents. The Poisson model shows not a very strong fitness to the data due to their lack of flexibility about rates that are mainly variable, and because the use of only one kind of variable.

3. Conclusion

a) In general, the accident severity index of Albania has shown an increasing trend, although there were an decrease in 2020. Various traffic engineering measures undertaken in the last few years may have helped in curbing the number of total accidents as well as fatal accidents. In 2020 there was a marked decrease of total accidents but some increase of fatal accidents.

b) We present a Poisson model under a Bayesian approach that can be used to predict the number of accidents occurring in individual location from data collected. This is useful to obtain a priori information of events that can lead to economical and personal damages in order to design strategies to avoid them.

c) Based on research done in other countries and provided similar data will become available to us by the Albanian authorities, we believe the Bayesian approach to estimation of safety has certain distinct advantages over the conventional methods, therefore it can be utilized effectively in situations where sample sizes are inadequate. Given that sufficient prior information is available Bayes approach can provide more reliable estimates of safety and results that enable statistical inferences to be made.[10]

4. Recommendation

Given the rapidly growing web of highways that crisscross Albania and the increasing number of crashing each year, we recommend that greater emphasis should be placed on the use of Bayesian methods in road safety research by scholars and government experts responsible for highway safety alike. There is a pressing need for more research into developing appropriate accident prediction models to support the application of the Bayesian approach.

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Redesigning the layout of an existing railway station according to the tsi and ordinance no. 55 requirements in the case of uninterrupted mainline operation

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Abstract: In this paper, the problems in redesigning a new track layout of an existing railway station according to the requirements in the TSI "Infrastructure" and Ordinance No. 55 are examined and analyzed in the case of maintaining mainline operation during construction. The paper has been compiled on the basis of experience in designing the track layout of 3 existing railway stations from the Bulgarian network, as well as experience working with the current regulations and interoperability requirements of the railway systems in the EU. The necessities for making changes in vertical and horizontal track alignment and switch layout are considered in opposition to the technological, electrical and gauge limitations when carrying out construction works without the complete disruption of railway traffic. The conclusions of the report are formulated as guidelines for good practices when redesigning an existing layout – the practices that fully satisfy the imperative norms and balances between contradictory requirements.

Ключови думи: interoperability, railway switches, railway stations, subsystem railway

1 Introduction

As the existing track on No IX railway mainline (fig. 1) /categorized as part of the comprehensive railway network according to Order No 601/21.03.2018 of the NRIC¹/ is reaching a near-emergency condition and a relatively dense freight traffic on a national basis is observed, technical designs for the reconstruction of sections of the line were assigned. Technical design projects were prepared for the reconstruction of the Razgrad, Hitrino and Pliska railway stations. The following key factors in designing the track layouts were taken into consideration:

- Preservation / Restoration of the mainline design speed in the main track through the railway station
- Design track geometry on the rest of the tracks in the station that satisfies the requirements for at least 40 km/h
- Relocating existing tracks when additional space is necessary for the construction of platforms considering the requirements of [1], [2] and [10]
- Supplying all arrival-departure tracks with stub 'safety' tracks as prescribed in art. 130 [3]
- Increase, if possible, the useful lengths of tracks for achieving the parameters prescribed in Order №601

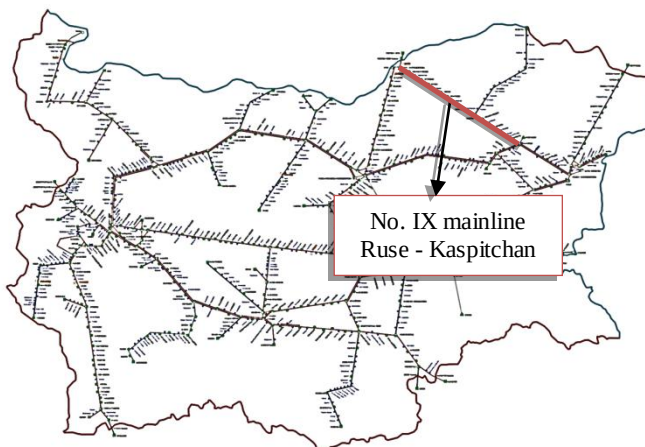


Fig. 1 Schematic railway network map of the Republic of Bulgaria, as of 2021, No IX mainline

