THE ANALYSIS OF THE INFLUENCE OF NEW MATERIALS APPLICATION ON CAR BODY CONSTRUCTION

АНАЛИЗ ВЛИЯНИЯ ПРИМЕНЕНИЙ НОВЫХ МАТЕРИАЛОВ НА КОНСТРУКЦИЮ КУЗОВ

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R&D Institute¹, Car factory Zastava Kragujevac, SERBIA

Abstract: The need for constant improvement of new or restyled car models imposes the creation of new possibilities, such as introduction of new materials. Possibilities and needs differ in dependence on valid regulations and particular markets demands. The improvement of construction can be realized through: constructive changes, introduction of new materials or by combined method.

In this paper, by using one car body model, the effects of realized changes were analysed with the aim of satisfying both the regulations and the need for change of existing technologies.

KEYWORDS: CAR BODY, MATERIALS, CHANGES.

1. Introduction

Reconstruction of passenger car body can be performed for many reasons: development of new model, restyling of the existing model, installing of new aggregates, satisfaction of regulations, weight reduction, introduction of new materials and technologies etc. It can be realised through: constructive changes, by introduction of new materials or by combined method. Development and introduction of new materials for manufacture of car body parts were adjusted to general community demands, available resources and need to preserve them, ecology preservation, increase of safety in traffic etc. Bearing all that in mind, the following materials are more and more used for manufacture of car body parts: sheet metals made of high strength steels (SHS), sheet metals made of Al-alloys, plastic masses etc. However, the introduction of new materials requires a sequence of technological adjustments to the existing production processes or introduction of completely new technologies. [1] presents the introduction of plastic masses of new generation with the aim of improving car body stiffness. Taking all aforementioned facts into account, including the need for installing the new drive unit and satisfying By-law ECE 12, 94 and 95, the reconstruction of vehicle Koral car body, from production programme of car factory Zastava was initiated.

2. Strengthening of the first car body

When defining the reconstruction of the FIRST strengthened car body, the results of all realised tests were taken into consideration. The following changes were performed on car body:

- constructive changes
- application of new materials.

2.1 Constructive changes

At the beginning of the project the aim was set - to apply the proposed reconstructions with minimal changes of existing solutions, i.e. existing car body parts. That was a significant limitation, especially regarding the year when the basic model car body was designed and regulations valid at that time. The following changes were undertaken:

- All open support sections on carrying construction, especially in critical zones, must be closed, which would significantly improve the carrying construction. Fig. 1 shows the carrying construction of vehicle Koral car body. Front upper cross support was defined by detail 1, see fig. 1 and 2. By introduction of the new support, a closed section support of carrying construction was obtained, which connects longitudinal supports in this zone much better, which is very important from the aspect of By-law ECE 94. The introduction of this support was focused on reduction of asymmetry of deformations of left and right side of front frame without changing the existing car body parts. The similar reconstruction was realised on many supports on the carrying construction.

- To reconstruct critical points on carrying construction. For the type of carrying construction such as the one of considered car body, front longitudinal supports are important elements of front frame carrying construction. When designing them, it is necessary to pay attention to: their position, i.e. direction of conveyance of longitudinal deformations onto the other elements of the carrying construction, cross section, method of connecting them to other car body elements, number and position of welding points etc. On the basis of static investigation results and developed quasi-static test [1,2] two sensitive zones can be identified on the carrying construction of the front frame: A (zone of connection of front longitudinal support, front inside coating and partition wall) and B (zone of connection of front inside coating, partition wall and car...
floor), as shown in fig. 3. By constructive reconstruction of this joint, a new support was introduced, see fig. 4, in order to strengthen this zone, as well as drive unit support point. The similar reconstructions were realised in other sensitive zones on carrying construction.

**Introduction of new supports**, whereat it must be taken into consideration that only the minimal changes are made on the existing supports and in the procedure of car body assembling. New strengthening on the joint of front inside coating and partition wall was designed, on passenger’s space side, with the intention to use this strengthening as a joint of front longitudinal support and floor frame (section 5-5, see fig. 5), as well as for strengthening the joint itself. Fig. 6 shows some newly-introduced strengthenings on carrying construction.

**Strengthening of side door.** Side door is important for car body behaviour according to ECE 94, and especially according to ECE 95. There were several serial solutions for strengthening the side doors on the vehicle, in dependence on the model. One strengthening solution within door band was selected, see fig. 7, to which new strengthening was added. In addition to that, two new pipe strengthenings were introduced. Side door frame was strengthened, as well as joints of frame with strengthening in band.

### 2.2 Application of new materials

- **Application of materials for strengthening car body joints.** From the aspect of By-law ECE 94 and 95, lateral side frame, in connection with side door frame, is important part of the carrying construction, especially on the vehicle without air bags. The analysis of the effect of one car body joint strengthening showed that the desired effects of car body joints strengthening were achieved. The total effect of strengthening of vehicle Florida car body as a whole gave good results [2]. Since the same procedure of car body joint strengthening was applied, the similar total effects of car body strengthening can be expected. In such a complex reconstruction, it is very important to identify, i.e. select car body joints which must be strengthened in order to obtain significantly strengthened car body as a whole. Fig. 8 gives a schematic display of strengthened car body joints on vehicle Koral car body by application of plastic masses of new generation.

For strengthening car body joint, materials of company Dow Automotive, named Betafoam 88100 and 88124, were used. In the special pump, the materials are mixed at room temperature and, afterwards, the obtained mixture is injected into the desired joint, after completed process of surface protection and car body painting. The material is formed and it gets its final shape at room temperature, after 20-30min, in dependence on size of strengthened joint, i.e. available space in carrying construction elements. Besides being applied for strengthening of car body joints into which they were injected, the new materials were used as a connection and support of pipe strengthening of lateral side frame. Without such a material, the desired effect of carrying construction strengthening would not have been achieved, especially in the zone of windshield glass.

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**Application of structural adhesives.** One of the methods for strengthening car body points, i.e. car body parts, is application of structural adhesives, which can reduce the number of welding points considerably. For additional gluing of car body joints, especially in critical zones where the access for spot welding is difficult, adhesive Betamate 1493 of company Dow Automotive was applied, as schematically shown in fig. 9. Bearing in mind the aim of application of these adhesives for connecting the elements of carrying construction, structural adhesive was first applied on front
longitudinal support, in order to strengthen its connection with other car body parts and connection with cross supports. The following point of larger application is lateral side frame, on points of longitudinal supports connecting and points of connection with other parts, i.e. carrying construction elements. This method is mainly used for improving longitudinal supports joints, as well as their connections to cross supports.

Fig. 10 Device for quasi-static tests

Fig. 11 Car body appearance after quasi-static test

Fig. 12 Impact test conditions according to ECE 94 in longitudinal direction

3. Analysis of the effects of vehicle Koral car body strengthening

The investigation of the effects of strengthening of the FIRST strengthened car body of vehicle Koral was performed in test simulation conditions according to ECE 94, according to methodology defined in [1,2]. Fig. 10 shows the device for quasi-static tests in conditions of by-law ECE 94. During the test, the following is realised:

- Measuring of total deformation displacements on all measuring points
- Measuring of deformation displacements on selected measuring points
- Recording of car body behaviour.

Fig. 13 Test conditions according to ECE 94 in cross section

Fig. 14 vehicle appearance after the test according to ECE 94

Fig. 15 Appearance of car body front after the test
Fig. 11, 15, 16 and 17 show the results of quasi-static investigations of the first strengthened car body of vehicle Koral. One of the main parameters when analysing the car body behaviour is the analysis of total car body deformation, see fig. 11 and 15. Car body deformation is considerably larger on driver’s side, which is conditioned by the test itself, adjusted to the demands of by-law ECE 94. Large deformation zones are the same as those on the vehicle after impact test according to ECE 94, see fig. 14. Performed test gave the expected results regarding estimation of car body behavior in front impact test.

Application of new materials and technological procedures, as well as reconstructions carried out on the carrying construction, influenced a significant increase of longitudinal stiffness of car body, see fig. 17, compared to basic model [1].

Based on results of car body behaviour investigation, car body behaviour expected in front impact test can be estimated. Strengthening gave good results, which was confirmed in vehicle test according to ECE 94.

In addition to the need for construction improvement, in the case of reconstructed car body particular procedures can also be applied with the aim of increasing the car body quality, since sensitive points on car body can be eliminated.

4. Conclusion

Development and introduction of new materials in car industry is a necessity, especially regarding increasingly stricter demands. However, introduction of new materials requires a sequence of technological adjustments or introduction of completely new technological processes. One of the reasons for possible delay is the price of such a process.

In addition to that, it is necessary to improve methods for estimation of performed interventions constantly. Shown results indicate necessity for new materials introduction, especially for previously designed models.

Literature

DECISION SUPPORT SYSTEMS FOR ALLOCATION OF LOGISTICS CENTRES
Ing. Denisa Mocková, Ph.D.
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Abstract: The facility allocation problem is to determine the optimal number of facilities to be opened. Based on multiple criteria evaluation, the optimal location of the facilities is usually solved subsequently. Several aspects as technical parameters, costs and finance must be taken into account. Economic analysis is carried out based on the concrete problem instance.

KEYWORDS: ALLOCATION TASKS, SET OF CRITERIA, MULTIPLE CRITERIA EVALUATION

1. Introduction

The problem of allocation tasks lies in selecting an optimal number of logistics centres for their subsequent location on the basis of multiple criteria evaluation. The difficulty of multiple criteria evaluation tasks does not result, though, merely from the number of evaluation criteria, but also from how these criteria are expressed and from the degree of their dependence on their nature in various units of measure. It is not uncommon the situation where there is a mixed set of criteria and where some criteria are quantitative, i.e. expressed numerically, and others are of a qualitative nature (expressed in a verbal description).

Decision making is one of the basic managerial activities, where a bad decision may be one of the key causes of a business’s failure. The importance of decision making depends directly on the level of resources (primarily financial) that are closely connected with the decision making.

The process of selecting feasible alternatives from a set of proposed alternatives forms a decision-making process and is a part of a broader decision-making task, namely the selection of an optimal alternative.

2. Preconditions and means for resolving the problem

Elements in the decision-making process

The key elements in the decision-making process include: decision-making objective, subject and object, evaluation criteria, decision-making alternatives and their outcomes, states of the world

Decision-making objective(s)

We understand the decision-making objective in solving a decision-making problem as a certain state that we wish to attain by means of a solution to the decision-making problem. In our case the single objective is a decision on the optimal number of logistics centres.

Evaluation criteria

Evaluation criteria represent aspects selected by the decision maker, serving for evaluating the advantageousness of individual decision-making alternatives from the aspect of meeting the objectives of the decision-making problem being solved. The evaluation criteria are usually derived from set objectives.

The selected evaluation criteria for allocation tasks:

- cost criterion
  1. one-off acquisition costs for a new logistics centre – direct material (equipping the depot with vehicles by purchase or leasing, with furniture, computers, mobile telephones, fixed telephone line and other office equipment)
  2. monthly operating costs for a branch – direct wages, other direct costs, operating margin, administration margin, etc. (basic wages, supplements and additional payments, bonuses and remunerations, operating expenses, depreciation charges, repair and maintenance fees, creation of repair fund, transport and travel fees, contributions from wages, fuel costs, telephone fees, energy, insurance, fines, penalties, loan repayments, leasing)
  3. costs for providing the branch with the essential supply of materials and spare parts – storage costs, funds tied-up in stocks
  4. environmental costs

The one-off costs and costs tied-up in supplies will grow along the curve with the growing number of depots; however, operating costs will decrease as a result of the smaller catchment areas.

- response times (speed) – by setting up another depot, the response period will be reduced on the basis of reducing the size of the catchment areas, something which will be reflected in the reduced average number of kilometres driven and subsequently decreased fuel costs
- technology demands – equipping the depot with special vehicles, machinery and the handling equipment
- customer convenience
- share of services in the public interest – fire-fighters, emergency service
- energy demands
- geographical possibilities
- economic importance
- social aspects – solution to unemployment
- importance of the hub as a transit hub
- importance of the hub from the aspect of resources – raw materials
- importance of the hub from the aspect of customers

Decision-making subject

The decision-making subject (decision maker) is the person making the decision, i.e. the person selecting the alternative intended for realisation. The decision-making subject may be an individual or a group of people.

