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Abstract: It is evident from the experience of operating the construction machinery (excavators, bulldozers, loaders etc.) that quite often the machinery and its operators are working under severe conditions. When the operators are at risk, it is advisable to deploy remote process control technologies on the work sites. This is what brings research and development of modern remote control systems to the top of the chart in order to improve the productivity of machinery, enhance the safety and quality of the jobs carried out.

KEYWORDS: AGGRESSIVE ENVIRONMENT, SAFETY, CONTROL SYSTEM, AVAILABILITY, VISIBILITY

Introduction.

The designers developing modern construction and road-making machinery have to take into account a variety of functionality indices determined by psychophysical capabilities of operators, to ensure efficient and safe operation within the man-machine-environment system.

It is due to the fact that, as long the industry development intensifies and new machinery is conceived, the operators’ activity is becoming increasingly complex and subject to stresses. The functional specifications of construction and road-making machinery do not at all times meet the requirements of the sites where it is operated. This results in deployment of substandard process layouts, which, in turn, leads to impaired efficiency and increased labor consumption [1, 2]. Such production sites feature specific operational conditions, whether natural and climatic or due to the highest level of man-made impact. Ensuring quality and safety of the operational tasks under such conditions becomes a real challenge, and the environment conditions set thresholds for the operator’s work. On great many occasions, when the personnel’s actions prove to be wrong, it is not due to poor skill level (though there are many problems on this side as well) but to the mismatch between the machinery’s design features and human capabilities [3]. The physical environment of the production site has to correlate with the human performance features, and only then one can expect high productivity from him/her. Certain conditions demand from operators to use their psychophysical capabilities to the utmost extent, which, under adverse operational environment, may provoke erroneous actions, resulting not from poor skill level but from the mismatch between the machinery’s design features and the operational environment, on the one side, and human capabilities.

Adverse factors in the operational environment provoke occupational diseases of operators, often resulting in permanent disability [4]. The operators of construction and road-making machinery are subjected to continuous vibration loads, noises, and dust, which can give rise to hand-arm vibration syndrome, hearing disturbances, diseases of peripheral nervous system, locomotor and respiratory diseases. Unfortunately, the design of modern digging and road-making machinery fails to ensure protection of operators from adverse factors caused both by operational environment and the machines [5].

A wide range of operational tasks require to limit the presence of operators on the production site [6]. Listed below are examples of construction and road-making machinery operation involving increased adverse effects:

- mining and concentrating mills, mines, ore dressing mills, open pits for commonly occurring minerals, construction material works;
- waste dumps, sanitary landfills for solid household waste and toxic chemicals;
- demolition of buildings and debris handling;
- mitigation of radiation accidents and incidents involving detection of uncontrolled radiation sources.

Various transport, digging, filling, compacting, and crushing machinery is used at the above sites, all subjected to aggressive environment and quickly going out of service.

If we consider a specific machine as a complex unit of equipment, the principal natural, climatic, and environmental factors produce the following impact on it:

- **High temperature**: reduced viscosity and modified structure of diesel fuel, lubricants, pressure and process fluids, impaired cooling of internal combustion engines, accelerated ageing of rubber seals and other insulating materials.
- **Low temperature**: increased viscosity of diesel fuel, congealed lubrication oils and solid greases, frozen condensate in pneumatic systems, reduced toughness of steels, hardened and embrittled rubber seals.
- **Increased humidity**: accelerated corrosion of steel parts, reduced insulation resistance, water intrusion into fuel and process liquids, mold build-ups.
- **Reduced humidity**: thickening lubrication oils, drying out seals, fracturing insulation materials.
- **Sun radiation**: changing coefficient of friction for friction materials, accelerated ageing of polymer coatings.
- **Wind**: drying of materials, increased heat output of machine parts and extra strain on them.
- Dust: changing coefficient of friction for friction materials, clogging of ducts and reduction of air flows, impaired cooling and ventilation, build-up on heated surfaces reduces heat exchange, and intensely heated items may become a source of ignition.

- Aggressive environment: accelerated deterioration of materials. The following groups of environments are among the most widespread: potent oxidizers (nitric, chromic acids etc.); mineral and organic acids (phosphoric, acetic acids, etc.); alkali; organic compounds (petroleum products, etc.); halogen compounds. Aggressive environments can produce chemical transformation, deterioration, cracking, stiffening, etc.

Therefore, research of machinery operation and operators’ activities within the single man-machine-environment system emphasizes the importance of finding new ways to reduce the risk of human errors and enhanced operational safety of construction and road-making machinery.

Method.
Working under complicated operational conditions relies on operation, upkeep, and maintenance costs of machinery. If insufficient capacity, inappropriate or unreliable equipment is selected, early failures may occur which, under urgent work pressure, may prove to be critical.

Special operational conditions for machinery are accounted for at the stage of design and manufacture. Modern equipment is manufactured in various climatic options as regards their fitness for operation in various macroclimatic zones: for cold, moderate, arid, or humid tropical climate. Standard machinery greatly outnumbers the specialized options, which is due to overwhelming proportion of brown field areas with moderate climate, as well as to manufacturing industrial facilities, production cost of machinery etc. In this connection, it is necessary to adapt standard machinery to special operational conditions by means of special refit and by changing their modes of operation. Such necessity arises during operation of standard machinery in climatic areas with high temperature fluctuations or when it is required to operate such machinery in a variety of meteorologic conditions.

To adapt process systems to their operational conditions, proven methods are used to refit such systems, thus obtaining high efficiency of standard equipment under special conditions. The solutions improving the efficiency of machinery have to be coordinated against each factor affecting the productivity (purpose, operational environment, operating mode, technical condition, technologies deployed) and the duration of the machinery operation, as well as any possible variations of all these factors. Therefore, the aggregate range of impact for each specific factor builds into the set of positive/adverse factors affecting the productivity of process systems.

Animated graphic modeling of the man-machine-environment system enables to suggest a way to reduce the impact of aggressive environment on such system:

- Develop a set of activities which have to include the selection and setup of specialized equipment;
- Remove the operator from the potential hazard area where the operations are carried out by implementing remote control;
- Comprehensive integration of technology to improve efficiency, safety, and enhance quality control of the processes and remake them into a single high added value production line.

This is what brings research and development of deploying modern remote control systems in construction and road making machinery to the top of the chart in order to improve the productivity of machinery, enhance the safety and quality control of the jobs carried out. There is a widespread solution for such tasks: a team of equipment enabling two operation modes, direct or remote, depending on the operational conditions.

Informative Part.
1) Currently the electronic control systems of construction and road making machinery are monitoring and optimizing the operation of the engine, hydraulics, all sensors and operating controls, and ensure that information is shown on the display. The consistent operation of such electronic control systems is due to digital communication and control features applied. Operators may use the electronic control system to adjust the operating force and receive feedback about the condition of and load on such machinery resulting from interaction with the objects [7]. Reliable feedback is ensured between the operator and equipment, to monitor the reaction force when actuators contact the working surface. The existing level of construction and road making machinery and the capabilities of radio electronic features enable creation of a set of radio devices which can be applied to provide remote control over operation of specialized machinery under a variety of conditions.

The capability to handle the necessary process operations is the key functionality for construction machinery remote control systems. It can only become possible subject to a fail-free control of the actuators of such machinery, which requires a homogeneity and optimization of operation for all units and modules. The construction machinery control system operation can divide into the following tasks:

1) Principal: a set of control features to carry out the machinery operational cycle (its core function).
2) Auxiliary: a set of auxiliary features enabling control between the operational cycles.
3) Visual and spatial control of process operations. A system of cameras, microphones, positioning sensors, and data from the electronic control console enables visualization of parameters and positioning of the machinery and of the working members of its actuators.

The remote control system must be capable to handle the above tasks. At the same time, it must ensure feedback regarding the force impacting each of the actuators.

The coordination between the operations of such machinery can be ensured using the Master-Slave system already widely spread in modern construction equipment [7].

A typical Master-Slave system is a team of coordinated devices consisting of the following systems:
- Master: controls one or several other devices (servo units).
- Slave: is set up to operate under control, ensuring that the operating forces are applied consistently with the gearing diagrams of the operational equipment and using the installed feedback system, and features a set of information features to ensure detection of mechanical loads during the operations.

Master-Slave system enables control of motions of working members and sends signals describing such motions of each working member, enabling their realtime positioning [7]. Feedback ensures adequate effect, based on the force applied by the operational equipment to the working surfaces. Such interaction ensures the degree of “sensitivity” between the components of the man-machine-environment system, thus promoting the process quality.

2) Generally speaking, the proposed modern single-purpose remote control systems for construction machinery operate as follows:
- The sensor gathers (detects) data from outside sources and information about the condition of the controlled equipment (taking into consideration the feedback channel data) and generates the control commands based on the inputs and the source (apriori) information.

A sequence of stimuli is generated for the machinery controls, ensuring the consistency between its operational mode and movement trajectory with the operator’s purposes.
- Further on the commands are sent via the control channel to the servo unit. As a result of inherent distortion, the commands received by the servo units may be somewhat different from the transmitted commands.
- The feedback line detects adequate effect, based on the force applied by the operational equipment to the working surfaces, and returns the operational data to the electronic control console.

The necessity to use a wide radio frequency range to ensure a reliable communication channel without cross distortion or
jamming, is a serious drawback of remote control systems. The operational conditions may impose limitations on the radio channel if side electronic noises are present.

**Conclusion.** Operational and design are the two types of requirements applied to the construction machinery remote control systems.

Operational requirements consist in fail-safe and reliable operation of all remote control systems under the given weather and climatic conditions. The importance of this condition is due to the fact that the current development of equipment mostly targets its improved precision and implementation into control systems of high speed computers assuming an increasing amount of the operators’ functions. Such control systems are complex and contain many different components. Whereas a failure of any single component may disturb the operation of the entire system, it is, therefore, of utmost importance that all components and the system as a whole should be highly reliable [8].

Design requirements consist in quality of the installed features’ operation. It must have minimal dimensions and weight, resist overloads, and be immune to vibration. These features should be operable under a wide range of temperatures, humidity, and pressure.

Remote control features fitted on the construction machinery will increase its base cost up to 30%. Taking into account the process operations carried out by the machinery and the conditions of such operation, the development of remote control sets for such machinery must be based on the value added. This consideration is viable both to design new machinery and to retrofit the existing equipment. For the latter, to avoid excessive costs, onboard equipment may be installed without any material redesign of the machinery. The consideration of extra costs is overshadowed by the totally different level of safety and comfort offered by the remote control systems. There are modern examples of successful deployment of remote control over machinery. In 2010 Brodrene Gjermundshaug Anlegg AS. was busy reclaiming the territory of a former military firing range on the territory of the actual Dovre National Park (Norway). The hazard consisted in the occurrence of many unexploded shells in the ground. One of the operators, Havard Thoressen, said: “It was quite a strange bit of experience, learning to do my normal job sitting in a steel box miles away from the place I am actually working at. It took me about two weeks to get used to the new way of working. First we had some difficulties to retain control over everything, but now there are no more problems” [9].

**Literature:**

Abstract: One of the most important characteristics of the vehicle, which characterizes the behaviour of the vehicle while driving, is the ability to reduce vehicle’s speed to stop point. Brake system requirements are set by statute ECE 13 and each EU Member State is obligated to implement them into their legislation. The brake system consists of a set of parts that serve to gradually reduce the speed of the vehicle to stop it and the system must keep it stationary if it has already been stopped. The quality of the brake discs and brake pads is decisive during braking as well as in removing heat from the brake area. This article discusses about the basic parameters compared during braking in changing the quality of brake components which impact road safety and the safety of passengers in vehicles.

Keywords: breaking, stopping distance, safety

1. Introduction

Distance, which is necessary for the complete halt of the vehicle, consists of several parts. There is the same composition for the time required to stop the vehicle. These times are theoretically shown in Figure 1. From the figure, it is clear that the vehicle has zero braking ratio during the reaction and thus the speed of the vehicle is the same as it was before the reaction time.

Fig. 1 Theoretical course of braking deceleration in time from the moment of the impulse for braking the vehicle Source: authors

1 - driver response time [s]
2 - delay time of brakes [s]
3 - increased time of braking deceleration [s]
4 - time of effective braking
5 - total braking time
6 - the time needed to stop the vehicle

2. Action forces between the tire and the road

Force application and transfer of tangential and radial forces are between the tire and the road. Three force components, which are involved in the transmission of forces, can be considered during braking the vehicle:

- Adhesive force - creates shear stresses between the surfaces, and its size depends on surface cleanliness and pressure, which the individual surfaces are pressed together
- Deformation force – is created, when the surface roughness is pushing into the surface of the tire.
- Abrasion force - this is the result of the work necessary for uprooting of particles in the tread. This force is the most apparent during heavy braking especially if the vehicle is not equipped with ABS. In terms of tires, it is preferable when this force is as low as possible.

Fig. 1 shows the course of braking deceleration. During the effective braking it is possible to consider the value of the mean fully developed deceleration.

The mean fully developed deceleration (MFDD) shall be calculated as the deceleration averaged with respect to distance over the interval \(v_0\) to \(v_e\), according to the following formula:

\[
MFDD = \frac{v_0^2 - v_e^2}{25.92 \cdot (S_b - S_e)} \quad [m \cdot s^{-2}]
\]

where:
- \(v_0\) – initial vehicle speed in km·h\(^{-1}\),
- \(v_h\) – vehicle speed at 0.8 \(v_0\) in km·h\(^{-1}\),
- \(v_e\) – vehicle speed at 0.1 \(v_0\) in km·h\(^{-1}\),
- \(S_b\) – distance travelled between \(v_0\) and \(v_h\) in meters,
- \(S_e\) – distance travelled between \(v_0\) and \(v_e\) in meters.

This article was created on the basis of measurements carried out in closed airport Rosina. Decelerometer XL Meter\textsuperscript{TM} Pro was used for recording during braking deceleration.

Fig. 2 Decelerometer XL Meter\textsuperscript{TM} Pro Source: [2]

This device, shown in Fig. 2, allows to evaluate and analyze the acceleration or vehicle dynamics. This feature is able to evaluate the acceleration of the vehicle at different time intervals. This allows to quickly and objectively compare different kinds of vehicles.

The results displayed from the device of Meter\textsuperscript{TM} XL Pro are:
- \(v\) [km·h\(^{-1}\)] – current speed when the measurement was stopped
- \(s\) [m] – distance from the beginning to the end of the measurement
- \(t\) [s] – time from the beginning to the end of the measurement.
3. Measurement methodology, used vehicle and brake components

Measurements were carried out on the vehicle of Skoda Octavia. The vehicle had the disconnected brakes on the rear axle. It follows that the measurements examined a braking distance only with the involvement of the front axle. Rear axle brakes were sealed at the end of the hole of brake pipe. Thanks to this, there was no leakage of brake fluid from the pipeline, see Figure 3.

![Image of brake pipe seal](image)

**Fig. 3 Seal at the end of the brake pipe. The rear axle of the vehicle - Skoda Octavia. Source: Authors**

Used brake linings were assessed on the basis of bid price in the market. Table 1 compares the parameters and the price of the brake discs and brake linings companies of STARLINE and BREMBO.