This report outlines the problems in designing the track layouts of these existing stations, which were first built and then reconstructed in the late 19th and 20th centuries respectively. The three stations - Razgrad, Hitrino and Pliska, shown in fig. 2 with their existing track layouts represent a challenge from the point of view of finding and developing a design solution, which at the same time satisfies the modern requirements for an interchange railway

station and optimizes to the greatest extent the financial resources invested in the reconstruction.



Fig. 2 Location of the stations on the railway line

2 Theoretical overview of the mutual arrangement of railway switches

2.1 From the aspect of railway track geometry

Switches are railway superstructure elements with pre-established and standardized geometric construction. This imposes geometric constraints on the line of the railway track in the horizontal and vertical planes. It is not possible for the two diverging tracks, which are parts of a switch, to have a different slope or a different level in the switch zone, as the two tracks lie on the same sleepers. Another limiting factor consists of the dynamic effects observed when a railway vehicle passes through the different parts of the switch. As a rule, new designs avoid dynamically dependent elements of the track geometry, which puts railway switches and their location in a key position in the plan and profile design of the railway line.

Switches include in their geometry a non-zero curvature element. I.e. this curve must be appropriately located, considering surrounding track geometry conditions.

Since the vehicles have a spring suspension, any change in the dynamic parameters of movement (speed, acceleration, first derivative of acceleration, jerk) leads to oscillations of the sprung masses. If the next element of the track changes the dynamic parameters of motion before the previous oscillations have subsided, this creates a possibility of resonance. We observe phenomenon most frequently in closely spaced horizontal curves. Such curves are dynamically dependent. As a rule, new designs avoid dynamically dependent curves, as their design is imperatively

¹ National Company for Railway Infrastructure

prohibited in [3] by instating the minimum value of the length of a straight element between two tangency points:

$$(1) L_{str} \geq 0.70 \cdot V_d \quad (V_d = 160 - 200 \text{ km/h})$$

$$(2) L_{str} \geq 0.50 \cdot V_d \quad (V_d < 160 \text{ km/h})$$

where L_{str} is the length of the required intermediate straight element, V_d represents design speed.

In Ordinance №55 the minimum distance between BS /Begin Switch/ or ES /End of Switch/ and the respective horizontal alignment tangency points is given as a constant of 25m (can be reduced to 6m as an exception). For track layouts in railway stations, only the minimum of 6m between two reverse curves is given. The ordinance allows for reverse curves with a common point of tangency in railway stations, but with a design speed restriction according to the selected radii without prescribing an analytical expression as a criterion.

In [4] the requirements are developed in more detail, taking into account the speed of movement. In order to validate a reverse curve without intermediate straight, both conditions must be met simultaneously:

$$(3) \frac{R_1 \cdot R_2}{R_1 + R_2} \geq \frac{V^2}{9}$$

and

$$(4) \frac{R_1 \cdot R_2}{R_1 + R_2} \geq 100$$

where R_1 is the first curve radius, R_2 – the reverse curve radius, V – design speed

Failing to satisfy the first condition gives:

$$(5) L_{str} \geq \frac{V}{10}$$

Failing to satisfy the second condition gives:

$$(6) L_{str} \geq 10 \text{ m (6 m)}$$

Expression (3) limits the abrupt change in lateral acceleration.

2.2 From the aspect of nearby switches

The railway switch allows for the branching of one track into two - ie. three directions - one outgoing at the BS point and two incoming in the ES points. On each of the three directions can be located an adjacent switch with a variation of its three directions. An orientation with the BS point has another case – with a left and right deviation. Three possible directions with four positions for the next switch gives a total of 12 possible configurations for the placing of 2 adjacent switches (Fig. 3).