Decision-making object

The decision-making object is, as a rule, understood as being the field for which the problem has been formulated, the objective of its solution has been set and that the decision making concerns (a decision-making object may, for example, be to determine the reserve stocks of logistics centre warehouses, equipment of logistics centres, financial provision for development, etc.).

Decision-making alternatives and their outcomes

The alternatives for solving a problem represent for the decision maker a possible course of action that is to lead to the solution of the problem, or, as relevant, to the fulfilment of the set objectives. While many decision-making problems have their solution alternatives given or known, there are many cases (especially in the case of complex decision-making problems) where the creation of alternatives is time-consuming and requires a creative approach for demanding complex processing and searching for information.

Decision-making alternatives are closely linked with their outcomes, which we can understand as being the expected impacts and effects of the alternatives.
States of the world

The states of the world (scenarios, risk situations) may be understood as future mutually exclusive situations that may occur following the alternative’s realisation, and which influence the outcomes of the given alternative with regard to specific evaluation criteria.

3. Solution methodology

- Determining the decision-making object, subject and objective
- Determining the criteria for evaluating the alternatives – information should be fully exploited in selecting the criteria. The basic key in setting the evaluation criteria may be primarily the objectives to be achieved by the solution to the decision-making problem. Besides the objectives for the problem being solved, the selection of evaluation criteria may be supported also by identifying the subjects whose interests, objectives, or needs may be affected by solving the problem or by choosing one of the alternatives. Furthermore, searching for and clarifying potential adverse impacts and effects of the alternatives are also important. Applying the above-mentioned criteria leads to at least partial elimination of shortcomings arising in decision making.

- Methods for setting criteria weightings – most methods of multiple criteria evaluation of alternatives require first that weightings be set for the individual evaluation criteria that will express the numerical importance of these criteria. The greater the importance of the criterion, the higher its weighting. In order to achieve comparability between the weightings of a set of criteria determined by different methods, these weightings are as a rule standardised so that their sum is equal to one.

- Generation of alternatives – this is the most important stage in the decision-making problem, the quality of decision of the whole decision-making problem depends on it
- Evaluation of alternatives and selection of the alternative intended for realisation – the final objective is to determine such an alternative of the decision-making problem solution that would meet best the solution’s objectives of the problem. The alternative intended for realisation should be feasible. Therefore it is necessary to exclude from the set of evaluated alternatives those alternatives that are inadmissible. Inadmissible alternatives are those that:
  - do not meet some of the objectives of the solution to the decision-making problem
  - do not fulfil some of the limiting conditions

4. Results and discussion

Multiple criteria decision making is modelling of decision-making situations containing a defined set of alternatives and a set of criteria according to which the alternatives will be evaluated. The result of the alternative evaluation process is the determining of the preferential arrangement of alternatives, i.e. ranking of their overall advantageousness, where the first place is occupied by the most advantageous alternative, i.e. the optimal alternative. Determining the preferential ranking is in general a demanding process, where its complexity grows along with the increasing size of the set of alternatives and with the increasing number of criteria.

If a given criterion is of qualitative nature, it is sufficient to rank the alternatives by their descending or ascending values (where this concerns a cost or revenue type criterion).

The complexity of multiple criteria evaluation of alternatives is often overcome by unjustified simplification of the task, where the number of evaluation criteria is reduced by neglecting less important criteria.

A different, more acceptable approach to multiple criteria evaluation attempts to convert all the criteria into the same unit of measure, which ensures that the individual criteria are enumerable, and thus that they can be converted to a single criterion.

Determining the preferential ranking of alternatives often depends on the importance attributed by the decision maker to individual evaluation criteria, i.e. it depends on the value hierarchy of the decision maker and his subjective appraisal. Different decision makers may reach different preferential rankings of alternatives.

5. Conclusion

Allocation tasks need be assessed and evaluated from the aspect of a greater number of criteria, i.e. they are problems of a multiple criteria nature. In determining the optimal number of logistics centres it is necessary to take account of the required technical parameters of centres, financial and cost aspects, etc. It is necessary to make an economic analysis based on the particular task assignment. Allocation tasks are, due to their nature, highly individual, therefore we have here merely outlined the theoretical side of using multiple criteria decision making and the solution methodology.

This contribution to the conference has been prepared with the support of the research objective “Development of Methods for the Design and Operation of Transport Networks from the Aspect of their Optimisation”, (MSM6840770043).

6. References

Abstract: In this century information more and more affect decision process of man and business. The transport sector is not exception. Carrier with his mean of business wants to make the best decision with the best and relevant information. The article deals with importance of railway goods transport, the position on the transport market, reasons of the low attractiveness and the modern trends in the informatics in the railway freight transport.

KEY WORDS: INFORMATION, RAILWAY GOODS TRANSPORT, WWW PAGES

1. Introduction

The last decades are often characterized as the period of the information technology. The information technology are more and more important in all decision processes of the persons and business entities as well, and the transport section is not an exception. Thanks to globalization of the market the transport constantly increase its performance. The gradual expansion of the European Union also contributes to overcome the artificial barriers, which interfered the goods transfer among the countries. The number of transported goods raises and the transportation distances become longer. The transport demand increases as well. The carriers search directly or through the forwarding agents for such the carriers who are able to meet their requirements within the maximum range. And this is the very moment, when it is important to keep at disposition the whole complex of information about transport possibilities as soon as possible.

2. Prerequisites and means for solving the problem

Even though the railway transport is to be considered as the transport which is expeditious especially in the transport of the bulk substrata and in the long-distance haulage, its share of the whole transportation output is constantly on the decrease (Table 1, 2).

Table 1 Comparison of freight transport by mode in Slovakia – part 1

<table>
<thead>
<tr>
<th>Year</th>
<th>1995</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport of goods - total</td>
<td>103 t</td>
<td>266 356</td>
<td>243 401</td>
<td>201 917</td>
<td>244 686</td>
</tr>
<tr>
<td>Railway transport</td>
<td>103 t</td>
<td>60 776</td>
<td>56 569</td>
<td>49 115</td>
<td>54 177</td>
</tr>
<tr>
<td>%</td>
<td>22.8</td>
<td>23.2</td>
<td>24.3</td>
<td>22.1</td>
<td>22.1</td>
</tr>
<tr>
<td>Road transport</td>
<td>103 t</td>
<td>203 918</td>
<td>185 659</td>
<td>151 294</td>
<td>188 901</td>
</tr>
<tr>
<td>%</td>
<td>76.6</td>
<td>76.3</td>
<td>74.9</td>
<td>77.2</td>
<td>77.3</td>
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Table 1 Comparison of freight transport by mode in Slovakia – part 2

<table>
<thead>
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<th>Year</th>
<th>2002</th>
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<tbody>
<tr>
<td>Transport of goods - total</td>
<td>103 t</td>
<td>215 990</td>
<td>226 122</td>
<td>230 166</td>
</tr>
<tr>
<td>Railway transport</td>
<td>103 t</td>
<td>49 863</td>
<td>50 521</td>
<td>50 445</td>
</tr>
<tr>
<td>%</td>
<td>23.1</td>
<td>22.3</td>
<td>21.9</td>
<td>19.6</td>
</tr>
<tr>
<td>Road transport</td>
<td>103 t</td>
<td>164 427</td>
<td>174 149</td>
<td>178 085</td>
</tr>
<tr>
<td>%</td>
<td>76.1</td>
<td>77.0</td>
<td>77.4</td>
<td>79.8</td>
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</table>

Table 2 Comparison of freight transport by mode in Slovakia - part 1

<table>
<thead>
<tr>
<th>Year</th>
<th>1995</th>
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<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport performance - total</td>
<td>106 t.km</td>
<td>41 680</td>
<td>30 937</td>
<td>30 039</td>
<td>26 957</td>
</tr>
<tr>
<td>Railway transport</td>
<td>106 t.km</td>
<td>13 674</td>
<td>11 753</td>
<td>9 859</td>
<td>11 234</td>
</tr>
<tr>
<td>%</td>
<td>32.8</td>
<td>38.0</td>
<td>32.8</td>
<td>41.7</td>
<td>42.5</td>
</tr>
<tr>
<td>Road transport</td>
<td>106 t.km</td>
<td>26 536</td>
<td>17 879</td>
<td>18 516</td>
<td>14 340</td>
</tr>
<tr>
<td>%</td>
<td>63.7</td>
<td>57.8</td>
<td>61.6</td>
<td>53.2</td>
<td>53.6</td>
</tr>
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</table>

Table 2 Comparison of freight transport by mode in Slovakia - part 2

<table>
<thead>
<tr>
<th>Year</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport performance - total</td>
<td>106 t.km</td>
<td>25 907</td>
<td>27 461</td>
<td>28 941</td>
</tr>
<tr>
<td>Railway transport</td>
<td>106 t.km</td>
<td>10 383</td>
<td>11 113</td>
<td>9 702</td>
</tr>
<tr>
<td>%</td>
<td>40.1</td>
<td>36.8</td>
<td>33.5</td>
<td>28.7</td>
</tr>
<tr>
<td>Road transport</td>
<td>106 t.km</td>
<td>14 929</td>
<td>16 859</td>
<td>18 517</td>
</tr>
<tr>
<td>%</td>
<td>57.6</td>
<td>61.4</td>
<td>64.0</td>
<td>69.0</td>
</tr>
</tbody>
</table>

Source: Statistical office of the Slovak republic

In Slovakia particularly the domestic railway transport is subject to decrease, in this sector the cut-down of the number of transported goods almost in 60% has been noticed since 1995. The decrease in the sector of the international transport (import, export, transit) was minimal up to now (Table 3).

Table 3 Railway freight transport in Slovakia in 103 t – part 1

<table>
<thead>
<tr>
<th>Year</th>
<th>1995</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>International transport of goods – total</td>
<td>43 956</td>
<td>41 638</td>
<td>36 738</td>
<td>42 300</td>
<td>42 271</td>
</tr>
<tr>
<td>National transport of goods - total</td>
<td>16 820</td>
<td>14 931</td>
<td>12 377</td>
<td>11 877</td>
<td>11 317</td>
</tr>
</tbody>
</table>

Table 3 Railway freight transport in Slovakia in 103 t – part 2

<table>
<thead>
<tr>
<th>Year</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>International transport of goods – total</td>
<td>39 425</td>
<td>42 162</td>
<td>42 514</td>
<td>41 183</td>
</tr>
<tr>
<td>National transport of goods - total</td>
<td>10 438</td>
<td>8 359</td>
<td>7 242</td>
<td>6 893</td>
</tr>
</tbody>
</table>

Source: Statistical office of the Slovak republic
While many countries support ecologically preferable railway transport, the situation for instance in Slovakia is different. There incomparably more investments of public resources are used to support the road-trafic infrastructure than to support the railway infrastructure (Table 4).

<table>
<thead>
<tr>
<th>Infrastructure type</th>
<th>1995</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway</td>
<td>1668</td>
<td>2522</td>
<td>1638</td>
<td>2330</td>
<td>7366</td>
</tr>
<tr>
<td>Road</td>
<td>2069</td>
<td>11833</td>
<td>8974</td>
<td>9680</td>
<td>8718</td>
</tr>
</tbody>
</table>

Table 4 Total investment expenditures in transport infrastructure in Slovakia (current prices) (in mil. SKK) – part 1

The information systems become an extraordinary competitive advantage. The transportation companies have no trouble in gaining information distribution as well as in term of information gaining. The transportation companies functioning on the transport market should monitor the trends quoted. Just the www presentation can become their new address, their new business card, which may be presented in whichever contact with the transport market. The website of the transportation company can be not only the source of the company's presentation, the simple possibility of providing contacts, but first of all the possibility of the presentation of the portfolio of the activities and products it provides.

The users can access to this information source without limits in term of time, geographic locality or reference to the company. The assumption is that the utilization of information must be realized especially by customers. In term of the division of the users we can presume their following division:
- searchers – they search for the possible contacts, addresses, etc.
- accidental visitors – they gained the specific website e.g. from the www-locators
- non-commercial readers – they use general information
- commercial readers – they use the information according to the commercial terms

The www-presentation quoted is one of the best and the most flexible possibilities for the railway transportation company to present itself, to provide not only the static information (i.e. information invariable in time, e.g. contacts, references, information about company), but also, and especially, the dynamic information, i.e. information variable in term of the offered services, time and accessing person (personalized access).