### Table 1: Comparison of parameters and prices of components on the front axle used for measurements

<table>
<thead>
<tr>
<th>Parameter of the brake disc</th>
<th>STARLINE</th>
<th>BREMBO</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter [mm]</td>
<td>288</td>
<td>288</td>
</tr>
<tr>
<td>inner diameter [mm]</td>
<td>136</td>
<td>136</td>
</tr>
<tr>
<td>thickness [mm]</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Price without VAT [€/piece]</td>
<td>24.19</td>
<td>68.19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter of brake lining</th>
<th>STARLINE</th>
<th>BREMBO</th>
</tr>
</thead>
<tbody>
<tr>
<td>thickness [mm]</td>
<td>19.70</td>
<td>20.6</td>
</tr>
<tr>
<td>breadth [mm]</td>
<td>156.28</td>
<td>156.4</td>
</tr>
<tr>
<td>Price without VAT [€/piece]</td>
<td>25.29</td>
<td>56.49</td>
</tr>
</tbody>
</table>

Source: Authors

During the measurements of the stopping distance, it was necessary to replace the original brake components with components of Starline in service workshop. Then, the measurements were made at the prescribed speed. Subsequently, it was necessary to replace STARLINE components with the components of BREMBO in the service workshop.

Measurements were made at the speed of about 50 km·h⁻¹ and 90 km·h⁻¹. At any speed, 50 repetitions were carried out. After achieving the required speed, a driver depressed the brake pedal. And at the same time he tried to brake with the maximum possible braking deceleration. The following variables were investigated for measurements:
- stopping time [s]
- stopping distance [m]
- MFDD [m·s⁻²].

4. Evaluation and outputs of the measured data

About 10 measurements, which reached a maximum speed approaching 50 km·h⁻¹ or 90 km·h⁻¹, were selected from each group of measurements. Subsequently, the individual measurements were compared to each other. Results at a speed of 50 km·h⁻¹ can be seen in Fig. 4.

**Fig. 4 Compared data from measurements at a speed of 50 km·h⁻¹ for brake components of BREMBO and STARLINE. Source: Authors.**

It may be seen from Fig. 4 that by using less expensive components from STARLINE, the average stopping time and stopping distance are greater than the values observed with the use of brake components from BREMBO. The average values of monitored parameters are shown in Table 2.

### Table 2: Comparison of average measured values of monitored parameters at 50 km·h⁻¹.

<table>
<thead>
<tr>
<th>Speed</th>
<th>Components</th>
<th>Stopping time [s]</th>
<th>Stopping distance [m]</th>
<th>MFDD [m·s⁻²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 km·h⁻¹</td>
<td>STARLINE</td>
<td>2.843</td>
<td>19.689</td>
<td>4.992</td>
</tr>
<tr>
<td></td>
<td>BREMBO</td>
<td>2.032</td>
<td>14.387</td>
<td>7.418</td>
</tr>
</tbody>
</table>

Source: Authors

As well as in the previous case, because of the speed limit outside the village 90 km·h⁻¹ were carried out comparative measurements in the meeting of approximations that speed. Comparison between the components, which were purchased at a higher or lower price are shown in Fig. 5.

**Fig. 5 Comparison of the data for measurements of the speed of approximately 90 km·h⁻¹ for brake components from STARLINE and BREMBO Source: Authors**

As well as in the previous case, the values were measured in achieving the speed of 90 km·h⁻¹ and the average values of the observed variables were worse with the components from STARLINE compared to the values obtained by using the brake linings and brake discs from BREMBO. Accepted mean for the measurements are shown in Table 3.
Table 3: The average values of monitored parameters at a speed of about 90 km•h⁻¹

<table>
<thead>
<tr>
<th>Speed</th>
<th>Components</th>
<th>Stopping time [s]</th>
<th>Stopping distance [m]</th>
<th>MFDD [m•s⁻²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 km•h⁻¹</td>
<td>STARLINE</td>
<td>5.512</td>
<td>69.872</td>
<td>4.619</td>
</tr>
<tr>
<td></td>
<td>BREMBO</td>
<td>3.716</td>
<td>47.019</td>
<td>7.191</td>
</tr>
</tbody>
</table>

Source: Authors

Conclusion

During measuring the stopping distance, it was found thanks to the calibrated equipment - XL Meter™, that during braking with using brake components from STARLINE, the stopping distance at 50 km•h⁻¹ was by an average of 5,302 meters longer compared to using the BREMBO brake components. This is related to the length of time required to stop the vehicle. This was on average greater by 0.811 seconds. The average value of MFDD was lower by 2.426 m•s⁻² by STARLINE components.

The similar results were achieved by measurements at the speed of 90 km•h⁻¹. Stopping distance by using the brake components from STARLINE was greater by about 22.853 metres compared to the average values measured with components of BREMBO. Time needed for braking the vehicle was longer in average by 1.796 seconds. The average value of the MFDD was lower when using cheaper components about 2.572 m•s⁻².

When using the mentioned components, the difference in price of brake linings and brake discs on the front axle is € 150.4 without VAT in favor of STARLINE. However, taking into account the road safety, the components from BREMBO can be considered as preferable based on measured data.

REFERENCES


PROCEED FOR THE SEPARATION SEQUENCE OF VERTICES IN DIFFERENT ROUTES

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Abstract: The objective of vehicle routing problem (VRP) is to deliver a set of customers with known demands on minimum-cost routes originating and terminating at the same depot. Similar to most GA that a chromosome S is a permutation of n positive integers, such that each integer is corresponding to a customer without trip delimiters. Christian Prins proposed an optimal splitting procedure to get the best solution, respecting to a given chromosome. In this paper, application of this splitting procedure to get the best solution, respecting to a sequence of vertices, produced by the heuristic approaches (or a new chromosome produced by the mutation procedure), is considered.

KEYWORDS: TRANSPORT, VEHICLE ROUTING, HEURISTICS, GENETIC ALGORITHMS, SPLIT DELIVERY

1. Introduction

In the vast majority of the literature, finding tours visited by commercial vehicles is considered as a Vehicle routing problem. The vehicle routing problem (VRP) consists of designing m vehicle routes of least total cost and: each starting and ending at the depot, such that each customer isvisited exactly once; the total demand of any route does not exceed the vehicle capacity, and the length of any route does not exceed a preset maximal route length. The basic VRP can be extended by taking into account: time windows of customers’ requests, heterogeneity of vehicle fleets, tasks conducted by vehicles, the number of home depots, and operational restrictions faced by vehicles.

A large number of algorithms have been developed to solve the VRP problem. Depending on whether an exact optimal solution or an approximate solution is reached, they can be categorized as the exact algorithms or the heuristic methods.

There are different families of heuristics for the VRP. They can be classified into two main groups: the classical heuristics, developed mostly between 1960 and 1990, and the metaheuristics, developed after this period.

The classical heuristics perform a relatively limited exploration of the search space and generally produce good quality solutions within modest computing times. The typical classical heuristics include the well-known savings algorithm (Clark and Wright, 1964), the sweep algorithm (Gillett and Miller, 1974), the petal algorithms (Balinski and Quandt, 1964; Ryan et al., 1993; Renaud et al., 1996), the cluster-first-route-second algorithms (Fisher and Jaikumar, 1981), and the improvement heuristics (Lin, 1965; Thompson and Psaraftis, 1993). Compared with classical heuristics, metaheuristics perform a much more thorough search of the solution space, allowing inferior and sometimes infeasible moves, as well as recombinations of solutions to create new ones.

Exact heuristics: Branch-and-bound; Branch and Cut Method etc.

Classical heuristics: Route construction heuristics; Savings algorithm - Clarke and Wright (C&W); Two-Phase Methods; sweep algorithm; Solution Improvement; l-opt heuristic etc.

Metaheuristics: Simulated Annealing; Deterministic Annealing; Tabu search; Genetic Algorithms; Ant System; Neural Algorithms etc.

Metaheuristics commonly used the initial solutions, typically created with some cheapest insertion heuristic.

In this paper is proposed a method for evaluation of the heuristic approaches (or new sequence, obtained by the procedure of mutation), in order to optimize them.

2. Problem Description

As mentioned above, for usage of sequence of vertices, derived from the use of heuristic approaches, we need of splitting procedure, that give an adequate solution, i.e with a cost equal to or better obtained by using the initial Heuristic approach. Based on a literature review, widely used is Splitting algorithm [6]. In its application, it was found that the result obtained by the algorithm, was not adequate to that, obtained of the used heuristics, as shown in Table 1. If output routes and their first-last vertex are arranged in a certain sequence, i.e. last vertex of a route and first of the next route are in the same cluster, then the result could be with even greater differences. For example, about the problem R101 [7] was obtained:

- „Clarke & Wright“, classical: 10 routes, total mileage - 892,464;
- „Clarke & Wright“ + opt.: 17 routes, total mileage – 1 361,639.

Table 1: Problems and result from used models for optimization

<table>
<thead>
<tr>
<th>prob.</th>
<th>method</th>
<th>R,pr</th>
<th>cost</th>
<th>method</th>
<th>R,pr</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>C&amp;W</td>
<td>10</td>
<td>892,464</td>
<td>+ opt.</td>
<td>11</td>
<td>1 070,284</td>
</tr>
<tr>
<td>C1</td>
<td>Sweep</td>
<td>10</td>
<td>1,096,739</td>
<td></td>
<td>22</td>
<td>1 860,281</td>
</tr>
<tr>
<td>R1</td>
<td>C&amp;W</td>
<td>8</td>
<td>888,266</td>
<td></td>
<td>10</td>
<td>1 094,554</td>
</tr>
<tr>
<td>R1</td>
<td>C&amp;W</td>
<td>8</td>
<td>1,029,858</td>
<td></td>
<td>10</td>
<td>1 150,004</td>
</tr>
<tr>
<td>C2</td>
<td>C&amp;W</td>
<td>3</td>
<td>632,432</td>
<td></td>
<td>3</td>
<td>740,894</td>
</tr>
<tr>
<td>C2</td>
<td>Sweep</td>
<td>3</td>
<td>800,268</td>
<td></td>
<td>5</td>
<td>950,471</td>
</tr>
<tr>
<td>R2</td>
<td>C&amp;W</td>
<td>1</td>
<td>523,204</td>
<td></td>
<td>1</td>
<td>523,204</td>
</tr>
<tr>
<td>R2</td>
<td>Sweep</td>
<td>1</td>
<td>620,492</td>
<td></td>
<td>1</td>
<td>620,492</td>
</tr>
<tr>
<td>R1</td>
<td>Sweep</td>
<td>5</td>
<td>556,480</td>
<td></td>
<td>18</td>
<td>1 738,847</td>
</tr>
<tr>
<td>C2</td>
<td>C&amp;W</td>
<td>2</td>
<td>693,330</td>
<td></td>
<td>2</td>
<td>724,657</td>
</tr>
<tr>
<td>C2</td>
<td>Sweep</td>
<td>2</td>
<td>809,187</td>
<td></td>
<td>2</td>
<td>809,187</td>
</tr>
</tbody>
</table>

To improve the result, we will investigate the possibility of using two main parameters - the distance of each vertex from the Depot and the distance from the previous one, according to the proposed order. They are applied to modernize the classic algorithm of Clarke & Wright [1]. Using these two parameters is shown in (3).

\[ S_{ij} = C_{0i} + C_{0j} - C_{ij} \]

here \( S_i \) is the corresponding savings and \( C_i \) – corresponding cost.

Several improvements to the C&W algorithm have been proposed, to lead to better results overall. Gaskell and Yellow (1967) have suggested using a positive parameter \( \lambda \) (the route shape parameter), through which taken of the relative importance of direct arc between two customers in the calculation of "savings". Paessens (1988) introduce in the model weight \( \mu \), for "asymmetric" solving (the distance from the depot for each of the pairs considered customers).

The formula for the resulting savings is as follows:

\[ S_{ij} = \alpha C_{0i} + \beta C_{0j} - \mu C_{ij} - \alpha \beta (C_{ij} - C_{0j}) \]

Here \( \lambda \) is a parameter that controls the relative significance of direct arc between two customers and \( \mu \) is the asymmetry between two customers with respect to their distances to the depot.
To take into account the use of the vehicle capacity, Altinel and Öncan introduce another parameter, aiming at increasing the loading of vehicles. The principle is: “larger combined route is better”.

\[ S_{ij} = C_{0i} + C_{0j} - \alpha C_{ij} + \mu (C_{0i} - C_{0j}) + \gamma (d_i - d_j)/\bar{d} \]

here \( \bar{d} \) is the average demand of all customers, \( d_i \) is the demand of customer \( i \).

Since the chromosome may be broken into several different routes, Prins [6] proposed an optimal splitting procedure, which can find the optimum split, ie, routes, by minimizing the total cost. The main idea can be described as follows. Let \( S = (1, 2, 3, \ldots, n) \) be a given chromosome. Based on the auxiliary graph \( H = (V', E') \), where vertices \( V' = \{0, 1, 2, \ldots, n\} \), and arc \( E_{ij} \in E' \):

\[ E_{ij} = c_{0i} + \sum_{k=1}^{j-1} (t_k + c_{k,k+1}) + t_j + c_{ij} \leq L; \quad \sum_{k=1}^{j} q_k \leq Q \]

here \( t_i \) is the service time at customer, \( q_i \) - the demand for customer \( i \).

Then \( E_{ij} \) is the total travel cost (time) for the route \((i+1, i+2, \ldots, j)\). An optimal split for \( S \) corresponds to the shortest path \( P \) from vertex 0 to vertex \( n \) in \( H \).

\[
\begin{align*}
V_0 &= 0; \\
& \text{for } (i = 1; i < n; i++) \{ V_i = +\infty; P_i = 0; \} \\
& \text{for } (i = 1; i < n; i++) \{ \\
& \quad \text{cost} = 0; \quad \text{load} = 0; \quad j = i; \\
& \quad \text{repeat} \\
& \quad \quad \text{load} = \text{load} + q_i; \\
& \quad \quad \text{if } ((i = j) \quad \text{cost} = C_{0j} + \sum_{k=1}^{j} t_k + C_{0i}; \\
& \quad \quad \quad \text{else} \quad \text{cost} = \text{cost} - C_{0i} + \sum_{k=1}^{j} t_k + C_{0i}; \\
& \quad \quad \quad \text{cost} = \alpha \cdot C_{0i} + \sum_{k=1}^{j} \mu (\text{abs} (C_{0j} - C_{0i}); \\
& \quad \quad \quad \text{cost} = \text{cost} + \text{cost}'; \\
& \quad \quad \text{if } ((\text{cost} \leq L) \& \& (\text{load} < Q)) \{ \\
& \quad \quad \quad \quad \text{if } ((V_{j+1} < V_j) \} \\
& \quad \quad \quad \quad j = j + 1; \\
& \quad \quad \text{until } ((j > n) \& \& (\text{cost} > L) \& \& (\text{load} > Q)) \}
\end{align*}
\]

Figure 1 A modified algorithm by using of the coefficients

Figure 2 Routes for C1-Sweep, produced by splitting procedure

In [6] by example the method was demonstrated. The auxiliary graph helps us understand the idea how to split a given chromosome \( S \) into optimal routes. But, we do not have to construct such graph \( H \). It can be done by a labeling algorithm and a splitting procedure [2]. Let \( S = (1, 2, \ldots, n) \) be a given chromosome. Two labels \( V_j \) in \( P_j \) for each vertex \( j \) in \( S \) are computed. \( V_j \) is the cost of the shortest path from node 0 to node \( j \) in \( H \), and \( P_j \) is the predecessor of \( j \) on this path. The minimal cost is given at the end by \( V_n \). For any given \( i \), the increment of \( j \) stops when \( L \) or \( Q \) are exceeded. The labeling algorithm is shown in Figure 1.