The mutual placement of railway switches is covered by the norms, providing instructions for 7 out of the aforementioned 12 cases. A rule for placement of long sleepers after the ES point is indicated. A formula for obtaining the required distance as a function of the transversal track distance is given. A table is given with pre-calculated necessary straights to ensure a minimum distance of 4750mm for two adjacent tracks. As for the other 5 special cases, the designer has to assess the required distances between adjacent switches thus ensuring their adequate mutual placement.

3 Existing and proposed track layouts

3.1 Razgrad station

The existing Razgrad station (Fig. 4) has 4 arrival-departure tracks and 3 shunting tracks. One of the arrival-departure tracks has been dismantled. Since the main track is the second one and arrival-departure tracks are located on both sides of the mainline, it was necessary to implement two safety stub tracks according to Art. 130 [3]. The placement of the stub tracks within the existing property boundary is constrained by the presence of existing office buildings, poles of the catenary and masts of the station lighting.

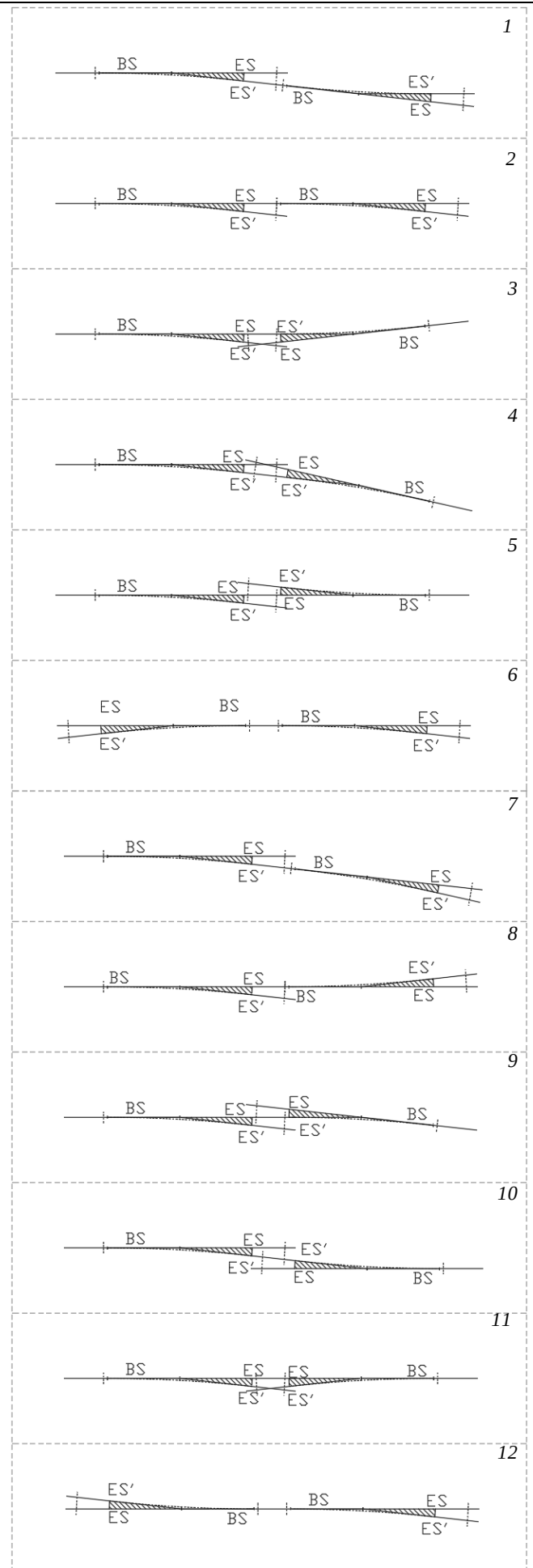


Fig. 3 Mutual placement of two railway switches – possible cases

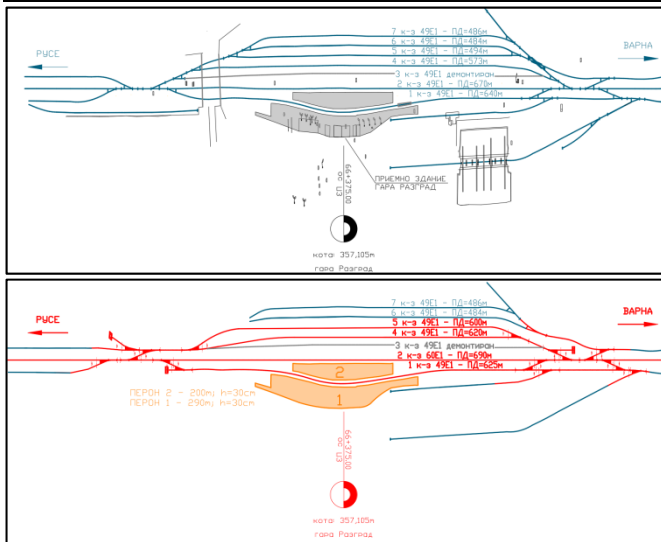


Fig. 4 Schematic view of Razgrad station – Existing and proposed layout

A serious limitation at the beginning of the station on the Ruse side was the fact that on the main track lie switches No. 2 and 4 leading to private sidings (Fig. 5), whose property limit lies on the automatic derailleurs immediately after the distance signs of the switches. Immediately after switch No. 4 follow switches No. 6 and 8, which unfold the track layout of the station. In this case, it was considered appropriate to connect the northern industrial siding (without construction activities before the derailleurs) directly with tracks 4 and 5, while providing a new rail connection to the mainline. In this way, the following improvements in the station layout are achieved:

- Fewer switches located on the mainline
- The possibility for unauthorized exit of a vehicle on the mainline from the private siding is excluded

At the end of the station (Varna) no changes are required - the arrival-departure tracks are guarded by the shunting sidings on both sides of the mainline. The position of the last switch on the mainline is limited by the subsequent horizontal curve after the station.



Fig. 5 Switches No. 2 and 4, Razgrad station

3.2 Pliska station

The existing station (Fig. 6) has 3 arrival-departure tracks, the mainline being a second track. To meet the requirements, a solution with 4 rail connections and 4 stub safety tracks is required - the solution doubles the number of switches in the station. Given that the horizontal alignment of the station is straight - a change in

the layout is not appropriate - any change would impose new curves in the layout, which is not favorable from an operational point of view.

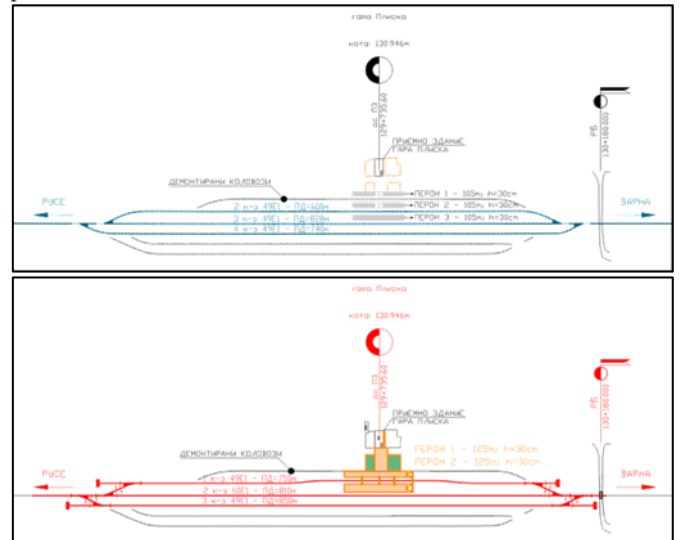


Fig. 6 Schematic view of Pliska station – Existing and proposed layout

On the other hand, as can be seen in the proposed layout, two pairs of reverse curves were implemented on the first track - a decision that was dictated by the need to construct a platform with a sufficient width to meet the requirements for unobstructed routes [2] and [10]. Although a platform height of 300mm is explicitly stated as permissible for the Bulgarian railway network in item 7.7.3.1 [1], the overall dimensions of the same were proposed so that in future reconstruction of the platform from 300mm to 550mm in height does not require a change in the geometry of the layout.