4. Results and discussion

The most important parts of the websites of the railway transportation companies are the primary information about company itself, about its activities and contacts. It creates the initial image for the visitor who searches for the detail information about the offered services and products and the possibility to choose the language mutation of the websites. The good image of the company is created also by implemented section, that monitors the news, the information (i.e. the image of the active events in the company) and by the company's publicity in the media. The visitors are interested in the offered products and services, but also in the financial aspect, i.e. for instance the domestic and international tariffs or service charge. As there are various group of visitors on the websites, also the possibility of the searching in the website content, reference to futher relevant websites and the map of websites (the transparent ordering of the company's website sections) are quoted.
portal content without the technology skills for the website development.
In term of the website's content analysis we can differentiate some spheres or units of information, that are important both in term of the electronic offer of the transportation company (companies) and naturally in term of the information sought by the visitor of the website.

References


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Abstract: This Paper deals with the definition of the general mathematical model for determination of the entrance fee to the bus terminal (BT) for any bus terminal operator in conditions of Czech Republic. Presently does not exist model for dermination of the entrance fee for any bus terminal in Czech Republic, which should be universal and suitable for determining the entrance fee per any bus terminal.

KEYWORDS: ENTRANCE FEE, BUS TERMINAL, BUS TERMINAL OPERATER, BUS TERMINAL OWNER, MODELLING

1. Introduction

This Paper deals with the definition of the general mathematical model for determination of the entrance fee for any bus terminal operator in conditions of Czech Republic. On the present doesn’t exist model for determination of the entrance fee for any bus terminal in Czech Republic, which should be universal and suitable for determining the entrance fee per any bus terminal. There are three basic types of the bus terminal operators in the Czech Republic - bus carrier, private subject, which is not bus carrier and community or city.

One of conditions of the economical stability of bus terminals there are well set prices of entrance fees to the bus terminal that are on the one hand acceptable for bus transporters and on the other hand cover costs for the operating of the bus terminal at least partially.

2. Prerequisites and means for solving the problem

2.1. Creation of a mathematic model for determination of the entrance fee to the bus terminal

This model should be universal and suitable for determining the entrance fee per any BT under the pre-determined conditions that are as follows: economic information of the BT, operational information of the BT and information of the interest of carriers in using the services of the BT (present as well as prospective customers – bus carriers).

The following procedure was chosen for creation of the mathematic model: the first step was creation of a demand function for entrance to the BT, the second step was creation of a cost function of BT operator, the third step was creation of a profit function of the BT operator and the fourth step was creation of the mathematic tool for determining the entrance fee to the BT, both for the price for which the operator’s profit is maximum, and the price when the capacity of the bus terminal will be maximally used.

2.2. Creation of the demand function – demanding the entrance to the BT

The demand function of the entrance to the BT is created on the base of data as acquired from the records of connections using the BT so-called database of bus connections. The analysis includes connections operated during the analysis as well as prospective new connections. A prospective connection means a connection of a bus carrier to create the demand function from his own inter-company economic information.

Generally is the demand function of specific goods dependent on the volume of production (for instance material costs) and must be thus covered even though the company does not produce, in case of the BT this is the status when no bus enters the BT and variable component – costs associated with the existence and operation of a company are its basic economic indicator and their cut-down is the main tool for profit creation at present. Therefore it is not difficult for the BT operator to create the demand function from his own inter-company economic information.

This function consists of two components: fixed component – costs independent on production (depreciation, rental, cleaning, lightening, control signals) and must be thus covered even though the company does not produce, in case of the BT this is the status when no bus enters the BT and variable component – costs dependent on the volume of production (for instance material costs).
mostly related to a production unit, in case of the BT there are the
costs related to a single entrance of a single bus to the BT. The
decision of what costs belong to what group is not currently
arranged by any regulation and it is purely the subject of economic
arrangement of every company. In the case of the bus terminal is
costs sharing on fixed and variable depend on, if the bus terminal
operator is or is not owner of the bus terminal.

2.4. Creation of the profit function – profit of the BT
operator

For creation of the profit function of the BT operator it is necessary
to define the function describing the dependency of receipts on the
number of entrances of buses to the BT. The amount of the entrance
fee at which the profit is maximum, may be calculated from the first
derivation of the profit function. This shall be laid equal to the zero
and then we can calculate the corresponding fee for maximal profit.
This value may be added to the demand function, cost function,
receipts function and profit function and thus we can determine the
demand, costs and receipts at maximum profit of the BT operator.

For determining the amount of the entrance fee with
maximally used capacity of the BT it is necessary to determine first
the price from the demand function at which the BT is maximally
used. Subsequently we may determine the costs, receipts and profit
for the maximally used BT.

3. Results and discussion

There are three basic types of the bus terminal operators in the
Czech Republic - bus carrier, private subject, which is not bus
carrier and community or city. Entrance fee collection by the first
and the third type of bus terminal operator doesn’t follow any
economical principles, just the second type of the bus terminal
operator – private subject, on which follow all economical
principles (demand and supply, costs, receipts, profit and loss).
Created model of entrance fee (for the price for which the operator’s
profit is maximum and the price when the capacity of the bus
terminal will be maximally used) is not model totally general,
which is given for any bus terminal operator, but is suitable just for
private bus terminal operator, which is not bus carrier and
whereupon follow all economical principles (demand and supply,
costs, receipts, profit and loss). The model could be general in case,
if of the unification of bus terminal ownership.

4. Conclusion

The model of the entrance fee is the model of a hypothesis, which is
a simplified image of the complicated reality. The model is created
on basis available information and qualified rating a given reality.
Created model is suitable just for private bus terminal operator,
which is not bus carrier and whereupon follow all economical
principles. The model could be general in case, if of the unification
of bus terminal ownership. Created model helps as a ground for the
objectification of the economical operating of the bus terminal.

5. Acknowledgment

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6. References

ON LINKAGE OF TRANSPORTATION THEORY AND LOGISTICS

РАЗВИТИЕ МОДЕЛИРОВАНИЯ СВЯЗИ ТРАНСПОРТ - ЛОГИСТИКА

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Abstract: Three areas of modelling in the logistic chain are specified in the article: the theory of transportation – the technology of transportation – logistics. Several directions of the modelling of links between the transportation technology and the quality of transportation are shown with respect to environments that are distinguished by deterministic, stochastic or non-linear data entries.

KEYWORDS: THEORY OF TRANSPORTATION, TECHNOLOGY OF TRANSPORTATION, LOGISTICS, MODELLING

1. Introduction

The initial theoretical platform which provides for the advancement of logistics systems consists in the development of the theory of transportation which is based on the examination of movements of an intangible transportation element within a defined transportation network in a technical, a technological and an economic reality. This theoretical basis also provides a platform for the transportation technology (organization of transportation) which explores the movement of means of transportation and transportation units in a technically defined transportation network comprising all technical types of transportation and their combinations, and which aims at its optimization in a system concept.

2. Prerequisites and means for solving the problem

This represents the fundamental pillar of the technological reality: theory of transportation – technology and management of transportation processes – logistics, in which:

- the field of the theory of transportation forms a methodological basis for the development of intensifying functions of relocation processes. The modelling concerns mainly the following areas:
  - fundamentals of the theory of transportation, the exact apparatus used for its management
  - prioritization of transportation networks
  - intersections of transportation networks on a horizontal basis (as for multimodal transportation) and a vertical basis (as for regional, national and international levels)
  - distribution of transportation (traffic) flows during their movement in transportation networks
  - throughput capacity of transportation networks and their sections in the deterministic and the stochastic regime of movement of transportation units, bottlenecks and solution of their impact on coherent networks
  - theory of relocation process quality

- the field of logistics focuses on two basic branches, i.e. the branch of fundamentals and general principles of logistics incl. the management of logistics systems, and the branch of transportation logistics which relates the transportation as a carrier of material flow to an integrated management of logistics systems. The modelling in the branch of general logistics fundamentals concerns mainly the following areas:
  - disciplinary fundamentals of logistics incl. applied methods of exact and heuristic optimization and methods of artificial intelligence
  - logistics marketing methods, logistics marketing strategies (in the globalization era)
  - stock and stock management, storage and handling systems in logistics chains
  - macrologistics and industrial logistics, assessment of contributions of logistics according to international methodology
  - corporate logistics, logistics reengineering, business logistics
  - logistics information systems, special supporting information technologies logistics chain management
Regulate the traffic with regard to:

- management of circulatory and relocation processes from the point of view of material transportation chains or the regional perspective of transportation chains
- transportation as a supporting phenomenon of intensification of material flows and logistic chains, the role of transportation as a state economic forming capacity
- organization of information flows in logistics chains, their utilization in order to optimize intensities of transportation flows
- logistics technologies based on distribution processes and optimum information flows
- quality of transportation as a critical factor of the offer of transportation services in the logistics chain, incl. the offer of multimodal transportation systems
- logistics system development prognoses
- interactive effects of changes in market mechanisms on the development of new logistics technologies based on distribution processes and information flows

3. Results and discussion

From the perspective of the transportation system it is necessary to regulate the traffic with regard to:

- optimum distribution of work among individual transportation types as to provide for the logistic transportation request
- optimum transportation quality
- minimizing costs of actual relocation process as well as circulatory processes as a whole

The complex of transportation system properties and the properties of individual types of transport based on a technical background and transportation technology can be referred to using an integrating term of “transportation functional effectiveness”. Some characteristics of transportation functional effectiveness are objectively given; i.e. they are not influenced by the transportation organization, on the contrary – these characteristics influence the organization of the actual relocation (ability of the transportation to create networks, capacity to transport any required quantity, easy reach of transportation means etc.) as well as characteristics which are directly dependant upon the organization (technology) and which contribute, to a certain extent, to the transportation quality (the transportation speed, degree of reliability, and the security of the transportation capacity).

Issues arising due to these characteristics can be handled by means of technological models of transportation system performance. In order to provide for the functional identity of the system and its model, other theoretical bases have to be employed. E.g. the models can be classified according to the data entry character as:

- deterministic, i.e. their data entries are uniquely determined (they repeat periodically – e.g. fixed timetable model)
- stochastic, i.e. their data entries range within specific values around a mean value and the model is then determined by a system of mean values and their probability characteristics (use of the queuing theory armamentarium). With the use of stochastic models, two factors concerning transportation in relation to the traffic quality can be defined – assessment of the risk that the output conditions will not be observed, especially as regards the speed and reliability characteristics, and a possible assessment of the probability of the occurrence of bottlenecks and their consequences.

4. Conclusion

Modelling and solutions to problems, which arise in situations when the choice of an appropriate transportation system or an appropriate logistic technology depends on the possibilities of predicting the transition from order to chaos and vice versa, will also be elaborated when developing the research project called Development of Transportation Infrastructure and Optimization of Transportation Network Operation at the Faculty of Transportation Sciences, Czech Technical University in Prague. It can be assumed that the solution will be also contributed to by a gradual application of transportation telematics. However, the enhancement of optimization procedures in the situation of a constantly increasing transportation network load will have to be based on nonlinear system modelling.

5. Acknowledgment

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6. References

1 Introduction

Cost-benefit analysis (CBA) has its fundamentals in theoretical framework of microeconomics and theory of social solution. It is application of these theories on practical problems of public sector, not only transport sector but also other sectors, e.g. health service, energetics and environmental protection. This paper is focused on CBA of transport projects.

Transport projects must be judged from the point of view of their feasibility, viability but also necessary financial flows. CBA brings enlargement of information value about a given project from the multi-criterion point of view, when benefits on one hand and costs on the other hand are judged in complex conception. Only on the basis of complete sum of information it is possible to make final decision about particular transport project.

Some of the basic principles of transport CBA we can generally summarize as follows:
- it should be judged costs and benefits of all influenced groups,
- some effects can be transferred from one group to the other or they can cancel one another in total analysis,
- total social impact is calculated as a sum of impacts on individuals,
- future costs, benefits and forecasts shouldn’t be underrated – it is especially important for the stage of demand appraisal,
- initial point of the appraisal is individuals’ willingness to pay for benefits – based on studies of time and safety value,
- adequate evaluation of cost and benefit items,
- money is the basic unit (though other units can be used, as well),
- respect for discount and growth rates of prices in the course of the time.