3. Application of the proposed algorithm

The influence of the coefficients \( \alpha \) and \( \mu \) was studied, for variant C1 Sweep with 22 routes, Figure 2.

In Table 2 gives the parameters for the routes of the viewed variant.

Table 2: Routes for C1-Sweep, produced by splitting procedure

<table>
<thead>
<tr>
<th>№</th>
<th>sequence</th>
<th>( Q )</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0, 90, 89, 88, 85, 84, 83, 82, 94, 92, 87, 86, 0</td>
<td>190</td>
<td>130,061</td>
</tr>
<tr>
<td>2</td>
<td>0, 91, 75, 1, 98, 96, 95, 97, 100, 0</td>
<td>150</td>
<td>111,786</td>
</tr>
<tr>
<td>3</td>
<td>0, 93, 0</td>
<td>40</td>
<td>86,023</td>
</tr>
<tr>
<td>4</td>
<td>0, 99, 0</td>
<td>10</td>
<td>67,082</td>
</tr>
<tr>
<td>5</td>
<td>0, 5, 3, 0</td>
<td>20</td>
<td>32,257</td>
</tr>
<tr>
<td>6</td>
<td>0, 7, 4, 6, 9, 8, 11, 10, 12, 14, 2, 23, 0</td>
<td>170</td>
<td>119,064</td>
</tr>
<tr>
<td>7</td>
<td>0, 26, 0</td>
<td>10</td>
<td>31,623</td>
</tr>
<tr>
<td>8</td>
<td>0, 28, 13, 17, 18, 19, 15, 0</td>
<td>140</td>
<td>90,800</td>
</tr>
<tr>
<td>9</td>
<td>0, 16, 0</td>
<td>40</td>
<td>80,623</td>
</tr>
<tr>
<td>10</td>
<td>0, 20, 21, 0</td>
<td>30</td>
<td>22,198</td>
</tr>
<tr>
<td>11</td>
<td>0, 22, 25, 27, 29, 34, 36, 39, 30, 24, 47, 0</td>
<td>160</td>
<td>105,041</td>
</tr>
<tr>
<td>12</td>
<td>0, 49, 52, 50, 51, 31, 35, 37, 38, 32, 0</td>
<td>150</td>
<td>97,873</td>
</tr>
<tr>
<td>13</td>
<td>0, 33, 0</td>
<td>40</td>
<td>67,052</td>
</tr>
<tr>
<td>14</td>
<td>0, 43, 0</td>
<td>10</td>
<td>33,106</td>
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<tr>
<td>15</td>
<td>0, 42, 41, 40, 59, 58, 60, 44, 45, 48, 46, 69, 66, 0</td>
<td>180</td>
<td>117,468</td>
</tr>
<tr>
<td>16</td>
<td>0, 68, 64, 61, 72, 55, 57, 54, 53, 0</td>
<td>150</td>
<td>105,164</td>
</tr>
<tr>
<td>17</td>
<td>0, 56, 0</td>
<td>30</td>
<td>90,000</td>
</tr>
<tr>
<td>18</td>
<td>0, 67, 0</td>
<td>10</td>
<td>24,413</td>
</tr>
<tr>
<td>19</td>
<td>0, 65, 63, 62, 74, 80, 79, 77, 73, 0</td>
<td>170</td>
<td>122,431</td>
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<td>20</td>
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<td>30</td>
<td>94,868</td>
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<tr>
<td>21</td>
<td>0, 78, 76, 71, 0</td>
<td>50</td>
<td>114,298</td>
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<tr>
<td>22</td>
<td>0, 70, 0</td>
<td>30</td>
<td>117,046</td>
</tr>
</tbody>
</table>

The results obtained are shown in Tables 3,4,5,6.

Table 3: Results for the influence of the coefficient \( \alpha \)

<table>
<thead>
<tr>
<th>( \alpha )</th>
<th>routes</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>22</td>
<td>1 860,281</td>
</tr>
<tr>
<td>0.2</td>
<td>22</td>
<td>1 866,047</td>
</tr>
<tr>
<td>0.4</td>
<td>20</td>
<td>1 735,151</td>
</tr>
<tr>
<td>0.6</td>
<td>17</td>
<td>1 571,181</td>
</tr>
<tr>
<td>0.8</td>
<td>15</td>
<td>1 473,184</td>
</tr>
<tr>
<td>1</td>
<td>14</td>
<td>1 435,887</td>
</tr>
<tr>
<td>1,2</td>
<td>15</td>
<td>1 393,637</td>
</tr>
<tr>
<td>1,6</td>
<td>16</td>
<td>1 323,340</td>
</tr>
</tbody>
</table>

Table 4: Results for the influence of the coefficient \( \mu \)

<table>
<thead>
<tr>
<th>( \mu )</th>
<th>routes</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>24</td>
<td>1 891,373</td>
</tr>
<tr>
<td>-0,6</td>
<td>25</td>
<td>1 923,156</td>
</tr>
<tr>
<td>-0,4</td>
<td>25</td>
<td>1 901,894</td>
</tr>
<tr>
<td>0</td>
<td>22</td>
<td>1 860,281</td>
</tr>
<tr>
<td>0,2</td>
<td>20</td>
<td>1 808,386</td>
</tr>
<tr>
<td>0,6</td>
<td>16</td>
<td>1 548,751</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>1 480,879</td>
</tr>
<tr>
<td>1,5</td>
<td>15</td>
<td>1 448,808</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>1 401,447</td>
</tr>
</tbody>
</table>

Table 5: Results for the influence of the coefficients \( \alpha \) and \( \mu \)

<table>
<thead>
<tr>
<th>( \mu )</th>
<th>( \alpha )</th>
<th>routes</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,15</td>
<td>1</td>
<td>14</td>
<td>1 349,104</td>
</tr>
<tr>
<td>0,5</td>
<td>1</td>
<td>15</td>
<td>1 382,475</td>
</tr>
<tr>
<td>0,8</td>
<td>1</td>
<td>17</td>
<td>1 462,267</td>
</tr>
</tbody>
</table>
The influence at issue parameters, independently apart, on the number of received routes are illustrated in Figure 3 and 4. In Table 6 are the routes and cost, corresponding for the best combination. When comparing the obtained results with those of Table 7, we see the difference in the number of routes - 4 and about 23% in cost. When comparing the obtained results with those of Table 7, we see examples, shown in Table 8, are closer to the input variants.

From these results is seen that with the introduced modifications, we do not achieve the desired final results. We can get the desired final results, using these coefficients with higher values, and achieve variant with more routes. Through an additional procedure for their optimization (applied to the "label" array $P_j$, Figure 1), was prepared desired result.

5. Conclusions
A large number of algorithms have been developed for obtaining the routes of commercial vehicles, ie to solve the VRP problem. При мета-евристики широко се използва евристика за получаване на изходен вариант. Particular attention must be paid to then local search method.

The proposed modification, by examining the two parameters to the decoupling algorithm generally has a positive effect, and through subsequent optimization, we obtain the result, with the parameters of the heuristics.

The proposed modification, using two parameters examined, to the splitting algorithm generally has a positive effect, and through subsequent optimization, we obtain the result, with the parameters of the initial heuristics.

The method is used for splitting a sequence of vertices resulting from the procedures for the drawing-up of new sequences by genetic algorithms, and also as a procedure for getting the routes after the use of the algorithm for the Traveling salesman problem.

REFERENCES:


[7] w.cba.neu.edu/~msolomon/problems.htm

Acknowledgements: The paper is published with the support of the project BG051PO001-3.3.06-0043 “Increasing, Improving and Extending the Scientific Potential of the University in Transport by Support to Development of PhD Students, Postdocs, Trainees and Young Researchers in the Field of Transport, Power Engineering and ICT in Transport” within the Human Resources Development Operational Programme co-funded by the European Social Fund of the European Union.
Abstract: One of the most important characteristics of transport systems is the reliability of their performance. Significant global efforts are being made in this direction, both by the relevant government structures, and individual transport operators. These efforts are justified because improvements in the sphere of safety and reliability entail considerable benefits to transport users (reducing the waiting time of passengers, improving the quality of service in general, increasing supply chains reliability level, etc.) and for operators offering such a service (higher level of competitiveness, more revenues, etc.). This article examines the nature, existing problems and opportunities for improvement of approaches and methods of analysis, evaluation and management of exploitation reliability (and respectively transport service quality) of transport systems.

Keywords: FUNCTIONAL RELIABILITY, TRANSPORT, TRANSPORT SERVICE QUALITY

1. Introduction

One of the most important characteristics of transport systems is the reliability of their performance. Significant global efforts are being made in this direction, both by the relevant government structures, and individual transport operators. These efforts are justified because improvements in the sphere of safety and reliability entail considerable benefits to transport users (reducing the waiting time of passengers, improving the quality of service in general, increasing supply chains reliability level, etc.) and for operators offering such a service (higher level of competitiveness, more revenues, etc.). This article examines the nature, existing problems and opportunities for improvement of approaches and methods of analysis, evaluation and management of exploitation reliability (and respectively transport service quality) of transport systems. It must be recognized that the management of functional reliability of transport systems is not unequivocal and cure for the problem solving. This is because transportation systems are complex hierarchical structures distinguished for their the availability of a wide variety of technical devices (rolling stock, means of communication and information management, special equipment, etc.) located and operated a large area. Nay, the normal work (and respectively offered by these systems transport service) could be impaired due to effects of great variety of influencing factors: technical devices operating conditions (to which the transport process), characteristics of the organization and management of the transport system itself, etc. There are rare cases where single and seemingly insignificant events exploitation activities give rise to serious operational disturbances of transport systems. The problem of functional reliability of transport systems is not new to exploitation science and practice. Today, however, when the national and global economies are highly dependent on transport, this problem is becoming more and more relevant and significant. Undoubtedly, its solution implies a systematic approach and taking of adequate decisions (including measures to improve) requires adaptation to the problem on known or developing of new models methods for analysis and management of functional reliability. In this article are examined the nature and characteristics of the functional reliability of different types of transport systems, the guidelines and the problems of her the research.

2. Nature of the functional reliability of transport systems

Through physical movement of people and goods transport systems play an important role in the economic development of the country, linking social and economic interaction. Key element of every transport system is the functional reliability. The market of functional reliability is determined by the demand and the level of the proposed reliability, which inevitably change over time. Functional reliability is at once product and factor contributing to the trends in the development of the transport sector. [1]

It should be recognized that today the development of reliable and quality transport services is spent substantial funds globally each year. As a result of the increasing complexity of transport systems and supply chains in combination with rising consumer expectations, functional reliability becomes increasingly necessary and important. On the other hand the vulnerability of the system also increases. Functioning of transport systems can be disrupted by various types of errors, leading with her problems to solve that there are different models.

Some of the primary sources of reliability problems associated with rail schedules are unexpected events such as lack of rolling stock and locomotives, lack of crew or long delays at border stations. For public transport sources of reliability problems can be connected with lack of capacity, lack of drivers, repair of the road network and congestion.

Most of us are faced with unreliable transport services in their everyday life expressed with unexpected delays, leading to a later arrival to school or work or to a missed train or bus. Whether for business or social event or supply of goods reliability is a key quality of movement. The success of rail and road transport is highly dependent on the ability of a transport system to deliver reliable customer service. Transport operators aim to provide higher levels of reliability for consumers, because reliable services are more attractive and can also reduce operational costs.

It must be acknowledged that there have been significant efforts by transport operators and agencies for increasing the quality and reliability of services. Improvements in reliability beneficial both for consumers and for transport operators (fewer variables services reduce the waiting time of passengers and allow efficient use of resources by the operators). This is a situation where everybody wins.
The reliability is a term that may be defined in different ways. This article will examine the reliability in terms of quality of travel, travel time meet the needs of consumers and enabling them to organize their activities.

3. Defining the problems of reliability and guidance to solve them

In order to define the problems associated with the reliability of transport systems must be determined:

- the role and tasks of transport in the lifestyle of the individual and society as a whole;
- the influence of unreliable transport systems on personal and commercial activities.
- measures to be undertaken for the development in the field of transport.

Transport systems are vital arteries of modern economies that facilitate the lifestyle of modern man. A transport enables economic development and enables travelers to travel, socialize and have fun. Transport is vital for our personal and commercial prosperity. Therefore, reliability of transport systems is gaining more importance.

The main function of the transport system is facilitating movement of people and goods between chosen destinations. Insignificant damages can lead to a serious deterioration in state of the entire functionality of the system. Unreliable transport systems have an impact on both personal and on commercial activities. Consumers of transport systems rely on reliable schedules and delays, as well as the early arrivals on the selected route adversely affects the commercial and personal activities. Unreliable transport system increases the time to reach the desired destination. The consequence of delayed transport leads to disappointing trip causing stress.

When talking about the reliability of transport systems, it is important to mention that can be defined in terms of transport operators and from that of consumers (fig.1) using the service.

Transport operators responsible for the designated transport lines are interested in the probability that the means of transport (trains and buses) used for the service will be operated in accordance with a pre-planned schedule (which may be designated as a reliable schedule). For them reliability involves costs as they have to devote part of their resources to deal with the consequences of unreliability. The user on the other hand is interested in the probability that he or cargo will reach its destination at the desired time.

It should be noted that the reliability of a given transport system influences the decision of the trip (time of departure, those decisions are made in order to reach the defined destination at a specific time). This is particularly relevant for business trips when the delay shall be adopted that there is a very high value of the harm. When deciding on departure time traveler strives to minimize the waiting time (futility) in his journey. The traveler should plan extra time for travel since it is forced to leave early to add buffer time and thus devour the unreliability of the transport system in time. This extra time the passenger is considered as costs of the person as taken away his time traveler can use for other potentially more productive activities.

Lack of reliable transport services can have a significant impact on costs and may also affect the transport system. On the other hand, the increase of reliability allows the operator to optimize the use of resources. By reducing the recovery time, operators can increase the availability of drivers and vehicles. Observance of schedules allows the operator to reduce the number of spare vehicles and drivers. The improvement of regularity will reduce the average waiting time of passengers and improve the efficiency of capacity utilization of vehicles. According labor [2] by improving the infrastructure can increase capacity: enhance transport service lines and transfer points, building new highways and roads, improving and constructing new railway lines and terminals. Increase the supply reliability of transport systems leads to reduced likelihood of an unexpected meltdown in service.