3.3 Hitrino station

The existing station (Fig. 7) has 4 arrival-departure tracks, the mainline being a second track. If the existing layout of the station is preserved, 4 stub safety tracks will be needed. However, with a change in the geometry of the mainline, it is possible to restructure the station so that the mainline passes through track 4 - thus all other tracks lie on the right side of the mainline and only one stub track is needed for each end of the station.

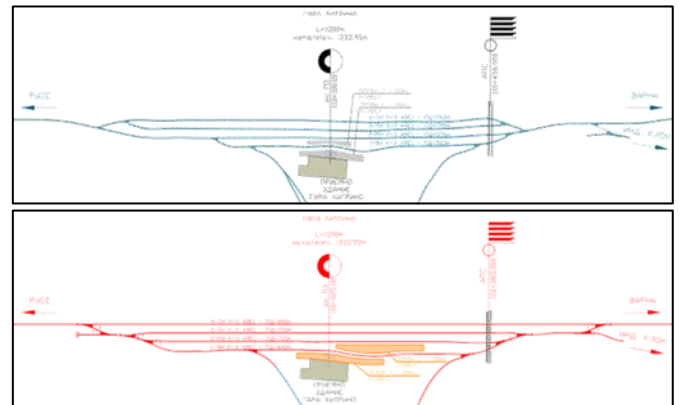


Fig. 7 Schematic view of Hitrino station – Existing and proposed layout

The proposed layout is favorable in terms of the following factors:

- Mainline design speed is restored - it rises from 60 km/h to 80 km/h
- Proposed horizontal and vertical geometry of all tracks is fully compliant with applicable norms
- Supplying all arrival-departure tracks with stub safety tracks according to the requirements of art. 130 [3] is observed with a

minimum number of additional switches and railway / *in fact - the proposed layout has 10 switches, as much as the existing one* /

- The useful lengths for achieving the parameters prescribed in Order №601 are increased – track 1 from 503m to 640m, track 2 from 576m to 715m, track 4 from 765m to 840m.
- More optimal use of the station's capacity - the heavier freight trains pass through the fewest number of switches. Upon consultation with the 2020 train schedule, it was established that there are a total of 31 scheduled trains in both directions in the Samuil-Kaspichan section. According to the schedule of BDZ-PP, 8 passenger trains run in the same section. I.e. 26% are passenger trains. Given that freight trains have a higher axle load, it is considered rational to specialize mainline and the 3rd track as arrival-departure tracks since they are accessed through the least number of switches.

In opposition to the above - the proposed layout does not lack shortcomings:

- Each passenger train scheduled to stop at the station must pass through all switches (in case of arriving on the first track)
- Changing the mainline alignment to pass through track 4 implies replacement of the entire subballast and base structure above the existing datum surface, since the requirements regarding mainline base soil properties are the strictest. In the course of the site surveys, a vertical deformation / *indication of a weak spot in the base* / was registered, cf. Fig. 8, **exactly** on existing track 4. Therefore, the design included additional subbase layers, which increased construction costs.

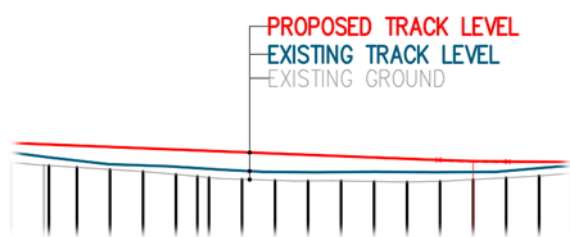


Fig. 8 – Vertical deformation zone on existing track 4

4 Technical limitations in changing existing railway station layouts

The most favorable method for the construction of a new railway station or the complete reconstruction of an existing railway station is the one in which all railway traffic is redirected – the catenary is switched off, no rolling stock gauge limitations are imposed. The construction time, respectively the construction costs decrease. However, this method is rarely applicable to mainlines with trains frequently passing. The additional costs of rerouting freight trains and transboarding passengers to other vehicles exceed the cost reduction achieved through continuous construction process that is unrestricted by railway traffic.