2 Heart of the appraisal

Investments in transport infrastructure influence many sides – supranational, national and local authorities, transport operators and users. Investments influence life quality of people, whose economic, social or environmental life qualities can be changed as a result of investment in transport infrastructure.

The main perspective of transport (transport infrastructure) projects appraisal by way of socio-economic CBA is social perspective. This is the perspective that takes into account all important effects regardless of the fact, who is affected by them. Relevant considerations involve:
- total economic, social and environmental effect of the project,
- scheme of profits and losses,
- financial viability of the project,
- feasibility of the project and identification of implementation risks.

For “social” appraisal of the projects it is suitable to use general approach including in its core CBA elements, which can be evaluated financially with sufficient addition of environmental impacts, wider economic impacts and further impacts (e.g. political aspects). The purpose of such approach is to take into account CBA and wider economic, environmental and political indicators together, i.e. in a cohesive way, with the aim to get a complex appraising analysis.

It is necessary to emphasize that environmental and further politically important impacts should be subject to proper forms of analysis. This analysis should, ideally, be quantitative. Where the quantitative analysis is not possible, qualitative analysis should be accomplished, based on expert estimate. The basis of the analysis should always be set as a part of information provided to decision makers. This information should form an input to the decision-making process, not an output of previous politically irreversible decisions.

Responsible decision makers then have the task to strike a proper balance between benefits for user and environmental and further impacts. The purpose of the appraisal is to provide relevant information as an input for the decision-making process. The scheme of the decision-making process is depicted in the figure 1.

![Fig. 1 Complex scheme of the appraisal process](source: CBA, authors)
passenger transport and freight transport. This cost reduction will probably result in a number of users’ reactions – changes in routes, choice of transport kind and destinations. Proper evaluation of these demand changes is vitally important for the appraisal. [16]

The impacts on transport providers are relevant, as well, in the framework of investments (investment costs), operational costs and revenues – for infrastructure, transport means and service operation.

3.1 Value of time and safety

Investment projects that improve transport infrastructure result in travel time reductions (as a consequence of shorter routes and higher speed) and in reduction of traffic accidents and victims number (as a consequence of safer design standards) in comparison with the situation without the project. Values of time and safety are not generally available in the form of market prices because they are not marketable commodities in its core. That’s why an alternative base for the evaluation of time and safety is necessary in the project appraisal.

Monetary value of travel time savings is one of the most important variables in CBA of transport infrastructure. Travel time savings represent a large share in total benefits of the project – numbers concerning latest experience of various EU’s national governments and European investment bank find that typical share is 80 % [1]. Therefore:

- heightened attention is required by time value determination,
- where some doubt about proper value exists, it is necessary to accomplish sensitivity tests in order to find out the impact of time value change,
- consistency in the appraisal must be kept – it is necessary to use consistent time values within the group of projects that are compared (e.g. TINA projects) [2].

If infrastructure is improved, time savings arise, both in passenger and freight transport. In the framework of passenger transport, evident difference among business trip and trips for other purpose exists. Working time includes either trips for employer’s enterprise or for own business in the case of private entrepreneurs. Non-working time includes all other kinds of trips. Generally, on that account there will be needful values for:

- working time savings [EUR/person-hour],
- non-working time savings [EUR/person-hour],
- time savings in freight transport [EUR/person-hour].

In the transport project appraisal, time values should be based on local values. Ideally, local values should be derived from local (or at least regional or national) data and from the results of transport market research and they should reflect willingness of individual user to pay for time savings [3, 4].

Nevertheless, if it is not possible to get reliable values based on willingness to pay, approximate estimates should be adopted.

For the purpose of providing a consistent set of values for safety impacts are necessary definitions for [5]: injuries seriousness, accidents seriousness and various cost items related to them. Relevant measures are [6]: costs in connection with an accident (EUR per one accident) and cost in connection with traffic accidents victims (EUR per one victim). Costs in connection with accidents and costs in connection with traffic accidents victims should be counted up in order to provide total costs of accidents within the network [7].

Costs in connection with an accident:

- material damage,
- police and fire services,
- insurance administration,
- legal and court costs.

Costs in connection with victims:

- treatment expenses and health care costs including administration,
- performance loss,
- human costs – smart money, grief, suffering.

3.2 Environmental impacts

Changes of transport system and final changes in the use of transport influence not only transport system participants but also those, who are exposed to the system and its emissions without being involved in it directly. Environmental impacts occur at the local, the regional and the global level (change of climate).

According to the theoretical principles of project management, projects should be designed in such way to balance any serious or dangerous effects by certain compensatory measures. As for environmental impacts, it is necessary to include costs of these measures in investment costs of the project [8]. Nevertheless, it is also necessary to report all remaining localized effects and ensure to be taken into account within the appraisal framework.

3.3 Wider economic impacts

Transport networks play a key role in economic development of countries and regions, which is the reason for financial resources allocation in transport investments through ISPA and international financial institutions (IFI).

Roles of a project in economic restructuring of regional and local economic systems in connection with wider economic impacts of transport investments include:

- in industry – incentive for local production/loss of local production; some sectors can profit or fail as a result of increased access to the market/increased competition,
- in financial economy and trade – incentive for local business activities/decrease of local business activity,
- incentive for tourism/decrease of tourism; incoming tourism can increase with improved access, while residents have tendency to travel at longer distance during their holiday,
- impact on regional balance of payments; net impact on the value of export minus import,
- on the labour market – incentive for local employment/losses in local employment; it can include the whole effect of improved access and economic changes in employment, in connection with working age population,
- on the market of land and real estates – incentive for new development/change in schemes of land use; it can include relocation of activities towards places close to transport connections and high quality junctions; possible consequences on car dependence and sustainable development.

3.4 Further political impacts

Governments (central and regional) invest in transport not only due to expected profit in the sphere of economic efficiency and mobility but also due to the fact that the investment is expected to have positive socio-economic effects on spheres of their political interest.

Further political impacts that should be taken into consideration in CBA:

- land use – whether the project promotes plans of the use of a particular industrial or agricultural sphere, housing, national parks/national preserve or if it contradicts them,
- transport networks,
- controversial questions of social politics and social cohesion,
- pricing,
- participation of private sector,
4 Selected appraising criteria

4.1 Cost-benefit ratio

Cost-benefit ratio (relation 1) represents the ratio of all benefits of an investment project and all costs that will be required by realization of the project [9, 10]:

\[
NKV = \frac{N_b}{K_b}
\]

(1)

where NKV is cost-benefit ratio, \(N_b\) - total value of all components that creates project benefit [EUR], \(K_b\) - total value of all project costs [EUR].

In case the appraised projects haven't the same duration of construction or lifespan, it is necessary to recalculate determined values to the same basis. That means, to express what benefit the project would have to a chosen year [11].

Without accomplishment of the above mentioned recalculation an alternative that would realize higher benefits in absolute numbers but during a longer time could be chosen. We can get further comparative base through the recalculation - relative benefits of the appraised project within the span of the unified period.

It is also necessary to take into consideration the development on financial markets and the development of the economy, which determines gross domestic product. Investment projects can calculate on anticipated inflation rate and determine expected costs on project realization on its basis [12]. However, in most cases projections concerning the development of the economy are not fulfilled. It is necessary to analyse the situation, when funds could be invested in a different way than in transport infrastructure, possibly to analyse particular alternatives with consideration of various interest rates. It is therefore necessary to consider discount rate.

If we want to get current benefit of the project, we must discount future incomes (relation 2) [13]:

\[
N_{p,i} = f \times N_i
\]

(2)

\[
f = (1 + p)^{-t_{a,i}}
\]

(3)

where \(N_{p,i}\) is present value of benefits of the investment \(i\) [EUR], \(f\) - discount factor, \(N_i\) - original (non-discountable) value of investment benefit [EUR], \(p\) - discount rate, \(t_{a,i}\) - base year for discounting, \(t_{a,i}\) - year that investment benefit is discounted at.

If constant investment benefit is expected for the whole period of service life, the calculation will be accomplished according to the relation 4 [13]:

\[
N_{b,j} = f \times B \times N_j
\]

(4)

\[
B = \frac{1 - (1 + p)^{-t}}{p}
\]

(5)

where \(N_{b,j}\) is present value of benefits of the investment \(j\) [EUR], \(B\) - capitalization factor, \(t\) - number of years with constant benefit of the investment.

Investment costs discounting can be accomplished with the use of discount factor (relations 6 a 7) [1]:

\[
K_{b,i} = f \times K_i
\]

(6)

\[
f = (1 + p)^{-t_{b,i}}
\]

(7)

where \(K_{b,i}\) is present value of the cost item [EUR], \(f\) - discount factor, \(K_i\) - evaluation of cost items in the current year [EUR], \(p\) - discount rate, \(t_{b,i}\) - base year, \(t_{a,i}\) - year that cost item is discounted at.

If information about cost distribution in the course of construction is not available, we suppose their uniform distribution. The calculation of current costs is then accomplished according to the following relation 8 [1]:

\[
K_b = f \times B \times K_j
\]

(8)

\[
B = \frac{1 - (1 + p)^{-t}}{p}
\]

(9)

where \(K_b\) is present value of investment costs [EUR], \(f\) - discount factor (between the moment of investment beginning and the base year), \(B\) - capitalization factor, \(K_j\) - value of average investment costs in the course of construction [EUR], \(t\) - construction duration.

The accomplished analysis shows how funds for construction are treated. For evaluation it is acquired present value of investment benefits and present value of project costs.

4.2 Cost-benefit difference

Another appraising criterion is cost-benefit difference. The criterion compares total discounted incomes following from the project with total discounted costs that must be invested in the project. The criterion refers to the base year and is determined by the relation 10 [14]:

\[
NKD = N_b - K_b
\]

(10)

where \(N_b\) means total current benefits of the project [EUR], \(K_b\) - total current costs of the project [EUR].

In case costs and benefits are determined in particular years, criterion value is calculated for every year with the use of capitalization coefficient according to the relation 11 [14]:

\[
NKD_j = N_b \times \frac{1}{B} - K_b \times \frac{1}{B}
\]

(11)

where \(NKD_j\) is annual cost-benefit difference [EUR], \(B\) - capitalization factor.

5 Results and discussion

The main part of CBA design is the estimate of users' benefits. The most important for economic side of many projects are user's benefits in the sense of time and money savings.

Three fundamental concepts that represent the basis of the user's benefit definition in transport CBA are generalized costs (GC), willingness to pay and consumer surplus (CS) [15]:

- generalized costs mean the amount of money representing total disutility or inconvenience of travelling between particular source (i) and destination (j) by means of particular kind of transport (m). Strictly speaking, they include all aspects of disutility including spent time, expenses and further aspects of inconvenience (in practise, these last are usually ignored);
- willingness to pay is the maximal amount of money that a consumer would be willing to pay to undertake a particular trip (this can be interpreted in the best way as maximal generalized costs that he is willing to pay to get from i to j);
- consumer surplus is defined as surplus of consumer's willingness to pay over current generalized costs of travelling from i to j.

For the travel market between i and j (for simplification we suppose existence of only one transport kind):

\[
UP_{ij} = SP_{ij}^1 - SP_{ij}^0
\]

(12)

where \(UP\) - user's benefit [EUR], \(SP\) - consumer surplus [EUR], \(m\) means the situation with the project and 0 the situation without the project.

Components of generalized costs will differ depending on transport kind. Users of public transport (bus, coach, railway and water) pay for the fare and spend time for the purpose of trips to their destinations. Users of passenger cars and lorries for own purpose (they give up time) pay charges for access to
infrastructure and pay also vehicle operating costs. That's why fundamental difference exists in reported user's benefits for different kinds of transport.

6 Conclusion

Transport infrastructure projects have a great impact on transport system and influence both transport users and subjects participating in its formation. These projects must be judged on the basis of multi-criterion comparison. It is difficult to apply free market competition because there are limited geographical conditions for transport constructions realization. Transport infrastructure represents a typical project realized in the public interest.

Another specific characterization of transport infrastructure investments is their long-term use and construction. It is therefore necessary to judge transport infrastructure projects mainly in the long run. The appraisal should be made with respect to public good, in particular.

Infrastructure projects can be generally judged on the basis of comparison between construction costs and construction positives that means through cost-benefit analysis. This analysis evaluates not only monetary impacts but also non-monetary ones, which is necessary in the case of such projects.