Reliability of the various transport systems can be defined in different ways. In the labor [1] reliability defined as the probability of realization of trips within a specified period of time. Travel time depends on many factors. It must be recognized that there are many indicators which are used for expression of efficiency of system reliability. Reliability of public transport is often expressed by the accuracy of the arrival and/or departure of stops and stations. In the railway transport accuracy can be defined as the number of trains run on time.

Unlike rail, the reliability of the road sector is often measured by the average travel time. Average travel time is determined by the expected and unexpected delays (fig.2). Unexpected delays lead to differences in the trip any subsequent trip. Can be identified two forms of unexpected delays. The first concerns the travel time for trips taken at the same time each day (variability) and the second, which concerns the random delays that are the result of accidents or repairs.

Given that the user of the transport system must take into account the expected average travel time and its variability.

![Tracking reliability in terms of transport operators and users.](image1)

![Travel time distribution](image2)

To reduce the risk of delay to reach the desired destination, the traveler must provide more than the average travel time. This is shown in Figure 2, where $\mu$ represents the average travel time. User expectations in terms of travel time are related to the variable of parameter $\mu$. 

Fig.1 Tracking reliability in terms of transport operators and users.

Fig.2 Travel time distribution
Common featured indicator for the reliability of the transport system is that they do not relate to possible options of travel time (day to day), its distribution or particular form of distribution. The distribution of travel time from day to day can be characterized by two features of this trip-width (variance of travel time) and the distortion (the model of distribution of travel time) or more widely or more distorted timing travel to definitely time of day and day to day of the week, less reliable travel time.

By increasing the quality of transport infrastructure that provides the ability to cope with the consequences of extreme weather conditions the probability of reliability (safe travel, meeting the requirements of the traveler, and allows you to organize activities) increases. Bad weather conditions affect the reliability of the transport system. On the one hand deteriorating road conditions leading to a reduction in speed and delays, and the other severe weather conditions increase the likelihood of accidents, leading to disruption of traffic flow and unreliability. The provision of higher capacity may also improve the reliability of the transport system, especially when the unreliability arises from high levels of traffic. The extra capacity can also lead to less vulnerability of the system, if they are provided with alternative connections.

Information plays an important role in the management of reliability. The provision of information to the user who uses a transport system, gives the opportunity to organize your trip (choose another route to arrive on time to the selected destination; delay may be inevitable, if no there is an alternative route). In this case the provision of information can soothe the user and reduce the stress of unforeseen delays. The information can be divided into pre-and during the trip. Probably consequences of delay can be reduced by both forms of information. Information before traveling enables the planning of the trip and thus avoids the possibility of unreliable trip. Information during the trip allows the user of the transport system to change initial planned trip according to current traffic conditions. The provision of information is helpful for both consumers and operators of transport systems. The prediction of travel time allows the operator to plan the response time to incidents and operational problems, while real-time information allows effective monitoring of events development. Reliability of transport systems can be influenced by the quality of information. The more accurate the information provided to the consumer, the more expected travel time approaches the actual travel time and leads to higher reliability of transport systems.

4. Conclusion

We can conclude that in terms of solving the problems of reliability, (fig.3) a transport system can be optimized by:

- Increasing the physical infrastructure capacity or by providing additional capacity or improving existing capacity;
- Better management of existing capacity. This can increase the reliability as well as poor management can increase unreliability;
- Provision of information to consumers, which enable them to reduce the adverse effects of reduced reliability. This can be a cost-effective way to reduce the unreliability and possible impact of unexpected delays in business or personal travel.

References

ROAD INFRASTRUCTURE AND TRAFFIC PARAMETERS - MAIN FACTORS AFFECTING TRAFFIC SAFETY

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Abstract: Within the transport process there is continuous interaction between the three main factors: behaviour of road users, infrastructure conditions and characteristics and vehicles. As a matter of fact, the aforementioned factors are key sources of causes for traffic accidents.

The purpose of the present article is to propose such a road traffic organization that would reduce congestions, minimize the number of road accidents and the risk to health and life and would enhance safety. In this context certain characteristics of a specific road section in Bulgaria will be examined. Furthermore measures for improving traffic conditions and safety will be defined.

Keywords: TRAFFIC ACCIDENTS, ROAD TRANSPORT SAFETY, VEHICLE, TRAFFIC

1. Introduction

Road accidents lead to huge social and economic losses for society. They are becoming a serious problem for the Bulgarian health, since they have a direct impact on mortality and morbidity.

The traffic process is a continuous interaction between the three main factors: behavior of road users, safety of road infrastructure conditions and characteristics and vehicles. An important indicator also participates in the interaction - pre-medical and specialized medical care. Equal attention should be paid to the improvement of each of these factors by developing goals and programs related to a higher level of safety.

Because of the mentioned above, the following study is related to measures that would help to: reduce congestion in a chosen area, minimize the number of road accidents, reduce the risk, prevent traffic accidents and enhance safety. For the purposes of the study and monitoring of infrastructure impact on traffic safety, the following are selected: an intersection and a road area with a high concentration of accidents. The activities that form the safe behavior of road users, better construction and maintenance of road infrastructure, lower traffic conflicts and ensure participants' protection are of a particular concern.

2. Key factors affecting road traffic safety and the choice of road section

2.1 Overview of the main factors affecting traffic safety

Traffic safety depends on the failure-free operation of all the elements in the ‘Driver - Vehicle - Road – Environment’ System, hereinafter DVR system. The system’s reliability depends on the perfection of its individual elements, which can be represented by the equation of the reliable operation of the system (1):

\[ P_{DVR} = P_D \cdot P_V \cdot P_R \]

Where:

- \( P_D \) - probability of a reliable operation of the driver;
- \( P_V \) - probability of a reliable operation of the vehicle;
- \( P_R \) - probability of a reliable operation of the road.

One of the main objectives is to study the influence of typical factors related to traffic safety. The most important and responsible element of the DVR system is the driver. His psycho-physiological capabilities are insufficiently studied and hard to maintain. Therefore the reliability of the driver can be assessed indicatively and this element appears to be the weakest in the system. According to formula (1), reducing the probability of a reliable operation of one of the three elements of the DVR system, safety deteriorates sharply and causes traffic safety problems, i.e. it leads to emergency situations that most often end with accidents.

The solution to the traffic safety problems, based on the systematic approach that takes into account the interactions and relationships of all elements in the DVR system, is shown in formula (2). The probability of an accident is presented as a function of factors, depending on the driver - D, vehicle condition - V, road conditions - R, traffic movement - TM and random factors - RF:

\[ P_{RA} = f(D, V, R, TM, RF) \]

The results of various studies on the factors above associated with accidents in several European countries are shown in papers [1, 6]. According to the data provided in these studies, it appears that the human factor is decisive in 68% of the accidents. When taking into account accidents in which the human factor is combined with other factors that are considered to have contributed for the accident, this rate reaches 91.5%. The human factor becomes even more important for reliable operation of the DVR system, if it is subjected to alcohol and drug influence. Research in Norway [3] shows the relative risk of a participation in an accident when drivers are with different levels of alcohol in their blood (grade of intoxication). The relative risk of participation into an accident increases in non-linear relationship with an increase in alcohol intoxication.

Different studies show that the biggest accident rate is in the highway and after that on secondary and tertiary roads. The traffic condition is presented by the characteristics intensity and speed. Accidents increase to about 80%, when the traffic intensity is increased from 10 to 100%. The proportion of people killed also increases by approximately 25 %, which means that an increase in intensity (especially when it gets close to the throughput of the road) raises driver's discipline, reduces the speed and hence leads to lighter consequences of accidents. Furthermore, streets with greater intensity are with better driving conditions. The rate of accidents in highways is the highest due to the high intensity and dissipation speed. Variance of speed has the most significant impact on traffic safety compared to the average velocity of the flow. Deviation from the average speed for the section leads to more interaction between vehicles and a greater likelihood of accidents. Drivers who move at a speed considerably lower or higher than the average speed of the traffic flow participate more often in accidents than those who stick to the average speed. Data for a tolerance of 50% of the average velocity of the flow (50 km/h) is given in [2, 7]. Surprisingly, the results show that the deviations from the average speed is the main reason for the accidents, not the level of speed. The highest velocity (speed limit) to pass through the turn without sideslip, provided that the driver did not slow down and/or accelerate the vehicle can be calculated by the expression:
Taking into account all the factors that influence the number of road accidents, it can be said that they are the same for Bulgarian conditions, but it is necessary to pay attention to the statistics in terms of the specific conditions of the chosen road section.

With regard to Bulgarian conditions as a result of road accidents 601 people were killed and 8193 were injured on Bulgarian roads in 2012. There is a decrease of 56 killed and 108 injured compared to 2011. The reduction of the victims for the two years (2012 and 2011) compared to 2010, which is the base - 156 (20.6%), shows a significantly faster rate of decrement of the number of victims compared to the national strategy objectives for improving road safety in Bulgaria [5]. The implementation of targets for the reduction of road casualties in Bulgaria by 50% until 2020 [4] continues, paying close attention to the priorities set in the national and regional strategies and action programs related to active and passive safety.

2.2 Characteristics of the chosen road section

The causes of road accidents can be divided into two groups: subjective - related to human behavior, as a participant in the movement; objective - related to the imperfection of the traffic conditions and vehicles. The aim of this article is to analyze road accidents in a chosen road section and to identify the most common reasons for their occurrence. The following main tasks are settled: identifying the object and scope of the study on various indicators of registered accidents; collection and processing of data from the records of accidents; identifying the methodology for processing data; statistical treatment of the data; analysis of the results obtained; conclusions and recommendations for improving traffic conditions and traffic safety.

The 'Pernik - Vladaia' road section is selected for the study, because it is part of the national road network in Bulgaria. The importance of the road section is defined by its affiliation to class road I-1, which is part of the national road network and important thoroughfare in the country. It is also a key link between the two neighboring countries: Romania and Greece. National Road I-1 is the westernmost of first class roads and connects the city of Vidin with the border checkpoint Kulata - Promachon, passing through Sofia. Its total length is 453.8 km. The road is part of the European route E79 - Oradea - Craiova – Vidin - Sofia - Thessaloniki. The concerned section starts from the 'Dragichevo' junction and ends up in the 'Vladaia' checkpoint. The section has a total length of 8.3 km. Daily thousands of cars, buses and trucks pass through it. The road surface is worn and not in a good condition. There are many bumps and holes that hinder the movement of vehicles and are a prerequisite for serious accidents. The number of accidents is extremely high and most likely the road is one of the busiest and most dangerous in the country. Traffic jams that occur because of the two-lane road pass 'Vladaia' are a routine.

According to the Bulgarian Road Infrastructure Agency the condition of the road surface of the section at the end of 2012 is extremely high and most likely the road is one of the busiest and most dangerous in the country. Travelers to Sofia are around 30 000 to 40 000 people. The movement is as follows: workers - 67 %, employees - 21 %, unemployed - 2 %, entrepreneurs – 6 % and others - 4 %.

In this sense, the 'Pernik - Vladaia' road section is not only a part of the transport artery of the country and a mean for improvement of the functioning of the transport links, but also the impetus for socio-economic development of the region. The commissioning of the 'Lyulin' highway significantly relieved the traffic intensity (Tab. 1), but the section still remains extremely busy. One reason is the steady increase in the number of vehicles.

<table>
<thead>
<tr>
<th>Years</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic intensity vehicles/day</td>
<td>50000</td>
<td>50000</td>
<td>50000</td>
<td>50000</td>
<td>50000</td>
</tr>
</tbody>
</table>

According to the 'traffic police', traffic over the years has doubled. The 'Lyulin' highway takes at least half of the potential traffic at the 'Pernik - Vladaia' section and almost 100 % of that of heavy vehicles. Traffic load reaches 90 % of the throughput of the road section and a pronounced unevenness in the morning and evening hours of the day. The flow is directed to the capital - in the morning and to Pernik – in the evening. Results obtained from the traffic counts show that the highest load is in the intervals 6:30 a.m. to 8:30 am and 4:30 to 6:30 pm, which is why they are defined as peak. An average daily traffic volume of 18 000 vehicles shows that 3 000 cars have passed through the terminal from which the observation was made during the peak hours. In some parts of the road section, where the traffic is one-way, separation of traffic flows is made in two-way traffic through road cones, which facilitates the movement.

An essential traffic characteristic is speed. Speed is limited primarily in conflict points between vehicles or between vehicles and pedestrians, as well as in areas with minimum turning radius according to weather conditions (respectively the coefficient of adhesion).

Parameters of the road that affect the speed driving mode are horizontal curves with their characteristic radii and the condition of the road surface (dry, wet and icy where the adhesion coefficients are 0.7, 0.2 and 0.4).

Drainage facilities in the greater part of the region are missing. Due to roadside vegetation, which varies seasonally, the visibility is limited. There is discrepancy between the actual road markings and visibility when cornering at the observed section. Some parts of the section are narrower than others. Speed limitation is made through road signs and artificial obstacles.

In the present road section there are three pedestrian crossings. Two of them are well signalized and marked with road signs. It should be noted that the third, except lane markings, does not have any other indicators. There are two well signalized intersections in the chosen section. Speed is limited to 40 km/h at the intersections. Speed limitation is 50 km/h in areas with high risk. Almost all of the remaining parts of the section have a limit of 60 km/h. These restrictions are aimed at reducing the number and severity of accidents, but they also reduce effectiveness of the transportation process, due to the lower average speed for the whole section, which is about 50 km/h. This leads to the formation of traffic jams in rush hours throughout the day. Continuous prohibitions for overtaking with the help of road signs lead to a strong variation in speed compared to the average speed of the site or the limited one. There are significant variations in velocity - from under 30% to over 110% at the section. The critical radii of the road curve are 2 and they cover about 800 meters of the road section or about 9.6 % of it. Longitudinal slopes uphill and downhill are negligible (less than 3%) and they do not affect significantly the speed mode. The
vertical signalization is acceptable - there are about 70 signs. Limits are signposted by road signs B26 and B24.

3. Analysis of traffic safety

Relative objective indicators to assess the status of road safety are weight factor of the consequences (severity coefficient) and mortality rate of the accident (fatality coefficient).

The weight factor is determined by the expression:

\[ K_s = \frac{n_f + n_i}{n} \]

The mortality rate is determined by the expression:

\[ K_f = \frac{n_f}{n_f + n_i} \]

Where:
- \( n_f \) - number of casualties (fatal) in a road accident;
- \( n_i \) - number of casualties (injured) in road accidents;
- \( n \) - number of the registered serious road accidents.

3.1 Road conditions in the 'Pernik - Vladaia' section

A summarized data for accidents in the 'Pernik - Vladaia' section is given in tab. 2 for the 2008 - 2012 period. Coefficients \( K_s \) and \( K_f \) have the highest values in 2011:

Most accidents occur in normal weather conditions: in clear weather - 113 or 54% (Tab. 3), dry roads - 141 or 68% (Tab. 4) and good visibility - 117 or 56% (Tab. 5). For the period between 2008 and 2012, there is no data for the passing vehicles and their distribution along the entire length of the road.