As according to current schedule more than 20 freight trains pass through the mainline in each 24 hours, and most of the trains being international, it is imperative to limit the need for traffic interruptions to a minimum by designing the proposed track layout appropriately.

Any change in the location of switches and tracks in a station intended for reconstruction is a decision that must be well justified - and above all technically feasible. This section of the report contains factors missing in current applicable norms and regulations that must be taken into account while designing a proposed layout.

4.1 Relocation of existing tracks

Preserving the possibility for a busy interchange station on a single-track mainline to continue to operate during construction is a key factor. In the general case, this presupposes the presence of at

least two arrival-departure tracks at any time during construction with a working catenary network and with provided construction and rolling stock gauge.

4.2 Relocation of existing switches

Another key factor is the location of existing switches. In electrified stations (as considered in this report) above each switch there is a catenary line crossing (Fig. 9) so that both tracks have their adjacent traction power supply. Any displacement of a railway switch imposes a displacement of the catenary line crossing, which in turn imposes erection of a new pole for tensioning the adjacent catenary.



Fig. 9 Catenary line crossing

4.3 Proposed track layout in the zone of level crossings

According to Art. 21 [9], the level crossings are brought in line with the Ordinance when reconstructing the adjacent roads. However, the reconstruction of tracks through the level crossing often leads to a change in the level or the position of the rail head in the area of the level crossing. This means that during the construction work the level crossing will be completely closed for a certain time. It is necessary to assess the socio-economic significance of the level crossing, as well as the availability of bypass routes, which is especially important for special vehicles (ambulance, fire brigade, etc.). In the case of Hitrino station, through the tracks of which passes the main street of the settlement, the bypass route has a length of over 6 km (Fig. 10). During construction activities, the contractor will rebuild the crossing taking into account existing slopes on the adjacent street.



Fig. 10 Bypass route around the closed level crossing, Hitrino station

5 Conclusion

In this report, theoretical and practical formulations in the design of new track developments at existing intermediate railway stations were considered. It is obvious that not only the quality of the geometry and construction of the railway itself, but also the future functionality of the station with all its' subsystems depends on the designer of the "Permanent way" project part. Safety and sustainability of railway traffic during construction depend on the design decisions in the "Permanent way" project part.

Conflicting requirements stand out. On one hand there are the regulatory restrictions on the mutual placement of switches. On the other hand –at existing stations on the railway network adjacent switches are frequently laid without intermediate straights. Redesigning the layout to conform with requirements for placement of switches imposes a reconstruction of the catenary, which is not compatible with continuous uninterrupted railway traffic during construction.

The key parameters that the design must comply with in order to be feasible are:

- Horizontal, vertical geometry of the railway, placement of the switches, track distances, distances to existing buildings and facilities intended for preservation.
- The rigid points for the plan and profile of the railway - the end switches in the station, entrance and exit signals, level crossings, retaining walls, bridges, etc.
- The available space within the property boundaries of the railway infrastructure, as compared to the requirements of the Contracting Authority regarding the reconstruction of the station (new tracks, widening platforms, increasing the length of the station, new stub safety tracks, etc.)
- The interoperability requirements of the subsystem "Infrastructure" and "Persons with reduced mobility" – line categorization, design speed, train length, axle load, usable length of the platforms, gauge and accessible environment for passenger traffic
- The future safety of the station operation during shunting activities and train receiving and dispatching activities (avoidance of hostile routes, minimum number of switches on the mainline, limiting the access to the mainline from other sidings or tracks)
- Consideration of the possibilities for constructing the catenary according to the proposed track layout
- Considering variants for implementation of construction: possible stages of construction, temporary traffic on adjacent tracks, temporary platforms and temporary access of passengers to the station during construction activities

Taking into account the above factors, as well as the identification of other project-specific features implies improving the quality, productivity and safety of the railway infrastructure at the expense of optimal capital investments for its reconstruction.

6 Literature

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