Note: The article is published within the solution of the research proposal VZ-MSM 0021627505 „Transport systems theory“.

7 References

THE ANALYSIS OF DOMINANT FACTORS OF LONGITUDINAL TRUCK VIBRATION WITHIN FREQUENCY RANGE 0-5 Hz

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Abstract: Human body is especially sensitive to longitudinal vibration within frequency range up to 5 Hz. The basic source of this vibration comes from the leap variation of engine torque, frequently followed by the intensive transmission vibration. The influential parameters of transmission vibration which are mostly analyzed are the following: time and flow of torque growth, frictional clutch characteristic, clearances in transmission, adhesion along wheel and ground, stiffness and damping characteristics of transmission and tires, etc. Based on the experimental investigation results of a truck of overall weight 19t, a mathematical model is developed so as to describe properly the longitudinal vehicle and driver vibration. In fact a model consists of two parts: one that includes transmission (linear model) and the other that introduces planar model for the analysis of vehicle longitudinal vibration. The paper presents in details a model that describes transmission torsional vibration of a truck wheel formula 4x4, easily transformed to a model 4x2 by use of simple mathematical constraints.

KEYWORDS: LONGITUDINAL ACCELERATION, TORSIONAL VIBRATION

1. Introduction

The most frequently analyzed influential factors of vehicle longitudinal vibration arc [2, 3]: time and torque increase flow, frictional clutch characteristic, clearances in transmission, adhesion between wheel and ground, stiffness and damping characteristics of transmission and tires, etc. In this paper a special attention has been paid to the analysis of processes caused by the shunt variation of engine torque, being a basic cause of vibration in the frequency domain up to 5 Hz, in which humans are particularly sensitive.

2. Mathematical models for calculation of vehicle longitudinal vibration

Mechanical transmission can modelled as a large number of inertial masses tied with elasto-damping elements that represent particular transmission elements. Published papers which analyze vibration in low frequency domain mostly apply 2-5 inertial masses. The simplest models [3] are based on application of two inertial masses, one of which represents the engine with flywheel and the other represents the vehicle body. These inertial masses are linked with elasto-damping elements that apply both on transmission and tires. The most of the damping effect comes from the slip in tire-to-ground contact area. Therefore, correct modelling of dependence of adhesion coefficient and wheel slip deserves special attention.

Radial force on the wheel is directly dependant to wheel slip, i.e. difference between rotation wheel speed and vehicle speed. In references there are many formulas based on empirical data, most of them are complicated. For the analysis presented in this paper a model [2] is adopted, which defines dependence between slip and adhesion coefficient in the following way:

\[
\mu = \mu_h \cdot \sin \left( \frac{2 \cdot \pi \cdot \lambda}{4 \cdot \lambda_h} \right) \quad \text{for } |\lambda| < \lambda_h, \ldots \ldots (1)
\]

or

\[
\mu = \frac{\mu_h - \mu_{-h}}{\lambda + \lambda_h} + \mu_{-h} \quad \text{for } |\lambda| > \lambda_h, \ldots \ldots (2)
\]

where

- \( \mu_h \) - maximal value of adhesion coefficient,
- \( \lambda_h \) - slip at maximal adhesion,
- \( \lambda \) - slip,
- \( \mu \) - adhesion coefficient at maximal slip.

3. Mathematical model for calculation of longitudinal vibration of 4x4 and 4x2 wheel scheme vehicle

The choice of optimal mathematical model capable to represent process has to comply with two opposed requirements. One of them is to describe credibly the process which is subjected to the analysis, taking into consideration as many relevant factors as possible, and the other is to be applicable in case of as few degrees of freedom as possible.

On the basis of the results achieved by experimental investigation results of a truck of overall weight 19t, given in details in [4], a mathematical model has been created to describe adequately vehicle and driver longitudinal vibration caused by shunt variation of engine torque, being a result of drivers command. The adopted mathematical model consists in fact of two parts: one that covers power train (linear model) and the other which applies plane model for analysis of vehicle longitudinal vibration. A model that describes transmission torsional vibration of a 4x4 vehicle is shown in Figure 1. and can easily be transformed into a model 4x2 by means of mathematical restrictions.

Vehicle plane model is often composed of sprung mass (body) and unsprung mass (wheels, axles) linked to each other by elasto-damping elements. In case of heavy trucks, cab is suspended flexibly and the model should be enlarged by a single sprung mass-cab, as well as driver’s seat, also flexibly suspended. Since the primary goal of this paper is the analysis of factors of longitudinal vehicle vibration excited by the vehicle driving system, the further attention will be paid to a model of driving system and for review of the whole vehicle model readers are advised to consult [4].

Generalized coordinates that describe vibration according to the adopted model of vehicle driving system, shown in Figure 1. are:

q(1)- rotation angle of engine flywheel
q(2)- rotation angle of gearbox output shaft
q(3)- rotation angle of input shaft of power distributor
q(4)- rotation angle of rear axle differential gear
q(5)- rotation angle of rear wheel rim
q(6)- rotation angle of rear tire wade surface
q(7)- rotation angle of front axle differential gear
q(8)- rotation angle of front wheel rim
q(9)- rotation angle of front tire wade surface
4. The influence of excitation originated from engine

Vehicle start with instant clutch release;  
Intensive acceleration after the engine brake regime;  
Instant accelerator pedal release followed by the intensive acceleration, also known as “back-out” – “tip-in” regime.

The appearance of high values of torque at vehicle start, with instant clutch release, close to the edge of engine performance, is not a phenomenon that often takes place in service conditions of such a kind of vehicle. Therefore, it does not represent a major significance for the analysis of vehicle longitudinal vibration from the aspect of vibration comfort. It also appears that the optimal case for comparison of levels of longitudinal accelerations is intensive acceleration after the engine brake regime, due to a minimal influence of driver’s behaviour.

The increase of engine torque can be defined by means of different approaches, but for this analysis the increase of torque has been specified in the form of ramp function with various duration time of engine torque increase up to the maximal value. Engine torque shunt happens in short time period starting from the initial value $M_{min}$ up to the $M_{max}$ according to the following expression:

$$M_{mot}(t) = \begin{cases} M_{min} & \text{if } t < T_1 \\ (M_{max} - M_{min}) \cdot \frac{t - T_1}{T_2 - T_1} & \text{if } T_1 < t < T_2 \\ M_{max} & \text{if } t > T_2 \end{cases}$$

where time of torque increase is $T_2-T_1$ $(\Delta T$ , in the further text).

Figure 2. shows flow of the engine torque applied as excitation for longitudinal vibration calculation, by use of the adopted mathematical model. Duration time of engine torque increase varied within the limits registered during the experimental investigation.

By use of D’Alambert principle [1], differential equations are written to describe small vibration around balance position[4]. Differential equations are nonlinear, with constant coefficients and are to be solved numerically, by use of Kutta-Merson method. The sample of increment is automatically changed. Initial one was specified to be $h_0=0.01$ and the adopted number of points was n=512, enough to enable analysis of vehicle longitudinal vibration for 5s duration time, in frequency domain 0.2-50Hz.

4. The influence of excitation originated from engine

On the basis of the experiments performed, it has been discovered that there are three basic cases of excitation coming from the engine that provoke high level of vehicle longitudinal vibration:
It should be noticed that the tested vehicle was equipped with the clutch of complex characteristic, producing the effects of torsional vibration similar to those caused by clearances in the system. Clearances in the system are present in minor or major extent at each attachment spots of the transmission elements, but in this phase only the influence of clearances in main gear, differential gear and half-shafts assembly have been analyzed as dominant.

Figure 4. shows separately the results of influence of clearance for the case of engine excitation in ramp form (ΔT =0.3s) on cardan shaft torque and longitudinal driver’s acceleration. From the figure it is obvious that longitudinal vibration increase with clearance increase, especially in the first vibration periods. Besides, due to clearances, cardan shaft torques shows broken amplitudes in case of zero torque.

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7. The influence of vehicle wheel formula

The previous discussion has pointed out on significant influence of duration time of torque increase on the levels of longitudinal vibration. The following text will focus on comparative analysis of dynamic processes of a vehicle subjected to the variation of wheel formula, either 4x4 or 4x2.

The analyses performed by use of the adopted mathematical model indicate that engagement of various wheel formulas, through variation of vehicle dynamic parameters, shows a significant influence on vehicle longitudinal acceleration, i.e. vibration comfort in “fore and aft” direction. Figure 6. presents comparative review of calculation results of variables concerning both cases (4x4 and 4x2) for duration time of torque increase $\Delta t = 0.3s$. Differences in vibration period and amplitude levels are obvious.

Similar to the case of unloaded vehicle, it is clear that there is a noticeable difference with respect to amplitudes and vibration periods. Vehicle with wheel formula 4x4 shows relatively short period of vibration damping, while this is not the case for vehicle with 4x2 wheel formula. It can be undoubtedly predicted that driver’s response to vibration comfort of a 4x2 vehicle will be unfavourable due to a long and intensive vibration in whole period of vehicle acceleration.

8. Conclusions

The analyses of longitudinal vibration of loaded and unloaded vehicle confirms the significance of the influence of excitations originated from the engine, clearances in driving system, engaged gear and exceptional influence of vehicle wheel formula. The dominant influence of excitation coming from the engine is mostly a result of duration time of engine torque increase.

About clearance influence, it has been confirmed that longitudinal vibration are increased with clearances, especially in first vibration periods.

The choice of higher gear engaged causes decrease of cardan shaft torque shunt, noticeable even in the first damping amplitudes. Engagement of wheel formula 4x4 or 4x2, without other dynamic parameters variation, directly influences variation of driver’s vibration comfort. Vehicle of 4x4 wheel formula shows relatively short damping period, unlike 4x2 vehicle. This fact is more significant for loaded vehicle.

Driver’s vibration comfort is estimated to be reduced in case of 4x2 wheel formula due to a long and intensive vibration in whole period of vehicle acceleration.

9. References

Abstract: The design life of engine hot section components is typically shorter than their cold section counterparts, due to the fact that they have to operate under elevated temperatures and stresses. Unanticipated failure modes can keep engines from achieving their expected design life and may even result in loss of engines. This paper describes an integrated prognostic approach designed to monitor hot section component degradation under elevated temperature, pressure, and corrosion, as well as to infer their useful remaining life. This approach combines both safe life and damage tolerance concepts, and takes into account of all the common hot section failure mechanisms such as creep, low and high cycle fatigue, oxidation and corrosion. Successful integration of this approach into modern diagnostic systems can reduce the cycle cost for gas turbine engines while maintaining the equivalent safety.

KEYWORDS: SAFE LIFE; DAMAGE TOLERANCE; ENGINE HOT SECTION; FATIGUE; CREEP; OXIDATION; PROGNOSTICS

1. Увод

Поддържането на работоспособността и изправността на авиационните газотурбинни двигатели, както и осигуряването на безотказна работа по време на полет зависи в голяма степен от ефективността и качеството на техническото обслужване, което авиационните оператори са задължени да извършвят в съответствие с одобрена за целта програма.

Традиционно за газотурбинните двигатели е периодичното техническо обслужване, базирано на фиксираните интервали от време за работа на двигателя. Съставят на необходимите за даден елемент регламентирани работи и тяхната периодичност се определят въз основа на механичните и циклични свойства на материала при максимално неблагоприятни условия на експлоатация. Този вид техническо обслужване е характерен за конструкции, проектирани с гарантиран ресурс. За да се осигури безопасност на полетите при двигатели, които се експлуатират по ресурс, дълготрайността на най-отговорните конструкционни елементи обикновено се определя като част от необходимото време за експлоатация на двигателя, преди поява на признаци за повреждане. При този подход за експлоатация не се отчитат възможности за преждевременно изчерпване на ресурса и снемането от експлоатация на даден елемент или на двигателя като цяло, а също така и възможностите за експлоатация на годни изделия след изтичане на ресурса им. Експлоатацията по ресурс на авиационните двигатели води до скъпо струващо и ненужно снемане на двигатели от експлоатация, както и до продължаваща експлоатация на двигатели, имащи влошени параметри и характеристики, което застрашава това степен безопасността на полетите.