It can be assumed with sufficient accuracy that along the road traffic volume was not large and in the variable range. Under these conditions, the density of accidents for the mentioned period for the individual sections can be calculated using the equation:

\[ K_{da} = \frac{N_f}{L} \]

3.2 Analysis of traffic conditions and safety of road section with a high concentration of accidents - I-1B

Terms and criteria for identifying and securing areas with a concentration of road traffic accidents (RTA) and categorizing the safety of roads (road infrastructure), open to the public, are regulated by Ordinance № 5 of the Ministry of Interior of the Republic of Bulgaria from 2003.

In the present 'Pernik - Vladaia' road section there is an area with high concentration of accidents (black spot), which is the intersection of Rudartsi. The identification number of the section is I-1B, with length of 300 m. The relative indicator of accident rate \( U_r \) (column 5 of tab. 7), according to the ordinance is given by:

\[ U_r = \frac{Z}{Q \cdot L} \]

Where:
- \( Z \) - number of accidents, occurring in researched road section for one period;
- \( Q \) – average daily traffic volume for the same period of time (vehicles per day);
- \( L \) – length of the road section (km);
- \( T \) – number of days in which \( Z \) number of accidents have occurred, i.e. \( T = 365 \).

The severity of accidents occurring in the Rudartsi intersection (column 6, tab. 7) is defined as the ratio between the number of those who have been killed and/or injured and the total number of accidents.
surface conditions, the brightness of the place of accidents and visibility of the road and its accessories.

Most accidents occur in clear weather - 88 or 72% (Tab. 8), on dry roads - 90 or 73% (Tab. 9) and good visibility - 84 or 68% (Tab. 11).

The most of the accidents occur during the periods of most active movement during the day, i.e. with the highest traffic volume. There is a rise in accidents due to poor perception of the movement and the road from drivers in the darkest part of the day. Drivers underestimate the situation and risk more than in conditions of poor visibility. The same applies to traffic movement on dry roads. Drivers are more careful and cautious on wet and snow-covered roads. Approximately 90 % of the accidents occur on straight horizontal sections. The obvious reason here is the absence of fast lane.

The most common accidents in the area are a consequence of driver's fault and are 'crashes with a moving vehicle ahead' and 'collisions between vehicles'. There is no practice in indicating poor road and weather conditions in 'Traffic Police' reports as a reason for an accident, although one of the accident causes is loss of control due to attempt of the driver to avoid bumps and holes in the lane. Most often the main reason related to road accidents is speeding, which does not allow the driver to avoid the collision. Other reasons include failure to comply with the necessary distance, which is a prerequisite for avoiding accidents or withdrawal of advantage. A small percentage of accidents are caused by inexperienced drivers or due to technical fault in the vehicle. Information processing allows a pooled analysis of the road section characteristics, contributing to the accident realization, to be made.

### 4. Activities for improvement of road conditions and safety

Based on the analysis, carried out in surveys and taking into account the objective and subjective factors the following measures can be identified to improve road conditions and safety in Bulgaria:

- by the supervisory authorities of 'Traffic Police': making arrangements for the exercise of active control, use of new tools for operational monitoring of traffic and the behavior of road users; increased control over compliance with the speed; zero tolerance for drivers engaged in serious violations of the Law of Road Traffic;

- by road users: learning the techniques and skills to control vehicles in complex traffic conditions, introduction to the benefits of timely information on the state of the road and the traffic conditions; targeted set of measures for younger and older drivers (over 65), introduction to the benefits of active and passive safety;

- from the bodies of administrative management (municipal and regional governments): to draw attention to the maintenance of markings and lanes; strict control over companies concerned with the excavation of roadways for maintenance and quality control of pavement reconstruction, continuous information on the Internet about the current status of road conditions and traffic in the area, construction of information equipment for speed registration and visualization of violations for places with high concentration of accidents. It is necessary that the road sections meet modern requirements for quality infrastructure.

### 5. Conclusion

The serious deficiencies in the training and qualification of drivers lead to increased number of accidents due to speeding and inability to respond quickly and adequately in distressed situations. The low road culture of the majority of road users violating traffic rules, poor state control and unsatisfactory road infrastructure conditions lead to the occurrence of accidents, which are enormous material and personal loss for society. It is necessary to identify priority areas in which traffic safety organizations to work. An interaction between state institutions is necessary to improve road safety at national, regional and municipal level.

### References


THE EFFECT OF FUEL VARIATION ON FLAME PROPAGATION IN IC ENGINES WITH STRONG MACRO FLOWS

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Abstract: In this paper some results concerning the evolution of flame propagation through unburnt mixture of two different hydrocarbon fuels, such as CH4 and C8H18, in engines with strong macro flows were presented. Flame propagation was represented by the evolution of spatial distribution of temperature in various cutplanes within combustion chamber. Flame front location was determined in zones with maximum temperature gradient. All results were obtained by dint of multidimensional modeling of reactive flows in arbitrary geometry of IC engine combustion chamber with moving boundaries. In 4-valve engines the fluid flow pattern during intake is characterized with organized tumble motion pursued by small but clearly legible deterioration in the vicinity of BDC. During compression the fluid flow pattern is entirely three-dimensional and fully controlled by vortex motion located in the central part of the chamber. For that reason these engines are designated as IC engines with strong macro flows (swirl, squish, tumble) yielding non-spherical flame shapes usually encountered in quiescent flows. Flame propagation results for both fuels were obtained with eddy-viscosity model i.e. with standard k-ε model of turbulence. The interplay between fluid flow pattern and flame propagation is entirely invariant as regards fuel variation indicating that flame propagation through unburnt mixture of CH4 and C8H18 hydrocarbon fuels is not chemically controlled but controlled by dint of turbulent diffusion.

KEYWORDS: FLAME PROPAGATION, TURBULENCE

1. Introduction

It is known for a long time that various types of organized flows in combustion chamber of IC engines are of predominant importance for combustion particularly with regards to flame front shape and its propagation. Some results related to the isolated or synergetic effect of squish and swirl on flame propagation in various combustion chamber layouts are already analyzed and published [1, 2] but results concerning the isolated or combined effect of the third type of organized flow i.e. tumble are relatively less presented and sometimes ambiguous [3, 4]. For instance some authors [5] studied the development of swirl and tumble in five different intake valve configurations and found that when both inlet valves are opened no defined tumble flow structure was created rendering quick vortices dissipation before BDC. In spite of the fact that tumble flow is inherent to multi-valve engines some authors have demonstrated that some two-valve engines exhibit characteristics similar to tumble flow [6, 7]. In addition, the fairly similar fluid flow patterns in the vicinity of BDC in various combustion chamber geometries yield entirely different fluid flow patterns, spatial distribution of kinetic energy of turbulence and integral length scales of turbulence in the vicinity of TDC [8]. In such occasions the significance of organized tumble flow is fairly relative. Some theoretical and experimental results show that tumble is of prime importance for specific power and fuel economy increase in modern engines with multi-valve systems.

From the theory of turbulence is known that vortex filament subjected to compression reduces its length and promotes rotation around its axis yielding the movement on the larger scale (“spin-up” effect).

It can be presumed that tumble pursues the same rule i.e. the destruction of formed and expressive tumble during compression stroke generates the higher turbulence intensity and larger integral length scale of turbulence in the vicinity of TDC contributing to the flame kernel formation period reduction and faster flame propagation thereafter. The aforementioned logic imposes the conclusion that the most beneficial fluid flow pattern in the vicinity of BDC is well shaped high intensity tumble. Some additional objectives in this paper were qualitative and quantitative characterization of fluid flow pattern during induction and compression in a particular 4-valve engine, the analysis of the valve/port assembly from the point of compliance with presumed ideal fluid flow pattern and the clout of turbulence model variation on fluid flow and turbulence parameters.

2. Model and computational method

The analysis of this type is inherent to multidimensional numerical modeling of non-reactive fluid flow and therefore it is quite logical to apply such a technique particularly due to fact that it is the only technique that encompasses the valve/port geometry layout in an explicit manner. In lieu of the fact that, in its essence, multidimensional models require initial and boundary conditions only their applications is fairly complicated and imply some assumptions and simplifications [9]. The full 3D conservation integral form of unsteady equations governing turbulent motion of non-reactive mixture of ideal gas is solved on fine computational grid with moving boundaries (piston and valves) in physical domain (500,000-980,000 cells) by dint of AVL FIRE code [10]. In this case the numerical solution method is based on a fully conservative finite volume approach. All dependent variables such as momentum, pressure, density, turbulence kinetic energy, dissipation rate, and passive scalar are evaluated at the cell center. A second-order midpoint rule is used for integral approximation and a second order linear approximation for any value at the cell-face. A diffusion term is incorporated into the surface integral source after employment of the special interpolation practice. The convection is solved by a variety of differencing schemes (upwind or donor cell, interpolated donor cell, quasi second order differencing, central differencing, MINMOD and SMART). The rate of change is differenced by using implicit schemes i.e. Euler implicit scheme and three time level implicit scheme of second order accuracy. The overall solution procedure is iterative and is based on the Semi-Implicit Method for Pressure-Linked Equations algorithm (SIMPLE). For the solution of a linear system of equations, a conjugate gradient type of solver (CGS) is used. In this quest a nearly forty years old k-ε model of turbulence was used. This model based on Boussinesq`s assumption is certainly the most widely used model of turbulence for engineering computations. On the contrary to some other models, such as Reynolds-stress closure model [11], its implementation is numerically robust due to simplicity of the model and at the same provides an acceptable level of accuracy for particular applications.

The second one, relatively recent k-ξ-ε model of turbulence i.e. eddy-viscosity model based on Durbin’s elliptic relaxation concept [13, 14] and its effect on flame propagation was already analyzed [12] and is not under the scope of this paper. This model solves a transport equation for the velocity scale ratio ξ instead of imaginary turbulent normal stress component. In addition, the pertinent hybrid boundary conditions are prerequisite.

3. Results and discussion

The flame propagation through unburnt mixture of two different hydrocarbon fuels, such as CH4 and C8H18, was analyzed by dint of the evolution of spatial distribution of temperature, represented in form of iso-contours, in six cutplanes passing through various parts of fairly complicated IC engine combustion chamber geometry layout presented in figures 1 and 2. Obviously, combustion chamber is constrained with dual intake and exhaust valves. The basic block
data sheet consists of bore/stroke ratio = 80/81.4 mm, squish gap=1.19 mm, engine speed RPM = 5500 min⁻¹ and mixture quality λ=1. It should be stated that maximum valve lift is 6.95 mm for intake valves and 6.63 mm for exhaust valves while the other geometrical data (relative location, valve shape etc.) could be seen in fig.1 and 2.

**Figure 1.** Perspective view of the combustion chamber geometry layout with 4-valves (upper view)

**Figure 2.** Perspective view of the combustion chamber geometry layout with 4-valves (bottom view)

The first cutplane is x-z plane passing simultaneously through both one intake and one exhaust valve displaced 1.16cm along y axe far away from the symmetry plane (y=const.=1.16). The second cutplane is x-z symmetry plane itself (y=const.=0). The third and fourth cutplanes are y-z planes passing either through both intake or exhaust valves respectively and displaced appropriately forward and backward along x axe (x= ± const.). The fifth cutplane is x-y plane passing through mid-height of the combustion chamber while the sixth cutplane is x-y plane passing through squish zone.

The flame propagation i.e. the evolution of spatial distribution of temperature in the first cutplane for C8H18 and CH4 fuels is shown in figs. 3-10.

**Figure 3.** Spatial distribution of temperature in x-z plane, y=const. (1.16) at 355 deg. ATDC, k-ε, C8H18

**Figure 4.** Spatial distribution of temperature in x-z plane, y=const. (1.16) at 355 deg. ATDC, k-ε, CH4

**Figure 5.** Spatial distribution of temperature in x-z plane, y=const. (1.16) at 360 deg. ATDC, k-ε, C8H18

**Figure 6.** Spatial distribution of temperature in x-z plane, y=const. (1.16) at 360 deg. ATDC, k-ε, CH4

The flame propagation i.e. the evolution of spatial distribution of temperature in the second symmetry cutplane for C8H18 and CH4 fuels is shown in figs. 11-20.

**Figure 7.** Spatial distribution of temperature in x-z plane, y=const. (1.16) at 365 deg. ATDC, k-ε, C8H18

**Figure 8.** Spatial distribution of temperature in x-z plane, y=const. (1.16) at 365 deg. ATDC, k-ε, CH4

**Figure 9.** Spatial distribution of temperature in x-z plane, y=const. (1.16) at 370 deg. ATDC, k-ε, C8H18

**Figure 10.** Spatial distribution of temperature in x-z plane, y=const. (1.16) at 370 deg. ATDC, k-ε, CH4

**Figure 11.** Spatial distribution of temperature in x-z symmetry plane, y=0.0 at 345 deg. ATDC, k-ε, C8H18

**Figure 12.** Spatial distribution of temperature in x-z symmetry plane, y=0.0 at 345 deg. ATDC, k-ε, CH4

**Figure 13.** Spatial distribution of temperature in x-z symmetry plane, y=0.0 at 350 deg. ATDC, k-ε, C8H18

**Figure 14.** Spatial distribution of temperature in x-z symmetry plane, y=0.0 at 350 deg. ATDC, k-ε, CH4
The flame propagation i.e. the evolution of spatial distribution of temperature in the sixth cutplane for C8H18 and CH4 fuels is shown in figs. 21-30.
fuels used (C8H18 and CH4) yielding the conclusion that flame front shape in all cutplanes were encountered for both hydrocarbon front shape and its displacement are not chemically controlled but due to chemical reactions. 

gradient across the flame front and the effect of large heat release behind the flame front, the sign and the magnitude of the density turbulence, compression by the flame, increase of the viscosity inter alia, flame generated and its displacement. These are, vortices into smaller ones and their dissipation into heat.

controlled by dint of turbulent diffusion i.e. by high intensity of are of prime importance for the determination of flame front shape and its displacement  yielding the conclusion that aforementioned invariance is valid for broad range of hydrocarbon fuels.

4. Conclusions

The flame front shape and its displacement in IC engine combustion chamber with strong macro flows are entirely invariant as regards fuel variation tested indicating that flame propagation through unburnt mixture of CH4 and C8H18 hydrocarbon fuels is not chemically controlled but controlled by dint of turbulent diffusion.

Heat release term due to chemical reactions on right hand side of energy equation is of no importance for flame front shape and its displacement yielding the conclusion that aforementioned invariance is valid for broad range of hydrocarbon fuels.

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PROECOLOGICAL ENERGETIC SYSTEMS FOR FISHING CUTTERS

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Abstract: In view of the hazards to the environment resulting from operating fishing cutters, a proposal for energy saving and proecological energetic systems for these vessels is presented in this paper. It also demonstrates the significance of the proecological energetic systems, includes a review of the impact of fuel type, renewable energy sources and energy conversion methods on the degree of the hazards to the environment. The proposed solutions regarding the energetic systems refer to the fishing cutters of the length from 15 to 30 m. The solutions are divided into two groups according to currently available technologies and future technologies allowing for alternative energy sources to be applied.

Keywords: FISHING CUTTERS, ENERGETIC SYSTEMS STRUCTURE, ECOLOGY

1. Introduction

The marine fishing industry constitute a major food supplier. This task is performed by fishing fleets belonging to the particular countries. The Polish fishing fleet operating at the Baltic Sea, in 2013, comprised of 142 of the fishing cutters the length of which equaled from 15 to 26 meters, while in 2004 there was 411 fishing cutters operated [3]. Such a considerable decrease results mainly from the catch limits, compensations granted to fishermen for vessels’ scrapping and from the age of the operating fishing cutters, most of which is over 30 years old [2,3]. The energetic systems of the Polish fishing fleet, due to the old generations and the long operation periods of machines and devices, are characterized by high energy consumption and considerable environmental load [2]. Grants from the European Fisheries Fund allow for obtaining financing only for the replacement of engines for the main propulsion system with the engines of newer generation with less fuel consumption, which very frequently, does not provide an expected improvement of the operational properties of the propulsion system [2].

The reduction of the energy consumption of the energetic system may be obtained by a comprehensive approach to the issue by: a development of concepts and system design, the selection of energy saving and proecological machines and devices, drawing up and the implementation of energy management procedures.

When designing prospective energetic systems for the fishing cutters, an option of using alternative fuels and renewable energy sources should be considered, too.

Such an approach during a design process is furthermore in compliance with the sustainable development principle, strongly promoted in the European Union states, which consists in the integration of ecological, economical and social goals, the IMO requirements regarding the environmental protection and the Code of Conduct for Responsible Fisheries developed by FAO [5].

Aspiration to the sustainable development, in practice, requires:
- closing material cycle: raw materials – production processes – product use – waste and impurities – after utility raw materials,
- the reduction of energy consumption by increasing energy efficiency [7], the use of the renewable energy sources and the alternative fuels,
- quality promotion including, but not limited to, in terms of product durability, the minimization of waste and the environment protection.

This paper presents the developed conceptions of the energetic systems for the fishing cutters of the length up to 30m, divided into projects in which modern technologies were applied and prospective projects including future technologies.

2. Significance of proecological energetic systems

The most beneficial impact on the environment protection may be achieved when certain actions, involving mainly the improvement of the existing technologies and the development of new ones, are undertaken at a design stage. The proecological designing will, inter alia, contribute to the reduction of generated waste and impurities, the limitation of materials’ and energy resources’ consumption. Above all, a product, which in the particular case is a fishing cutter, should have higher energy efficiency and its operation should have the least effect on the environment.

The processes of generating mechanical energy, electricity and heat for the fishing cutters include the opportunities for actions directed at the improvement of energy and environmental indicators. The most significant are:
- further development of internal combustion engines, boilers, electric generators and auxiliary devices and control systems leading to the improvement of ship energetic system efficiency and the reduction of the burden on the environment,
- the wider use of alternative liquid and gas fuels, in particular hydrogen,
- the implementation of fuel cells in connection with hydrogen application
- the use of hybrid systems based on fuel cells and heat engines
- the use of energy from renewable sources,
- energy use rationalization.

Certain abovementioned actions require a comment. The use of energy from the renewable sources is strongly promoted in the European Union member states. Not all onshore technologies, using renewable energy sources, may be efficiently applied at ships. One of the physical properties of the renewable energy is its low density when compared with the conventional energy. For instance, solar radiation is characterized by a density <1,33 kW/m2, wind by a density <3 kW/m2, while e.g. coal combustion in a boiler is a value of 500 kW/m2 [4,6,12]. This property of the renewable energy causes that it is hard to use it at ships, in particular at small vessels, where the space is limited. Nonetheless, in case of bigger cutters it is worth to consider to use photovoltaic panels installed at the roof of the superstructure. Return to sail supporting main propulsion system may also be intentional. The actions aiming at using the energy from the renewable sources refer also to biofuels.

Hydrogen, the wider use of which is also postulated in shipbuilding, is a perfect fuel in terms of the environment since water is a product of the combustion process. In nature, hydrogen in a free form occurs in a small amount as it combines easily with other chemical elements. Its resources are considered to be an infinite supply as it is a water component and together with it circulate in a closed cycle in the nature. However, in order to
produce hydrogen, energy is necessary. That causes that at the current conventional fuel price level hydrogen is less attractive. Nowadays most of hydrogen is obtained from the decomposition of hydrogen-rich compounds, including hydrocarbon fossil fuels, which also involves CO₂ emission. If hydrogen is intended to replace hydrocarbon fuels then its production should be related with the use of the renewable energy. Only with such a production method hydrogen is a clean fuel.

Figure 1 presents a scheme showing how fuel type selection or the renewable energy sources and the solutions regarding the propulsion in an energetic system for a fishing cutter affect the environment load.

![Image 1](Fig.1. Impact of energy source and propulsion system configuration on environmental load)

Figure 1 contains liquid and gas fuels which may be used at the ships. The renewable energy sources, as an alternative to the fuels, are included given the fact that their use has the minimum impact on the environment. In that case they are solar energy and wind energy. The proposal to install wind engine as the least burdensome environment may be also debatable, because in effect its impact on the environment is comparable with a photovoltaic cell supplying an electric motor.

Summing up, using the components listed in figure 1 leads to the development of a propulsion system that is more environmental friendly and energy saving, and thereby the entire energetic system for a fishing cutter.

3. Proposed energetic system

Complex energetic systems are at the fishing cutters in question. They consist of more technological devices of the higher total energy demand. Therefore, a proper solution regarding the energetic system is of particular relevance. In that group of the energetic systems many opportunities providing high efficiency occur. The selection of an appropriate energetic system will depend on the specific balances of mechanical energy, electricity and heat.

For instance, the systems with two engines for the main propulsion system may be considered. Such a system, presented in figure 2, is characterized by the high power availability of the wide range of variable operational conditions. An open issue is a power share of each engine i.e. whether to adopt two identical engines or of diversified power. Such solutions also increase propulsion system redundancy. An alternative to the above may be, presented in figure 3, an energetic system occupying less space in the engine room with the use of a shaft generator, which may work also as an electric motor supplied by an auxiliary power generator set. Due to that an auxiliary or emergency propulsion system is provided. Such system's efficiency is slightly lower comparing to a system with two internal combustion engines driving the propeller by a mechanical gear. The final selection may be determined by an engine room size and operational issues. The said systems also include a boiler for heat generation. It should be also mentioned about recommended waste energy use contained mainly in the engine cooling water.

![Image 2](Fig.2. Energetic system scheme for a fishing cutter with two internal combustion engines)

![Image 3](Fig.3. Energetic system scheme for a fishing cutter with internal combustion engine and shaft generator operating as engine)

Particularly recommended solution regarding the energetic system is a system corresponding to a concept of all electric ships [1]. The proposed solution of such a system is presented in figure 4.

![Image 4](Fig.4. All electric ship energetic system scheme)

As presented in the figures 2-4 it is possible to use hydraulic drive for winches instead of the suggested electric propulsion, however, the electric system is subsequently less effective.

4. Prospective energetic systems

It is essential that the decreasing resources of petroleum were taken into consideration upon developing solutions regarding prospective energetic systems for the fishing cutters and basing their work on unconventional fuels. In the short term it will also be possible to use natural gas since its resources are bigger than petroleum. Whereas, in the long term, only unconventional fuels as biofuels or hydrogen are remaining. Temporarily, it may also be intentional to use hybrid propulsion systems based on the
conventional energetic systems in relation with the unconventional energetic systems.

The use of hydrogen as the fuel is usually associated with storage problems due to its specific volume which results in the fact that its supplies require a large volume. In case of the fishing cutters with very limited autonomy usually to 72 hours, the issue virtually does not exist. The use of hydrogen as the fuel is possible not only in piston internal combustion engines but also in fuel cells constituting an electricity source.

For small vessels such as fishing cutters, low-temperature fuel cells may be particularly useful, especially PEMFC (Proton Exchange Membrane Fuel Cell) deemed as the most prospective [9,11]. They are characterized by low work temperature not exceeding 100°C, high density of generated current, short, measured in seconds, start-up period and the possibility of fast load changes. The efficiency of such systems is at the level of around 40%-50% and is higher than the efficiency of internal combustion engines of low power installed on the fishing cutters. The difference is even more noticeable in the partial loads on which internal combustion engines operate less economically than on the nominal load. However, the efficiency of the cells in that case is considerably higher. Such cells are promised to be used extensively in the automotive industry. Apart from the undoubted advantages presented above quite long durability should also be mentioned for this type of cells as well as the lack of competition for them in the ecology field.

The energetic system based on the fuel cell comprises of, except the cell as an electricity source, an inverter converting direct current generated in the cell into alternating current, batteries and electric motors.

One of the advantages of the fuel cells is that water is a byproduct of the reaction of so called hydrogen cold combustion in the cell and therefore due to that there is no need to ensure water supplies. Such a solution eliminates the necessity to dedicate separate room for technical water tanks and reduces the vessel weight. There is also an opportunity to use waste heat from the cell cooling system.

Nevertheless, it appears to be the most realistic in the near future to use the cells as emergency electricity source or to supply the propulsion system during sailing at low speed in ports or at water areas covered by restrictive regulations on exhaust gases toxic components or noise emission. The fuel cells may be also a very good alternative for diesel engine generator sets. Their use in that case comes down to produce electricity only in a limited period e.g. during maneuvers or stay at a port. They may also be used as a local energy source for individual receivers at a vessel.

The energetic system for the fishing cutter with the fuel cell as an auxiliary power source is presented in figure 5 below. While figure 6 shows the energetic system entirely based on the fuel cell, which shall be treated as the furthest prospect for execution.

**Fig.5.** Energetic system scheme for fishing cutter with fuel cell as auxiliary power source

**Fig.6.** Energetic system scheme entirely based on fuel cell

Although costs regarding the energetic system solutions based on the fuel cells are still significantly higher than the cost of the energetic system solutions with internal combustion engines, their development potential should be borne in mind. Further price reduction should be expected upon cell volume production is commenced for vehicles.

Another prospective energetic system that may be applied, in particular at small fishing vessels using passive fishing gear, may be the hybrid system [4], which apart from an internal combustion engine, comprises also of the electric motor, supplied by batteries charged from the photovoltaic cell or from the shore.

Figure 7 presents a scheme of the energetic system with a photovoltaic panel.

**Fig.7.** Scheme of hybrid system with photovoltaic cell

It is also possible to charge the batteries by the internal combustion engine when the electric machine operates as a generator. The propeller may be propelled by the internal combustion engine itself, by the electric motor itself or by both engines simultaneously. Sailing using only the electric motor, beyond the emission limitation of harmful exhaust gas components, has also an advantage that the energetic system does not emit noise.

**Summary**

The energetic system proposals for the fishing cutters presented in the paper are the concepts with regards to the modern and future technologies which may be applied in the shipbuilding, providing the reduction of energy consumption and impact degree on the environment. In order to select the solution for a specific vessel, the system efficiency should be determined, demand for mechanical energy, electricity and thermal energy should be specified on the grounds of an energy audit as well as machines and devices should be fitted.

The energies’ demand is significantly affected by the hull resistance which depends on it shape, by catch type and the fishing gear related thereto. These issues are not presented in the paper as they have no decisive impact on the energetic system configuration. The employees of the Marine Engineering Faculty of the Maritime University of Szczecin have conducted research on marine energy issue for many years. An energy audit methodology has been developed [10], energy research has been carried out [2,3] as well as an energy audit of a number of the fishing cutters. The possibility to use LNG as the fuel has also been considered [8]. The research are implemented in close cooperation with fishermen, scientific and research institutions in
Poland and abroad and with the financial support from the European Union within the granted projects.

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FUNCTIONAL DESIGN, MODELING AND NUMERICAL ANALYSIS OF THE REGENERATOR OF STIRLING ENGINE WITH UNCONVENTIONAL MECHANISM FIK

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Abstract: The paper deals with a design of a regenerator of Stirling engine with unconventional mechanism of engine FIK. The final design of the regenerator is based on previous simulations of flowing of a working fluid, created in software Fluent. The paper presents basic requirements to be followed in the design of the regenerator. The contribution also contains a dimensional computation of the regenerator, which describes basic procedures and boundary conditions in the computation of the designed shape of the regenerator.

Keywords: REGENERATOR, THERMAL EFFICIENCY, UNCONVENTIONAL MECHANISM OF ENGINE FIK, NUMERICAL ANALYSIS

1. Introduction

One of the possibilities of utilization of unconventional mechanism of engine FIK with inclined board is its modification in Stirling engine. [5] In the figure 1, there is a sectional view of a virtual model of the mechanism shown. Stirling engine is a displacement machine, which performs work on the basis of changes of temperature, pressure and volume of the working medium. Stirling engine belongs to a group of engines with external continuous combustion. [6] Its characteristic feature is a closed circulation of the working medium. Nowadays, as the working medium in the design of Stirling engine is used air, helium and hydrogen.

Regenerator represents the heat exchanger and temporary heat accumulator between the heated and cooled side of the engine. Regenerator has a great impact on the efficiency and overall performance of the Stirling engine. Sufficiently large temperature gradient between the heated and cooled side of the engine has favourably influence at a thermal efficiency of the Stirling engine. The greater the temperature difference, the higher the thermal efficiency.

2. Synthesis of knowledge in the design of the regenerator

Regenerator, from the design point of view, may be of a various shape and arrangement. In most cases, the regenerator consists of one or more axial passages. The individual passages are filled with a filler of the regenerator (Fig. 2). Regenerator together with the connecting pipes must be designed for the smallest lossy volume. The lossy volume of engine means the volume, into which, during the work cycle, does not interfere neither the heated cylinder nor cooled cylinder [7].

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together with the filler was exposed to simulation in Fluent software. Functional properties of the regenerator and its filler were verified by using the Fluent software [4]. During the simulations were monitored various parameters such as the temperature inside the regenerator, the speed of heat transfer between the working medium and the filler, the direction of flow of the working medium in its transition between heated and cooled side of the engine, the pressure progressions in the regenerator and more other parameters. On the basis of simulations of flow of the working medium through the various constructional designs of the regenerator was created the final shape of the regenerator, which is shown in Figure 3:

![Figure 3](image)

**Fig. 3** Virtual model of the regenerator: 1 - flange of the cooled cylinder, 2 - flange of the heated cylinder, 3 - body of the regenerator, 4 - connecting tube, 5 - coupling flange, 6 - transition cone.

The bodies of the regenerator with flanges create a major part of the regenerator. The body of the regenerator is made of a copper sheet with thickness of 2 mm and an internal diameter of 51 mm. The steel coupling flanges are welded to the end faces of a regenerator. The inside of the regenerator body is filled with filling from an aluminium material. Used filler of the regenerator depicted at the figure 4 has louvre structure. Aluminium filler is set along in a body of the regenerator. The frontal areas of individual elements of the filler in the body of the regenerator are oriented normal to an axis of the regenerator. These elements are asymmetrically swing concerning to an axis of the regenerator, whereby similar structure as in the figure 2 b) is created.