За да се намали вероятността за ранно възникване и развитие на повреди в отговорни елементи от конструкцията на експлоатирани по ресурс газотурбинни двигатели, допълнително се извършва визуален и инструментален контрол на състоянието и анализ на данни за изменението на вибрациите и газодинамичните параметри на двигателя. Този начин за оценка на състоянието се използва при конструкции, проектирани за експлоатация с допустимо повреждане. В тези случаи се извършва мониторинг на състоянието на елементите с помощта на различни методи и средства за диагностика, като се следи развитието на повредите да не надхвърлят съответните значения на експлоатационните допуски. Допуските на повредите се определят на базата на експлоатационния опит, с помощта на специални методики за изчисляване и по резултатите от експериментални изследвания.

Възможностите за своевремена и правилна диагностика на състоянието на елементите от горещия газовъздушен тракт на двигателяте, в случаи на преждевременно повреждане по незадължителни причини, се увеличават с навлизането на нови сензорни технологии, осигуряващи локализиране на повредите и откриване на влошени свойства и характеристики на отделни елементи. Пример в това отношение е оптичната система за контрол на горивния процес чрез детекция и анализ на интензивността на фотонните емисии в горивната камера. С помощта на тази система се открива наличие на претръгти зони и нагар по огневата тръба, различни примеси в горивото, непостоянен факсел на пламъка, повреди на елементи от горещия газовъздушен тракт на двигателяте в резултат от неуточнена работа на компресора и т.н.

Други примери за развитието на сензорните технологии са: определяне на разпределението на температурата по повърхността на турбинните лопатки с помощта на оптичен пиrometer; контрол на устойчивостта на горене чрез сензори за оценка на динамичното натоварване, вибрационна диагностика на лагерите, мониторинг на термо-акустичните емисии и др.

Фиг. 1. Определяне на остатъчния ресурс.

Основна тенденция при съвременните диагностични системи на газотурбинните двигатели е стремежът за разширяване на техните възможности по отношение на прогностиката. Това ще позволи да се извършва прогнозиране на състоянието на отделни елементи чрез правилно свързване на откритите повреди с остащата полезен ресурс на отделния елемент. За да се реализира на практика тази идея е необходимо да се разработват надеждни прогностични методики, които обединяват диагностичната история заедно с условията на експлоатация и физичния механизъм на развитие на повредите.

Традиционната методология за прогнозиране на полезния остатъчен ресурс е илюстрирана на фиг.1. Нейното предназначение е да осигури създаването на прогностични
системи за оценка на ресурса, които да допринесат за увеличаване на полезния експлоатационен ресурс на двигателите в максимална степен и в частност на елементите от горещия газовъздушен тракт. Това ще осигури едно по-високо ниво на безопасност на полетите в сравнение с експлоатацията по ресурс на газотурбинните двигатели, комбинирана с планови инспекции. Тази цел може да бъде постигната само чрез съчетание на авангардни диагностични технологии с непрекъснат анализ на параметрите на състоянието и използването на газотурбинните двигатели.

2. Преходства и начини за разрешаване на проблема

2.1. Механизми за повреждане на елементи от горещия газовъздушен тракт:

Горещият газовъздушен тракт на газотурбинните двигатели включва горивната камера и турбината, чито елементи са подложени на действието на много високо температури. Турбинните лопатки имат основен принос за увеличаване на разходите за техническо обслужване на газотурбинните двигатели [1, 2].

Ресурсът на елементите от горещия газовъздушен тракт на двигателя зависи в голяма степен от следните фактори:
- подръжка на температурата в установени граници;
- подръжка на равномерно температурно поле на входа в турбината;
- свеждане до минимум на инцидентните поради претоварване на въртящите се елементи;
- въздържане от използване на корозивни горивовъздушни смеси;
- интензивност и честота на горещо пускане на двигателя.

Поради повишени температури и експлоатационни напрежения, предиспяният от производителя ресурс на елементите от горещия газовъздушен тракт е почти два пъти по-кратък от този на елементите от студената газовъздушен тракт. Тенденцията при експлоатацията на авиационните газотурбинни двигатели е получаване на все по-високи температури и напрежения в елементите от горещия газовъздушен тракт, което е в съчетание с използването на нови материали довежда до възникване на нови, не срещани по-рано повреди. Тези неочаквани повреди могат да повредят на елементите на двигателя да достигнат предварително предиспяният им от производителя гарантiran ресурс [3, 4, 5].

Обичайните механизми на повреждане, които могат да прогресират в резултат на нормална експлоатация или неправилно техническо обслужване на двигателя са:

- малоловколова умора на материала;
- многоловколова умора на материала;
- пълзене / откъсване на материала;
- окисляване;
- корозия;
- повреждане от навлизане на чужди предмети.

Първите четири механизма са свързани основно с проектирането на двигателя, докато последните три произтичат обикновено от условията на експлоатацията.

Малоловколова умора на материала. Елементите от горещия газовъздушен тракт на газотурбинните двигатели са подложени едновременно на действия на променлив температури и напрежения, в резултат на което възниква термомеханична умора на материала. Традиционните методики за прогнозиране на ресурса, базирани на условието за постоянна температура и еластично поведение на материала, не са приложими в случаите на малоловколова термомеханична умора, поради различия в механизма на повреждане. При нискочестотни променливи напрежения, съчетани с високи и променливи температури се наблюдават два основни механизма на повреждане от умора на материала: синхронна термомеханична умора – възниква когато максималните стойности на деформациите и температурата съвпадат по време; несинхронна термомеханична умора – възниква когато максималната стойност на деформациите съвпада с минималната стойност на температурата по време. Пример за несинхронна термомеханична умора на материала е зараждането и развитието на пукнатини в ръб на турбинните лопатки в резултат от повтарянето на работните цикли на двигателя [3, 6].

Многоловколова умора на материала. Многоловколовата умора на материала е процес за зараждане и развитие на пукнатини като резултат от действието на променливия напряжение с малка амплитуда и голяма честота, в комбинация с металургически дефекти и други концентрато. Съвремените лопатчични машини са проектирани да издържат на високи напрежения, но многоловколовата умора на материала не се обикновено като резултат от асиметрични вибрационни натоварвания, отличаващи се с малка амплитуда и големи средни напрежения на цикла. Многоловколовата умора на материала, водеща до повреждане и разрушаване на лопатки и дискове от газотурбинните двигатели, по настоящем е основна причина за настъпване на внезапни повреди и откази.

Окисляване. Поради много високи работни температури, турбинните лопатки са доста податливи на високотемпературно окисляване. Окисляването насяква в резултат от формиране на кръкъх окисен слой по повърхността на турбинните лопатки, който може да доведе до пръстеновидно изместване на поврежден участък от умора на материала. При турбинните лопатки обикновено се използва въздушно охлаждане за понижаване на температурата и образуване на защитен охлаждач слой, препазващ перото на лопатката от връзкото действие на горещите газове. Ако настъпи изменения в непрекъснатия въздушен поток или в температурата на околната среда, лопатките може да се разрушат преди определения им при проектирането гарантиран срок на експлоатация [7, 8].

Пълзене на материала. Пълзенето е продължителна деформация на материала, подложен на действието на напрежения при определена температура. В условия на висока температура, се влошават свойствата на материалите и процесът на пълзене се ускорява. Пълзенето на материалите може да породи малки пукнатини, които по-късно да нараснат до критичен размер и да доведат до разрушаване на съответните конструкционни елементи. Тези разрушения могат да бъдат катастрофални, особено в случаите когато залязт елементи от ротора на компресора или турбината. Оценката на повреждането поради пълзене на материал може да се извърши с помощта на кривата на пълзене, която се състои от три участъка: първоначален (преходен), вторичен (установен) и третичен (неустойчив), който води до разкъсване [6, 7, 9].

Времето до разкъсване на материала при пълзене  

$$t_p = \frac{1}{\varepsilon_p}$$

където $M$ е константа на материала, изменяща се в диапазона 0.1-10. Когато $\varepsilon_p$ нараства, кривата на пълзене става по-вертикална и времето до откъсване на материал намалява.

При по-ниски температури, деформациите на пълзенето на повреждането обикновено не са големи и рядко водят до повреди. При средно високи температури (между 40% и 90% от границата на топене на материала), скоростта на установено пълзене на материал може да се представи като функция на напрежението $\sigma$ и температурата $T$ във вида:

$$\varepsilon_p = \frac{AB\sigma^p}{e^{\frac{Q}{kT}} - 1}$$

където $A$ е константа, $B$ и $p$ са константи, зависещи от вида на материала, $R$ е универсална газова константа, $Q$ е енергията, необходима за активиране на процеса на пълзене на материал.
На фиг. 2 са представени няколко криви на пълнение за един и същ материал, съотвестващи на различни температури и напрежения. Тези криви са получени на базата на изравнение (2) и данни за свойствата на материал S-590, съгласно [10].

На фиг. 3 е представен обобщен модел за прогнозиране на остатъчния ресурс на елементи от газопламенен тракт, разработен през последните години от Сърбия [3, 4, 5, 11]. Моделът е линейно-нестационарен и се използва в инженерната практика за прогнозиране на остатъчния ресурс на елементи от газопламенен тракт, разработен през последните години от Сърбия [3, 4, 5, 11].
помощта на съответен модел се определя скоростта на нарастване на пукнатината, на базата на различни спектри на натоварване и се прогнозира времето за достигане на пукнатината до критичен размер и разрушаване на елемента.

В предлагания обобщен подход за прогнозиране на осталящия ресурс на елементи от горещия газовъздушен тракт, натрупването на повреди се определя като сума на няколко компоненти.

Натрупването на повреди от малочислова и многочислова умора на материала се определя с помощта на правилото на Palmgren-Miner вида:

\[ D_i = \sum \frac{n_i}{N_i} \quad i = 1...m, \]

където \( n_i \) е брой цикли с дадена амплитуда на натоварване, \( N_i \) е бой цикли до разрушаване, \( m \) е общ брой нива (амплитуди) на натоварване. Ресурсът на даден елемент се определя от условието \( D_i = 1 \).

Натрупването на повреди от пълненото на материала се определя по аналогочен начин вида:

\[ D_o = \sum \frac{t_i}{t_{oi}} \quad i = 1...m, \]

където \( t_i \) е времето, съответстващо на определена температура и деформация, \( t_{oi} \) е времето до разкъсване на материал, \( m \) е общ брой на комбинациите от различни температура и деформация.

Натрупваното повреждане поради окисляване на материала при турбинни лопатки, съставени от три слоя различни материали се определя вида:

\[ D_b = \sum D_i^l \quad l = 1, 2, 3 \]

(5)

където \( l \) е номер на слоя, \( t_i \) е времето, съответстващо на определена температура, \( t_{oi} \) е времето до разрушаване, \( m \) е общ брой на комбинациите от различни температура и натоварване.

В предлагания подход за прогнозиране на осталящия ресурс на елементи от горещия газовъздушен тракт на газотурбинни двигатели, откриването и следенето на развитието на пукнатини включва установяване на зараждането на пукнатини, диагностиране на тяхното местоположение и степен на опасност и прогнозиране на скоростта на нарастване на пукнатините. Обикновено това се извършва чрез събиране и анализиране на данни от различни датчици. Например, необичайно повишаване на напреженията, вибрациите и/или неравномерност на температурното поле могат да бъдат индикатор за наличие на пукнатина в турбинна лопатка.

4. Заключение

С цел постигане на по-пълна и точна прогноза, представената обобщена методология за оценка на осталящия ресурс на елементи от горещия газовъздушен тракт на газотурбинни двигатели обединява в себе си подходите за определяне на ресурса на елементи, проектиране за експлоатация с гарантирани ресурс и на елементи, експлоатирани по същество. При първия подход натрупването на повреди се използва за определяне на гранични гарантирани ресурс за даден елемент, докато при втория подход се разчита на използване на информация от датчици за откриване и наблюдение на пукнатините.

Представеннят обобщен подход за прогнозиране на осталящия ресурс дава възможност за оценка на натрупването на повреди чрез използване на параметрични данни от детайлния апарат и двигателя при различни натоварвания и условия на експлоатация. При всеки полет натрупването на елементите се следи и определя на базата на данни за натоварването и скоростта на развитие на повредите, възникнали в резултат от умора, пълзене и окисляване на материала. При отсъствие на пукнатини, осталящият ресурс на елементите се определя в съответствие с натрупаниято повреждане. След като се откриват наличие на пукнатини, оценката на полезния осталящ ресурс на съответния елемент се извършва вече на базата на следене и прогнозиране развитието на пукнатините. Тази функционалност на представения обобщен подход осигурява защита от разрушаване на отговорни елементи преди достигане на определения при проектирането им гарантиран ресурс и спомага за повишаване на надеждността на авиационните двигатели и безопасността на полетите.

5. Литература

THEORETICAL ACCESSES TO ANALYSIS OF A USER BEHAVIOUR IN TRANSPORT

ТЕОРЕТИЧЕСКИЙ ПОДХОД К АНАЛИЗУ ПОЛЬЗОВАТЕЛЬСКОГО ПОВЕДЕНИЯ В ТРАНСПОРТЕ

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Abstract: The paper deals with the general principles of user’s behaviour and consequently the principles of user’s behaviour within choosing, buying and using transport services. It defines four basic points of view, which can explain user’s behaviour with greatest attention to economic rationality point of view. Behaviour of transport services user can be explained through the three relatively independent parts – understanding the user’s reactions on external initiatives, understanding the user’s train of thought after receipt of external initiatives and before making purchase decision and finally understanding the user’s behaviour within the realisation of particular purchase decision steps.

KEYWORDS: UTILITY, USER, TRANSPORT SERVICE, PURCHASE DECISION

1. Introduction

The issue of user’s behaviour generally deals with users’ choosing, buying and using products that serve for satisfaction of their needs and wishes.

The behaviour of users on a market is a complicated process. Motives and behaviour of people in the frame of the buying process are mostly unpredictable and complicated. If often happens that users behave themselves in different ways in relation to their declared needs and wishes or they react in the fact of being at the place of purchase. The buying users tend to satisfy their wishes and needs or to solve their specific problems and so for example when you need to solve any matter at the region office, transportation can help you to solve your problem because you are able to transfer yourself to the region office.

2. General principles of user’s behaviour

From the above mentioned it is clear that the only good knowledge of a level, time and space division of users needs can be the base for the choice of buying, marketing, technological and logistics strategy of a transport company.

With some specific probability we can indentify four basic view directions that are trying to explain the consumption behaviour of users [5]:

• on the point of economic rationality,
• on the point of psychology,
• on the point of sociology,
• on the point of marketing, so called model „stimulus – reaction“.

On the point of economic rationality

This point of view is according to the orientation of our research project understood as a key one. The user is considered as totally rationally thinking subject behaving according to principles of economic profitability. The user behaving this way follows two basic elements [2]:

• satisfaction of needs brought by a product,
• costs of gaining product.

Costs of gaining product are determined by prices. To define the term satisfaction of needs economists use the term utility that determine a subjective feeling of satisfaction from consumption of a product. It performs scientific creation that economists use for understanding a principle how rational users divide their limited financial sources among products that brings them satisfaction.

Total utility is the function of quantity of consumed products for the same conditions “ceteris paribus”. [3]
Marginal utility depends on:

- importance and intensity of a need (if needs are urgent than each next unit of a product brings relatively big utility),
- dispensable quantity (the rarer is the goods the bigger is the marginal utility from the goods). [2]

Except the term marginal utility, also the term total utility has a big importance that express a total level of satisfaction of a need. User tries to maximize his utility that brings him purchases of consumed goods. If a user change his consumption the way that each separated product brings him the same marginal utility on a money unit of expenditures then he reaches maximal satisfaction and utility from his purchases. [1]

\[
\frac{MU_1}{P_1} = \frac{MU_2}{P_2} = \frac{MU_3}{P_3} = \ldots
\]

where \(MU_i\) are marginal utilities of separated products, \(P_i\) – prices of these products.

The term of marginal utility was appreciated for understanding the law of decreasing demand. But in several last decades the economists have come with alternative access for the analyses of demand and this access uses so called indifferent curves. This access offers deeper view on factors that usually cause sensitivity of demanded quantity to a price. It has been found out by the identification of income and substitute effect of a price change. [2]

On the point of psychology

There are especially focused psychological percepts and circumstances of consumer behaviour.

On the point of sociology

According to the sociological point of view one should on current conditions follow rules of social behaviour and social norms even if they are formal and often undefined but strongly used.

On the point of marketing

The behaviour of a user is explained on the reactions after conditioned stimulus.

### 3. Process of behaviour and decision making of users in transport

As a user of transportation services it is usually considered a forwarder of a consignment, passenger or a orderer of transportation.

On the general principles of user behaviour the total utility of a user of transportation services can be expressed as the whole level of satisfaction of a transportation need (a need of transportation from place A to place B) with the consumption of the product quantity. The total utility of a user of transportation service can be mathematically defined as a function [4]:

\[
U = f(S, \theta)
\]

where \(U\) is total utility, \(S\) – vector of service level: \(S = (t, p)\), here factually two most important factors – time of transportation and price for this service, \(\theta\) – vector of evaluation parameters of the time and price factors \(\theta = (\alpha, \beta)\).

Vector of parameters reflects preferences of separated customers and substitute relation of these parameters can be expressed as a proportion \(\alpha/\beta\). [4]

The process of user behaviour in transport services can be divided into three relatively separated parts. The outgoing point in research of user behaviour is the knowledge of a user reaction on different external stimulus.

Especially following stimulus are focused [3]:

- marketing stimulus:
  - product of transportation service,
  - way of distribution,
  - price,
  - sale support,
  - people offering transportation services,
  - processes of service offering,
  - material environment.
- others:
  - political,
  - economic,
  - legislative,
  - technological,
  - natural,
  - cultural.

Marketing stimulus perform separated elements of marketing mix that transport companies use for influencing and gaining users.

Second part of the process of user behaviour in transport services is the only user who works as a “black box”. The main task of marketing staff in a company is to recognize how the users think in time between gaining of external stimulus and buying decision making. [3]

This process is influenced by:

- user characteristics:
  - personal,
  - cultural,
  - social,
  - psychological,
- procedures of decision making of a user:
  - notifying of transportation need,
  - collection of information,
  - evaluation of alternatives,
  - decision making about a purchase,
  - behaviour after usage of transportation service.

Third part of the process of user behaviour in transport services perform the succession of separated steps in buying decision making [3]:

- choice of transportation service mode,
- choice of an afford company,
- time of decision making,
- volume of service usage.

It is important to recognise that behaviour of transport service users and transport service suppliers is different from buying behaviour of users and organisations of consuming and industrial products. Among most important differences belong following facts:

- users have limited possibilities of service suppliers choice and limited assortment of transportation services on a transportation market,
- risks of transportation service suppliers and users are bigger than buying of consuming and industrial products,
- user evaluate the quality of transportation service during or after its offering,
- acceptance of some kinds of transportation services is usually slower than consuming products,
- transportation service can not be storable,
- user of transportation service has limited possibilities to influence the process of service creation,
- users’ opinions of transportation service are created according to their personal experience and information.

### 4. Results and discussion

Among main factors influencing buying behaviour of users in transport belong: [3]

- Personal factors:
  - age
  - life cycle
Motivation research serves to finding out the users’ motivation at buying a product. When we want to examine the motivation of transport services users it is convenient to come out from the philosophy of their thinking. The wish of transportation service users it is convenient to come out from the highest quality, because e.g. travelling for culture belongs to facultative needs that should be satisfied in requested volume.

Social factors:
- referent groups
- family
- social roles.

Psychological factors:
- Perception – from the point of view of a user in transport the perception of price and risk connecting with purchase is very important (a user perceives price especially in relation to quality, where it is generally valid that the higher price of a product the higher perceptive quality and as for risk it is perceived by a user the way that realization of bought transportation service need not to fulfil expectation).
- Learning – if a user does not have any experience (e.g. in city public transport in unknown town, travelling abroad) at decision making about buying of a product, the buying process becomes for him a solution of an extensive problem; the more a user learns about a product and has more experience the sooner a buying situation becomes a solution of a limited problem or behaviour works automatically (e.g. every day commuting).
- Attitude – people being interested in railway technology will follow not only its history but also its future development and tend to use more railway transport than other transport modes.
- Motivation – basic element of motivation is actual need of a person; transportation need of persons do not exist separately but they are part of his/her way of life, profession, social interests, relations and attitudes and these needs are changing during his/her life (e.g. minimal number of change, minimal transport distance, minimal transport time etc.).

The main criteria for decision making of users in freight transport are:
- price for transportation,
- transportation time,
- direct delivery,
- maximal volume of transferred load,
- regularity and reliability of transportations,
- possibility of stocks minimizing at the side of a user (e.g. system Just-in-time).

Above mentioned criteria must be covered into specific aims, activities and programs of transport services suppliers. The most important conditions and presumptions for finding the equality between suppliers supply and requirements of transport users are hard market conditions, care of a current and future user, assurance of transportation capacity, usage of rules in different transport modes competitiveness etc.

5. Conclusion

General principles of users’ behaviour at the choice, buying and usage of products that serve to satisfaction of their needs and wishes are of course also applicable in the field of transportation services but we must respect specifics of this sector, as for example the situation that a user is able to evaluate the quality of offer transportation services even in time of realization or after it, transportation services are not storable, users opinion is created from personal experience etc.

A model of typical buying process in the field of transportation services covers plenty of steps (notifying of transportation need, collection of information for possibility of need realization, evaluation of alternatives, decision making about a purchase of a transportation service, behaviour after usage of transportation service). This model also reflects that buying process starts a long ago before the purchase and continues long time after it. From the practical life we know that users do not need to go through all these steps. In the case the user uses transportation services of the same company in personal transport every day; it skips and excludes the steps of information collection and evaluation of alternatives.

Note: This paper was made as a part of solution of the research project VZ-MSM 0021627505 „Theory of Transport Systems“.

6. References

Abstract: The effective management in the modern business word is practically impossible without strategic planning and constant monitoring over the supply chain management through the operators – transport companies. The development of the transport logistics in the EU is a precondition for that.

KEYWORDS: LOGISTICS, TRANSPORT COMPANIES

1. Увод

Навсякъде световните компании срещат предизвикателството за подобряването на ефективността. Начин да се постигне това е да приложат по-добро управление веригата на доставките или SCM (Supply Chain Management).

Управление веригата на доставки – SCM (Supply Chain Management) обхваща целия цикъл от закупуване на суровините, производство, съхранение до разпространение на готовата продукция и включва такива елементи като:
- управление на запасите;
- проследяване на стоката;
- информацияния поток.

Ефективното управление в съвременият бизнес е практически невъзможно без стратегично планиране и постоянен мониторинг върху управлението на веригата на доставки.

Най-прогресивно научно-приложно направление в тази област е логистиката. Нарастващият интерес към логистиката е обусловен от потенциалните възможности за повишаване ефективността на функциониране на различни организации. Практиката показва, че компаниите, използвайки решения за управление на свояте логистични операции, са по-конкурентоспособни и значително са увеличил своите печалби за сметка на по-малко загуби и разходи. Ефективното функциониране на предприятието, ползвайки система за Управление на веригата на доставки се постига за сметка на:
- рязко понижаване себестойността на продукта; по-висока надеждност и качество на продукта;
- пълен контрол върху всички операции;
- намаляване влиянието на човешкия фактор в работата;
- доверие.

2. Обща транспортна политика

Една особена област на извършване на услуги при логистичните процеси, представляват услугите за преодоляване на разстоянията те се извършват от транспортните предприятия, които осъществяват своята дейност чрез обединяване на активните елементи - съоръжения, хора, машини, енергия и информация, така че при съществувашата структура на разпределение на активите и върху човешкия фактор в работата; документацията е средство, но абсолютно недостатъчна за постигане на печална сметка. Ефективното управление на транспорта дава възможност да се изготвят графики за пристигане/изпращане на стоките, тяхното движение в предприятието, моделиране на маршрутата, регулиране на тарифите, подръжка на база данни, изготвяне на товароперативни документи, планиране и оптимизация на процеса на натоварване на поръчките.

От такива позиции може и по-подробно да се изследва взаимодействието на активните и пасивните (суровини, спомагателни материали и енергоносители, полуфабрикати) елементи в логистичната верига и заедно с това да се обяснени икономическите и конкурентоспособните обекти на транспортните услуги в рамките на процеса на създаване и разпространение в производството с потреблението.

Използване на единна технологична система за работа със стока и информация позволява високоскоростно получаване и обработване на поръчката и съгласувано планиране.