![Figure 4](image)

**Fig. 4** Structure of the filler of the regenerator.

A transition piping of the heated and cooled cylinder are screwed on the body of the regenerator by flanges. A material of the body of the regenerator and transition piping were designed on the basis of requirements on good heat conductivity and low weight of the entire system. According to figure 5, the construction of both transition pipes is the same. The difference between each of transition piping is just in particular flanges, which are made from steel and by which the whole assembly of the regenerator is screwed on the cylinder head of the nonconventional engine FIK. The transition piping is made from a copper sheet metal thickness 2 mm and inside diameter 19 mm. A part of the transition piping is also a non-coaxial conic passage. This way designed atypical shape of the conic passage is significant due to better flow of the working fluid through the regenerator. Individual parts of the transition pipes are welded to each other. A material of individual flanges, which creates connecting elements between individual parts of the regenerator, is designed on the bases of requirement on higher stiffness of the construction [3].

![Figure 5](image)

**Fig. 5** Transition piping: a) heated cylinder, b) cooled cylinder.

In the figure 6 there is a real model of the regenerator depicted. Before production of the regenerators, numerical computation was realised to verify safety against overloading of admissible stress of the body of the regenerator by an influence of internal overpressure.

![Figure 6](image)

**Fig. 6** Real model of the regenerator.

This computation was realised by computing program Adina. Numerical analyse is in major part of cases markedly less expensive than real testing and experiments. With its help, it is possible to realise many versions of a solution in a very short notice and to appoint a variant, which meets the needs of the production and the usage of the specific mechanical component the best.

4. **Dimensionally verification of the regenerator by the numerical analyse**

By using a finite element method it is possible to simulate loading of a component and so compute an effect of the loading in its volume. It is concerned about a distribution of load and critical position finding with high local value of stress (e. g. sharp edges, step change of a cross section of a component, etc.). Primarily, it is necessary to provide a model of a component to program (fig. 7), which may be built directly in the FEM program or in whatever computer aided program for design and subsequent import to FEM program.

![Figure 7](image)

**Fig. 7** 3D model of body of the regenerator created in the program Adina (left), on the right 2D depiction for better illustration of the shape of frontal area of the regenerator.

If the model of the component is created, it is necessary to put material properties to program. For simple computation of static loading (most of components in engineering), a program for its correct function, makes do with values of elastic modulus,
Poisson’s ratio (presents absolute value of fraction of specific strains), if appropriate density. Chosen material of the regenerator body was a high purity copper 99.9% with a value of elastic modulus $E = 1.1 \times 10^{11}$ Pa, elastic limit $R_e = 60$ MPa, density $\rho = 8940$ kg.m$^{-3}$, Poisson’s ratio $\mu = 0.34$. A computation was carried out with these values of parameters. If we consider thermal loading, it is necessary to assign values of dilatability and heat conductivity factor with known value of elastic modulus at the temperature of the heated regenerator. Whereas this temperature (about 250 °C) presents small value against fusion point of copper (1084.62 °C), an influence of increased temperature (difference between elastic modulus at 20 °C and 250 °C) will be intercept by increasing of surety factor $k$, which will include the influence of loading of regenerator (disappearing compression stress) and increased operating temperature of the regenerator (250 °C). Therefore it was chosen required surety factor $k_{\text{min}} = 2.7$. The following is a loading of component, which needs to be “anchored”, thus define number of degrees of freedom for some of points or surfaces of the component (fig. 8 left).

![Fig. 8](image)

**Fig. 8** Gripping of the regenerator (left) and loading of the regenerator by inside pressure $p = 0.2$ MPa (right).

Gripping of the regenerator is practically solved as fixing into transition piping (as seen on fig. 1, 3, 5 and 6). Therefore gripping of the component was chosen to be a fixing into an area, where transition piping will be attached at assembly (fig. 8 left – green coloured circles). Subsequently, we can apply external loading, if appropriate temperature (at some of surfaces, points or entire solid). In this case, it is a distributed inside pressure about the size $p = 0.2$ MPa (fig. 8 right). After defining material properties and boundary conditions, designing and creating of the mesh follow (fig. 9). A component is divided into many small finite elements and each element has defined material properties in its nodal points.

![Fig. 9](image)

**Fig. 9** FEM mesh of the regenerator.

The entire component is meshed by triangular four – nodal elements (as it is solved as a shell, owing to small thickness of a body wall of the regenerator – 2 mm). Creation of the mesh is the most important step before the computing, because at generation of a wrong designed mesh may come to deformation of the elements in areas with complicated shape of the component – this, during computation, leads to inability of program to accomplish the computation. An important step is setting of time step length of computation or number of steps, because the computation is iterative and must converge. Iterative methods are useful at solving (generally) large systems of non-linear equations by successive approximation to an exact solution.

If we use very dense mesh from complicated elements (i.e. elements from many nodes), it is necessary to enlarge number of steps of the computation to ensure faultless running of computation. After accomplishing of computation by the program, we can display results by post processor (fig. 10 and 11).

![Fig. 10](image)

**Fig. 10** Displayed displacements on the body of the regenerator by the influence of the loading.

5. Conclusion

By numerical analyses it is possible to simulate a process of the loading very real and on the bases of the reached results (stress and strain, temperature field, material structure, hardness, plastic deformation, etc.) is possible to effectively perform optimization of technologies. In this case, maximal effective stress detected by numerical analyse at program Adina, as seen in fig. 11, is located in frontal area of the body of the regenerator in fixing area.

![Fig. 11](image)

**Fig. 11** Simulated effective stress von Mises detected on the regenerator’s body.

Value of this effective stress is 20.78 MPa, what is third of the value of admissible stress of the material, which the component is made from. It means that regenerator’s body designed in this way (geometry, loading) is suitable for utilisation at purpose for which has been engineered with sufficient surety factor in running.

Acknowledgement

This contribution was created within the framework of the project VEGA 1/0482/11 Stirling engine with non-conventional FIK mechanism, which is supported by the Ministry of Education of Slovak Republic and within the framework of the project ITMS 26110230117 Support of education quality and human resource development in the field of technical research and development in the area of modern knowledge society.
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Subject of research was TiAl6V4 alloy in the form of the fine powder. This light alloy (see Fig. 2) has excellent mechanical properties Tab. 2 and corrosion resistance in combination with low specific weight and biocompatibility. The material is mainly used in aviation, in the manufacturing of racing cars and in medical applications (manufacturing of implants, see Fig. 3).


TRANSPORT PLANNING ON THE LIBERALIZED MARKET OF PUBLIC SERVICES

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Abstract: The importance of transport planning in public services gradually becomes to be fully appreciated in the context of the Czech Republic. Public transport such as investment and operationally intensive industries require a guaranteed long-term strategy, not only in the field of transport infrastructure, but also in the field of transport services. The first prerequisite for successful transport planning is the most accurate description of passenger flows, including the parameters affecting the choice of transport mode. These inputs are an important basis for additional steps: the creation of a line network, timetable design, creating circulation of vehicles and courses of staff, controlling, and any requests for infrastructure improvements. At the end of this article are referred specific practical examples, where thanks to a compliance with the rules of theoretical transport planning it has been achieved the increased operational efficiency of public passenger rail-transport.

KEYWORDS: RAILWAY TRANSPORT, PUBLIC TRAFFIC, RAILWAY TECHNOLOGY, TIMETABLE DESIGNING, PERIODIC TIMETABLE, TRANSPORT PLANNING, TRANSPORT DEMAND ESTIMATION, VEHICLE CIRCULATION

1. Defining the objectives of transport planning

Currently, the transport planning in the Czech Republic stands in their factual beginnings. Institutionally transport planning establishes the "Law on public passenger transport services" (194/2010 Coll.), and individual orderers of public transport are thus required to build transport plans for its scope. Public transport in the concept of quality of transport service is more than just a social service for those who have no other option but to achieve an overall transport accessibility of the region so that public transport represent an attractive alternative to individual transport. The law on public passenger transport services (194/2010 Coll.), Title I, § 2, defines the transport service as follows:

Transportation services means the ensuring of transport every day of the week, especially in schools and educational institutions, the public authorities, to work, to health facilities providing basic health care and to meet the cultural, recreational and social needs, including transportation back, contributing to sustainable territory development.

The interpretation of this provision is quite clear, because it does not specify objectives, waiting time, number of transfers, number of connections, the number of people with the same destination and purpose of the trip, walking distance or other parameters of transport services and thus depends entirely on the specific access of the orderer to public transport services. All these parameters of transport services must identify the orderer and transport services are defined as the transport plan.

It is clear that public transport cannot cover all the passenger flows, nor all the transport needs of individuals. Public transport with regard to the need for compensation (income from fares do not cover the cost of providing) must have elements of the mass. If in a particular place and time together transportation needs of individuals in a transport flow, then it can be addressed by public transport organized on a collective basis. With regard to the rational planning of public transport and the final volume of funds for compensation payments (compensation) cannot be on the one hand these resources inefficiently spent on transportation of individuals and on the other hand not to have the resources to ensure transport in relationships with much higher demand.

Theoretical public transport planning takes place at 7 classic steps:

1) Estimation of passenger flows, part of transport modelling
2) Formulation of the line network plans
3) Implementation line network to the infrastructure, revision modal choice
4) Timetable design
5) Circulation plans of vehicles and staff courses
6) Evaluation of the operation performance, controlling
7) Defining the requirements for the infrastructure improvements

This article briefly summarizes selected procedures leading to greater operational efficiency. On the example of planned tender for a rail carrier in the regional transport on the selected lines in the Region Jihočeský kraj, it is shown, how the compliance with the theoretical rules can lead to a reduction in the number of operating rolling stock, while increasing the supply of the connections. Because the regions compete in a regular public transport by the so-called "gross principle", where the yield risk is on the side of the public authority, this article focuses primarily on such transport-planning processes that affect the cost side of the transport concept.

1.1. Characteristics of passenger flows

The information of passenger flows is currently available mainly from the CSO data - data on the number of permanent residents in the municipalities and their local areas, information about regular commuting. Further information is available from carriers - information about the load-factor, number of boarding and alighting passengers at each stops, shortly will be provided the origin-destination matrices. For more information on the origins and destinations relate mainly to number of employment opportunities (data from major employers) and regular commuting school children - these data are used in abundance in the case of larger optimization of timetables in the region.

Available CSO data are not broken down by mode of transport attributable to a specific origin-destination, because this is the information about the total passenger flows - across all modes of transport. On the contrary, data from carriers are related only to a particular type of service and thus have explanatory power only for passengers who already use the public transport.

For a description of all passenger flows in the region across all transport modes can only be used the theoretical transport models. Thus established passenger flows can be followed on the basis of the
availability of origins and destinations of share assigned to each mode of transport - theoretically calculated passenger flows thus assign theoretical modal split. It shows how important is the role of public transport in a whole transport system where there is generally a high demand for transport and the passenger flows which makes it suitable to be targeted and at the same time, in which relations there is a most unused potential for public transport.

Contemporary no region today has processed quality transport model, because the benefits of high-quality and comprehensive transport modelling in the Czech area are still not fully appreciated. What is missing, is a quality travel surveys, surveys on the transport behaviour and sensitivity of users to parameters of public transport offer. Finally, it is difficult, often impossible, to group the time incommensurable data needed for the transport model setting.

For the purpose of transport planning are so often used incremental theoretical gravity models of passenger flows in the region. The output of these models is the proportional comparison of significance of passenger flows, often associated with the theoretical calculation of the modal split.

From the gravity model taking into account the modal split can be seen, how the public transport is successful in individual relations. Clearly then follows the disproportion in the region and the relations that represent the greatest potential for growth in public transport. Juxtaposition of relations can also be inferred where is potential for core railway lines, collecting railway lines and core bus services.

All the above information is important for line network planning and timetable improvements. Outputs of gravity model introducing the core and collecting lines with high (not yet used) potential will be applied gradually to the ongoing optimization of individual areas in the region.

1.2. General rules for the ensuring of transport services

Definition of passenger flows form the first input for the formulation of the line network. The second input is the restrictive conditions, which formulates each individual public service orderer. These restrictive conditions usually relate to the minimum limit for operating public transport. From our experience, there is a "critical" size of settlements where the passenger flows are not possible to capture on the collective principle and where the providing of public transport is very inefficient. Operation of such settlements is left to individual transport, or social services, and in these cases there are not provided public transport services. They are defined as:

- Municipalities and local area without an operation of public transport (where it is possible to solve transportation services using e.g. subsidized taxi service, social services, etc.)
- Community and the local area that are served to a minimum - there is usually used the limit according the number of permanent residents, combined with the requirement of minimum average daily exchange of passengers at the bus stop
- Parameters of the hierarchical organization of other lines that make up the network core / superior and subsidiary network

It is clear that in regular commuting is the greatest potential for public transport and should thus concentrate on measures that affect the modal split in favour of public transport in just this type of passenger flows. The key is to make the public transport system so attractive that it will use and the passengers who are free in their choice of means of transport (driving license holders and owners of a car - referred to as captive drivers and choice drivers) and not only those who do not choose (e.g. school children - captive riders).

1.3. General rules for line-planning in public transport

When creating a line network plan is necessary to combine aspects of passengers and technological and operational aspects, which combine the need of such a proposal, on the one hand positively affects Modal-Split in favour of public transport and on the other hand, such a proposal will be operationally viable.

This combination includes consideration the most important factors monitored by passengers:
- can be used between all points “shortest time” path
- the minimum number of changes

and most important operating factors:
- similar need of the vehicle-capacity along the whole length of the line
- minimum number of vehicles on providing the required operation performance

Based on the generated line networks of public transport, it is necessary to proceed to the definition of each segment of transport services. In this step, the plan will specify the stop/service strategy of lines in the network and define the function of individual lines in parts of the network where multiple lines were proposed simultaneously. When positioning time slots of each connection of particular line are assayed assuming the achieving of certain nodes in the network.

The line draft must consider the needs of homogeneous groups of passengers, for which is the line intended in terms of segmentation.

The main modifiable criterion is travel time, which is mainly based on network suspended waiting time. Due to operational capabilities and transport requirements (mainly interconnections for transit passengers) there are produced technology links in the timetable, i.e. the time dependence between two connections, respectively systematically between the lines. Scheduled line network significantly influences the Modal-Split and so should be given to the preparation of appropriate attention.

When creating the structure and hierarchy we can use a variety of terms that are easy to characterize a soft system (for example "regional services"), but if we want to project these concepts into a hard system, we are dealing with certain problems, since in the fully deterministic system is not possible to use intuitive definitions that work with the majority interpretation.

Building the structure of the public transport system must follow the hierarchy downwards, i.e. building the functional core systems. The reasoning used model layers (segments) of public transport, which together form an integrated structure. Segmentation method clarifies the structure of public transport.

Segmentation according to transport functions:
- Rapid transit between agglomerations (A)
- Rapid transport service between regions and within regions (B)
- Core regional transport (C)
- Collecting/distributing regional transport (D)
- additionally it could be considered an alternative segment (E) of additional transport systems

The individual operating segments have with regard to the time competitive with individual transport general recommended length of intervals based on general assumptions that the mean waiting time for a service should not be longer than the actual travel time. In the segmented system by transport function is very difficult to define the concept of regional transport, which is essentially perceived very intuitive. In practice, although institutionally defined by another orderer, but the actual impact of passenger flows this definition does not logically.

Regional transport we can delineate the way that a regional transportation means all that falls within the daily commuting. The structure and size of the confidence ellipse can be so intuitively define the concept of regional transport, while regional transportation is implemented in this concept across all segments A - E.

1.4. General principles of timetable design

Timetable of public transport is a direct result of the application of transport planning in the area and determines the structure and form of the offer.

The distribution of types of timetables for timetables without a fixed interval and with fixed period so there is a choice of type:
- Classic commercial timetable (connections are spread in the projected traffic demand)
- Interval schedule (fixed intervals always unchanging within part of the operational period, without a broader network of interconnections)
- And integrated periodic timetable (systematic coordination of timetables of individual lines, which are used in the selected interconnected periodic nodes to achieve maximum of optimal connections, to create a coherent network-wide interconnected periodic timetable. Unified cycle time on all lines is observed throughout all the civil day. Local requirements are addressed beyond periodic system by additional special connections)

The following figure expresses general applicability of different types of schedules depending on demand and interval combination:

Fig. 1: Models for the three levels of offer and demand (SMA und Partner)

In the concrete operational level is not easy to find a specific time / place to change the type of schedule, because if the individual lines are hierarchically interconnected, then the change type between fixed and without a fixed interval almost always at the expense of transfer relations.

In the case of scheduled commercial applications are usually mostly covered with rush hours, which clearly determines the number of necessary sources (vehicles, staff), which are then often during the day unused. Commercial timetable means at our conditions almost always less operation performance than in periodic timetable and its ensuring is so associated with a relatively high proportion of fixed costs. The unit’s performance is usually very expensive.

The transition from a commercial timetable to periodic in the initial phase all of the vehicles needed to ensure the transport peak in the intervals seeded throughout the operational period. So decreases the relative loss per unit of output, even though the variable costs are rising. Increasing offer leads to a progressive increase in the number of passengers carried and thus a more favourable development of revenues and reduce pressure on operating compensation payments.

The main benefit of integrated periodic timetable is consistency of public transport offer for passengers. Simplicity, ease of memorability, transfers without undue delay, and above all territorial and network availability. The concept of periodic and integrated periodic timetable is particularly appropriate where there are large passenger flows without clearly grasp time requirements (as in the commercial timetable), while the frequency of operation cannot be so high as to be able to give up on interchange links (as in the interval schedule). The concept of integrated periodic timetable is currently the highest possible level of public services offer.

1.5. Methods of circulation of vehicles and staff courses

There are many methods of production cycles of vehicles and staff courses. In the methods of operations research, this is called the assignment problem to be addressed such as the Hungarian method, which is generally known, and therefore will not be reported in detail.

Number of vehicles on the line does not be in itself determinative of their circulation. In any software solution assignment problem is passed optimization confronted with the need for operational maintenance. Existing software currently cannot take into account the operational maintenance in a particular location in the network after driving certain number of kilometers necessary for operating the maintenance. Number of possible combinations gives rise to NP-hard problems. Most software allows you to manually enter the transition vehicle (connection/connection) - so if there is circulation, which is at the normal operating maintenance option noticeable time vehicle downtime for this maintenance, then the transition will be set manually and optimization of the number of vehicles will take place again with this restrictive condition. But this is a manual intervention, which must always be done by the user. In an extreme case, this intervention leads to an increase in the number of vehicles. Operating maintenance options and associated increases the regular number of vehicles, as well as the extent of empty runs are directly associated with the location of depots/service centers. Choosing the appropriate service center for line servicing is connected to the schedule - his appearance, scheduled downtime of connections etc.

2. Application methods of transportation planning to the operating area of Šumava

On the concrete case of the operating regular public transport in the area Šumava in the region Jihočeský kraj were in the operational planning previous general principles applied. Jihočeský kraj is one of 14 regions in the Czech Republic responsible for ordering of public transport. Operating area Šumava is now generally geographically bounded by the towns of České Budějovice – Strakonice – Volary – Český Krumlov. Operational performance of around 1,38 million train-km per year providing 12 trainsets (vehicles), the average daily run of one vehicle is about 315 km in a day. This value is low and
create opportunities for increase. The costs associated with the vehicle (depreciation, maintenance), personnel costs (salaries, payments) and traction costs (fuel, electricity) are generally usually more than two-thirds of the total costs of transport capacity. When designing the most realistic operational concepts, from the outset attempt to apply maximum operating efficiency.

Operating concept Šumava is characterized by containing performances, that have character of purely regional transportation with daily commute, and performances, that are mostly tourist. Seasonality of several trains is so high, that in the summer, occupancy of individual connections are reaching to quadruple levels than during the off-season.

Based on the review of known facts about the occupation and load of individual train connections and CSO data were applied methods of timetabling leading to shorten of transfer- and travel times, with the following modifications:

- narrowing of transfer connections in the nodes
- introduction of fast regional trains in the peak tourist season (as a substitute for some of today's passenger trains)
- introduction of new embedded connections during the downtime of vehicles
- reducing the travel times during the tourist season contributed to the shortening of the vehicle-circulation-time, which extended the combinatorial possibilities for creation of their circulation and helped to reduce their number
- definition of the two-stage operation concept with identical demand of the number of the vehicles (where the second concept defined the requirements for modification of the infrastructure - with particular benefits to additional travel time reducing)

After designing of the basic structure of the periodic timetable and IPT-junctions were made minor changes in the raster of periodic timetable. In the morning peak hours were separately taken into account the requirements of the local time (starting times by significant employers, beginning of school hours) and the structure of IPT was often partially deflected. At the same time, during the morning peak hours was usually a structure of IPT preserved primarily in the main transport directions and main change linkages, which led to the minimization of the number of vehicles in the morning peak hour of the workday. It is just a morning peak hour of the working day, which determines the number of vehicles. The total volume of operational performance has been increased to 1,57 million train-km per year.

To minimize the number of vehicles in the network was used authors-own heuristic procedure, which can achieve such solution that takes into account the specifics of the operational processes (or as refueling or changing staff in a specific place, etc.). This procedure has 6 basic steps:

1) for every point in the network, where are starting or ending courses of single lines in the operational area, is created table of arrivals / departures
2) create a sets of "network conditional transitions" (such transitions of vehicles between course to course, whose failure leads to necessary occupying the default connection of an additional vehicle)
3) from these sets of network conditional transitions are by a sequence of courses created integrated continuous strings (the string terminates just at such place and time, when the vehicle has equivalent combination, crossing to another string - i.e. there does not arise network conditional transition)
4) individual strings are evaluated by its kilometric (for an operating treatment, or tanking) or time (in case of deployment of personnel and compliance with time breaks) length
5) thereafter follows coupling of strings into the complex circulation (for vehicles), or stays (for staff)
6) if the fact, that a string exceeds the beginning of the specified limit (the mileage or time duration), it is obvious, that it is necessary to use additional vehicle / personnel, which will further extend the possible combinations

This approach is equally usable for the production cycles of vehicles on road and rail, as well as for creating personal session. The procedure itself does not guarantee the creation of an optimal proposal (in terms of steady running vehicles, or optimal use of staff), provides however, that will be deployed only the minimum number of vehicles (or staff) in compliance to the boundary conditions. Limit to the number of vehicles in the application of this procedure lies in manual processing of approximately 30 vehicles, which from experience usually leads to the need for a combination of about 60-150 strings.

Application of these principles fully reflected in the operation costs. In operational area Šumava was the number of operating vehicles reduced by optimizing from 12 to 11, while the average daily running of the vehicle has increased from the current 315 km/day to the proposed 390 km/day. Since the extent of ordered transport was limited, it was not possible to further enhance the performance of vehicles. Such modified operational concept is prepared for the tender of Jihočeský kraj for selecting new rail-carrier.

3. Conclusion

The overall problem of transportation planning is very extensive. The aim of this article is not to describe in detail all the procedures and methods, which hides behind each step of transportation planning. Transportation planning as such is a complex task that is involved in many scientific disciplines. Individual tasks are closely related and cannot be resolved individually, without overlap in the overall context of the transport plan. The aim was to go through the steps that are necessary from the initial entry, the need to create operational concept to final product, including its timetable technical support. It was also the purpose to show, that the theoretical rules compliance can be achieved by increasing operational efficiency.

On the specific case of the operating area Šumava in the region of Jihočeský kraj, these principles fully take effect, when the current number of vehicles has been reduced, performance volume slightly increased, and additionally it was observed shortening travel times. The operating concept was also prepared for two states of operation - without modification of the infrastructure, and with infrastructure modifications. To ensure upward compatibility are both operational concepts optimized for the same number of vehicles, and the differ is in benefits in the region in the travel times. Thus prepared optimized operational concept is ready for the competition on the rail-carrier. In the case of market opening of public services should be preparation of the operational concept performed together with operational optimization. It’s one of the few ways to ensure long-term sustainability of public rail services. In a liberalized bus market in the
Czech Republic, the optimizing procedures of the operation brought the transport price reduction by 10-25%. These savings were reinvested back into enhancing the quality of public service. It will be interesting to see, whether similar results come even in regional rail transport.

REFERENCES


INTEGRATED TECHNOLOGY AND MULTIMODULE TRACKED VEHICLES UNIT FOR WETLANDS PROTECTION

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Abstract

Integrated technology and new generation of multimodule tracked vehicles unit was designed by PIMR - Industrial Institute of Agricultural Engineering in Poznan within the research project WND-POIG.01.03.01-00-164/09. The Tracked Vehicles Unit (TVU) was built as a part of cooperation with Polish firm Hydromega. TVU is dedicated to work on wetlands and should have positive impact on ecology and better environment protection thanks to use of biodegradable oils and lubricants, diesel engine with Stage III emission standard, innovative tracks which have different internal and external speeds during turns. A single-phase technology is designed for harvesting/collection and transporting biomass (reeds, grass, bushes, small trees) on wetlands, especially those that are located in National Parks and Nature 2000 areas. The TVU is designed to work with different tool modules for cutting, shredding and transporting collected biomass on wetlands. Amphibian type of the TVU's hulls allows for work in inlands water (rivers, lakes, canals).

Keywords: VEHICLE, TRACKED, UNIT, BIOMASS, MOWING, TRANSPORT, WETLAND, ENVIRONMENT, PROTECTION

1. Introduction

PIMR - Industrial Institute of Agricultural Engineering in Poznan, Poland realizes R&D project No. WND-POIG.01.03.01-00-164/09 on implementation of the technologies for works related to stopping unwanted (grass, reeds, bushes) greenery succession on wetlands and restoring the breeding areas of endangered species of birds [1].

Existing technology in Poland

The farmers used outdated and worn out vehicles and machines, which are potentially and very often the real cause of decreasing the environment’s protection – mainly, because crawler-type vehicles – snow grooming ratracs - are poorly adapted by farmers or operators for harvesting biomass in summer months. Overheating of the ratrac’s engine with protecting cover lifted (Fig. 1) is very dangerous; a few times the biomass dust and residues of oil and grease ignited a fire resulting in destruction of the engine and oil spillage from broken hydraulic hoses. To our knowledge, the ratracs had mineral oil rather than biodegradable oil, the spills have not been recovered and remediation actions have not been taken. One cc of mineral oil can spoil up to 5000 cc of clean water and it will be in ground or water for years [2].

Devastation of peat’s top layer that was made by sharp edges of grousers of the tracks in the field is very dangerous for vegetation and environment, especially on wetlands located in National Parks in Poland and Europe as well (Fig. 2).

2. Virtual models of tracked vehicles unit

The virtual models of Tracked Vehicle Unit (TVU) prototype with track modules that are powered by 6 hydraulic engines and independently steered was designed in PIMR. The TVU is designed to work with different tool modules for cutting, shredding and transporting collected biomass on wetlands (Fig. 3-5)

Fig. 3. Virtual model of the Tracked Vehicle Unit for cutting grass, reeds

Fig. 4. Virtual model of the Tracked Vehicle Unit for cutting reed, underwater plants on lakes and channels

Fig. 5. Virtual model of the Tracked Vehicle Unit for moving, collecting and transporting biomass (grass and reeds)

During turns the delta shape tracks (fig. 6) in tractor unit have ability to lean out in different direction (fig. 7). In addition, developed by small medium size firm Hydromega [4], hydraulic tracks’ steering system will control speed during making such turns and/or turning.
3. Prototype of tracked vehicles unit

In 2013 year the PIMR-BE Research Group designed prototype of the TVU that is dedicated for harvesting and collecting the biomass and transporting it to temporary storages. The prototype unit was built together with Hydromega [4].

The main purpose is that innovative tracked vehicle unit should be able to move on boggy, muddy terrains and, in addition, that can work on lakes, small rivers, and channels. Caterpillar vehicles, like snow groomers (ratracs) and tracked tractors, can drive on boggy terrains, harvest and transport biomass, but when there is a few centimeters of water on the surface of the ground, they can get stuck, if one of tracks will sink into a hidden meliorative ditch or hollow.

An amphibian type unit can minimize threats - survive in such situations and continue harvesting work on wetlands.
The Racelogic’s systems [5] (Video Vbox equipped with two HD video cameras and Vbox3i) were used to collect data during fieldwork and video equipment for recording images from cameras placed: in the cabin, on the top of the telescopic mast (fig. 8) and on the Unmanned Aerial Vehicle (UAV), that was rebuilt as KoBE in PIMR and adapted to take-off and land on fields or lakes [6].

3. PIMR’s integrated technology for removing biomass on protected wetlands

Developed by PIMR integrated technology for removing unwanted greenery from protected wetlands includes following operations:

1. mowing grass and reeds,
2. cutting reeds and underwater plants,
3. removing small trees and bushes
4. collecting biomass
5. transporting biomass to temporary storages and/or special prepared places in the field
6. Transporting biomass to the warehouses located outside protected areas

Operations 1-5 need to be checked in different locations and weather condition during 2014-2015 years. Operation no. 6 is alternative technology of transporting biomass to the warehouses located outside protected wetlands that was invented by PIMR and it already got several Polish and European patents [7, 8]. This biomass train technology is practically ready for market implementation, especially on mires and peat land of the protected wetlands.

New innovative technology is based on special steel adapters that are used to form biomass train and transport it, by rolling bales on the ground, behind towing vehicles e.g. agricultural tractor with wheels (fig. 17) or tracks, the tracked tractor of TVU (fig 18) or medium size trucks and pickups equipped with delta track modules or 4x4 wheels (fig. 19).
4. Conclusions

1. The preliminary results indicate a good drive ability of new tracks units, practically, with no negative impact on the ground as in the case of machines built on the snow grooming vehicle’s (ratrack) chassis.
2. Diameter of turn using only front pair of tracks is around 34m, but when two pairs are actively helping to turn - it is around 9-10m.
3. The Tracked Vehicle Unit ran easily on the grass, as well as on peat land or snow.
4. More advanced filed tests of mowing, cutting, shredding and transporting biomass as well as of the TVU’s impact on peat land will be run during 2014 and 2015 years.
5. Developed and patented by PIMR technology of special adapters and methods of forming biomass train is practically ready for demonstrator type projects and for market implementation.

5. References

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