Развитието на транспортната логистика се обуславя на предположението за увеличение обем товари във връзка с членството на България в ЕС (фиг.1). Ръст се отбелязва особено при товарните внос в страната с инвестиционно предназначение, като по предварителни прогнози на база опита на други страни, очакваме увеличение на товарните потоци може да се очаква след третата година от членството в ЕС. Намаляването на транспортното време, свързано с отпадането на митническите процедури на основния обем прети от външнотърговския стокообмен на страната е също положителен фактор за повишаване ефективността на превозите.

Фиг. 1. Превозени товари от български транспортни фирми 2005г

За постигането на целите на Общата транспортна политика е необходимо хармонизирането на транспортното законодателство, правилата и процедурите със съвъкупното право на Общността (acquis communautaire) да се извършва по
такъв начин, че съответните закони на ЕС да станат изцяло включени в националната правна система. Законодателството в областта на транспорта включва всички директиви, наредби и решения, приети на базата на съответните класни от Договора. Освен това са включени правните принципи и интерпретации на Европейския съд, всички транспортни споразумения, в които участвува Европейската общност, както и съответните декларации и резолюции на Съвета на министрите. Изискванията към превозвачите се групират както следва:

- Наличието на финансова стабилност -достатъчно финансови средства за нормално и законосъобразно стартиране на дейността и нейното добро функциониране и уравнение, което условие следва да се проверява на всеки пет години;
- Изискване за професионална компетентност- Наредба № 11 за международен автомобилен превоз на пътници и товари и изменената Наредба № 33 за обществен превоз на пътници и товари на територията на Република България;
- Задължителни технически (социални) изисквания за превозните средства.

3. Резултати и дискусия

По данни на ИА "Автомобилна администрация" лицензираните за международни превози на товари фирми в България са намалели през последните шест години от 4709 на 3674 - с над една четвърт (фиг.2).

Прочините на това са няколко, но на първо място достъпът до бизнеса е твърде скъп. Според Закона за автомобилните превози всяка година изискванията за финансова стабилност на превозвачите растат. За да запазят лицензия си, компаниите трябва да докажат наличието на поне 7200 евро капитал за първия си камион и по 4000 евро за всеки следващ. За 2007 г. този пари е 9000 и 5000 евро съответно за първи и всеки следващ камион. Допълнителен натиск в посока консолидация и заличаване на малките фирми идва и от системата за разпределение на многократните СЕМТ разрешения за превози в Европа. Според нея колкото повече автомобили от типа Евро 4 има една компания, толкова повече такива разрешения получава. Тоест превозвачите не са само стимулирани, но и принудени да подменят парка си. Според "Автомобилна администрация" обаче това не означава по-малко камиони - техният брой дори се е увеличил от 2001 г. досега на 16 000 на 17230 (фиг.3). За размерите на РБългария данните са твърде показателни.

Тези развития намират отражение в европейския транспортен сектор както следва:

1. Транспортните пазари във всички държави-членки и РБългария се интегрират в общностните транспортни пазари.

2. Премахване на оставащите ограничения за международното въвеждане на товари в ЕС, за по-ефективно организирани транспортни операции.

3. Използване максимално икономическите възможности на съседните на ЕС страни, чрез развитие на транспортните връзки с тях, както и съответните технологии и инфраструктури.

Фиг.3 Тежкотоварни автомобили в ЕС

Фиг.4 Превози по страна на разтоварване 2004-2005г-млн. тонометри

От графичните на фиг.4 се вижда нарастващият товарооборот от страна на българските транспортни фирми, който в рамките само на една година е 16,04%, като почти двойно е увеличението на превозите за Руската Федерация и Украйна.

4. Заключение

Очакваното нарастване на международния шосен превоз на товари за периода 2007 г. до 2013 г., изчислено на 20,5 милиарда тонометра на година за 25-те държави-членки на Европейския съюз, е с отрицателни последствия по отношение на разходи за допълнителна пътна инфраструктура, ППП, задържане, местно и глобално замърсяване, належността на веригата за доставки и логистичните процеси и увреждане на околната среда. В Бялата кутия на Комисията относно Общата транспортна политика от септември 2001 г. се наблюдава на развитието на интермодалния транспорт като практично и ефективно средство за постигане на балансирана транспортна система. В тази връзка:

- Програмата Марко Поло II предлага различни видове дейности, които следва да допринесат за измеримо и устойчиво прехраняване на товари и по-добро сътрудничество на интермодалния пазар.
- Насочени са усилията към изграждането на производствени, търговски и логистични складови площи за общо ползване.
- За да устоят на ценовата конкуренция и за да поддържат високо качество по веригата доставките, много български фирми са принудени да приемат нови решения, съобразявайки се с тенденциите и да потърсят услугите на професионален логистичен провайдър.

5. Референции:

1. Kortschak B., Що е логистика? НТС и АЕБТРИ, С.
2. ИААА www.rta.govament.bg
METEOROLOGICAL SECURITY IN ROAD TRAFFIC THROUGH EXAMPLE OF TRANSPORT ROAD NETWORK IN REPUBLIC OF MACEDONIA

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Abstract: In Europe and Balkan boundaries, R. of Macedonia is important crossroad through which many important and intense transit routes are passing by from Western and Middle Europe to Near East. R. of Macedonia is in position of mediator of international traffic routes between above mentioned regions. This basic traffic routes, as part of Europe routes have power of economic, social, cultural and other kind of integration of Europe and nations from that part of world. This makes clear why question for road meteorology, which is accentuated in this paper, is of high importance for road traffic in common, and especially for international transport corridors. The question is how and how much meteorology conditions can increase/decrease road traffic safety, and also how much road meteorology can make gain for more quality, more efficient and more economic work of all instances in charge for road traffic safety.

KEYWORDS: ROAD METEOROLOGY, INFORMATION SYSTEM, TRANSPORT CORRIDORS

1. Introduction

Meteorological conditions have important influence on safety and capacity of roads. Comparing to air and water vehicles, road vehicles are less affected by meteorological appearing, but they are equal in need for methodological secure because of the number of vehicles involved in road transport and its intensity.

Numerous measures are taken in place to increase safety in road traffic, for example road maintenance. In this context, road meteorology should be seen as service for user oriented information and information about weather, necessary for deciding which measures should be taken by all services for maintain and secure road network. This information contains data from usual special meteorological measurig and observing, refining collected data, forecast of meteorological conditions and information system which will provide user’s access to informations. Irregularities of transport volume and transport engagement makes difficulties to the working rhythm of vehicles in vehicle park. For decreasing negative consequences it is necessary to adjust the working rhythm of vehicles in vehicle park, which means to adjust transport ability to dynamics of change of transport demands. Also it is necessary to adjust level of technical correctness of vehicles in vehicle park to exploitation demands. With this highest level of technical correctness is achieved in the moment when there is highest demand for transport tasks and lowest level in period with lower transport demands.

2. Terrain and climate informations for R. of Macedonia

Republic of Macedonia is mountain country. Almost 79% of its territory is mountain, and 19.1% is plain. Other 1.9% is water. Macedonia has different climate characteristics or mixture of continental and Mediterranean climate. Such condition is caused by direct climate influences from north and south, which results with temperature regime typical for both seasons: warm and dry summer and relatively cold winter. Average summer temperature is between 24.3°C and 20.6°C, and absolute maximal temperature is between 44.5°C and 40.0°C. Average winter temperature varies between 4.9°C and 0.9°C, but absolute minimum reaches to -29.4°C and -13.0°C.

Based on long term measures and observations, basic climate parameters in R. of Macedonia are defined in few relatively homogenous regions:
- Sub-Mediterranean climate region: Gevgelija–Valandovo, on (50-500)m above sea level. This is warmest region in R. of Macedonia, with average air temperature of (12-14)°C and highest temperatures during month July. July/August is driest months during year with average rain showers of 30 mm/m².
- Continental-Sub-Mediterranean climate: Central part along river Vardar, Stip, Veles, Kocani, Strumica and Radovish region. Average above sea level height is up to 600 m. Average air temperature is between (12-13)°C with highest temperature during July. Lowest temperature is in January, between (0-2)°C.
- Warm Continental climate region: Eastern part of R. of Macedonia. Average air temperature is between (10-11)°C.
- Cold Continental climate region: Western part of R. of Macedonia. Average air temperature is about 9°C.
- Sub-Mountain climate region: on about 2250 m above sea level and average air temperature of 5°C.
- Coldest are regions with Mountain climate: Solunska glava, on above sea level height greater than 2250m and average air temperature below 0°C.

This kind of terrain, climate and temperature characteristics of our country territory emphasizes very important need of meteorologically securing road traffic and on time information to its users. Use of it is multiple: state, people involved in traffic, road maintenance services, insurance companies and lots of other instances.

3. Meteorological measurings

Meteorology is based on measuring of different atmosphere parameters, among which most important are: temperature, humidity and air pressure, direction and wind strength, visibility, rain occurs (type, intensity and duration of), duration of sunlight, road surface condition and others. Necessary for process of measuring metrological parameters are continuousness, exactness and validness.
- Continuousness is provided by permanent measuring in certain network and point.
- Exactness is achieved by using appropriate instruments and apparatus.
- Validness is condition which guarantee that measured values is valid for place by which is gathered. Validness of measurements is most hard to obtain, because of fact that metrological parameters on relatively small distance may significantly vary.

It is true and maybe only way to make measurements which will provide relevant picture of metrological conditions of the road is automation. For this purpose Automated Meteorological Stations (AMS), are used with great reliability, exactness and automate work, and in the end with great economics because measurements performed do not ask large number of employees.
3.1. Meteorological measurements of critical points in road traffic

Critical points in road traffic are places on which meteorological conditions are significantly different than other in immediate surroundings. It can be digs, curves, bridges and other places where meteorological phenomenon happens with different meteorological conditions than other in immediate surroundings which have negative and surprising influence on road traffic users.

Effects of negative meteorological conditions are more emphasized on out of town traffic networks, but its influence is also great in towns, where traffic jam and delays burdens with extra load, and can even paralyze town living.

Bridges are important objects which are especially exposed and sensitive on metrological conditions. During low temperature, with increase of air humidity visibility is lowered in bridge areas, and ice on roads occurs. Also strong winds along rivers can have great influence on vehicles. Above mentioned metrological conditions hardens and slow down traffic and is cause for lots traffic accidents with great material damage.

For increasing safety in traffic, especially on critical parts and bridges, it is recommended to install automated meteorological stations for measuring metrological parameters which has influence on traffic. Additionally road surface conditions has to be measured and also the degree of ice on road. This measured date should be accessible in real time and can provide quick and on time preventing measures such are: slowing down or redirect traffic, cleaning and sanding the road with anti-ice products etc. Also this meteorological condition data for critical points of roads enable forecast for negative conditions development and it’s on time announcement which will help to make decision for appropriate and on time traffic safety measures.

3.2. Treatment of metrological data and meteorological condition forecast

High safety in road traffic has need for long term and short term weather forecasts, climate analysis and very short term weather forecasts. For performing such forecasts very narrow specialization is necessary for analyzing measured meteorological parameters

- Long term forecasts are unreliable and do not provide necessary data for road services.
- Short term forecasts for one to tree days are used for preparation of road services and eventual technical activity on the road networks.
- Very short term forecasts are used for decision making on road actions, and especially on type and kind of activities.
- Climate analyses provide long term preparation, service organization, for deployment and size of services planning. They are important for designing roads; define the trace of road and securing passive safety measures.

4. Road meteorogy condition in R. of Macedonia

In our country public services responsible for road maintenance and all road transport companies and unions on one way or another have need of use or show meteorological data, they use informations provided by Hydro-Meteorological Work Office (UHMR).

Hydro-Meteorological activity on territory of R. of Macedonia has rich and long tradition. It starts since 1891 when first meteorological measurements and observations are made, but organized network of meteorological stations has since 1923. Until 1947, despite the conditions has temporary interruption in measurement and observations. In that year Hydro-Meteorological Service of People’s Republic of Macedonia is founded and new hydro-meteorological network is formed.

In UHMR there are following departments:

- Department for analysis and forecast;
- Hydrological department;
- Department for analysis of nature environment and water
- Department for artificial influence and modifications.

Department of synoptic is in charge for making and defining all forecasts. Computer forecasts are made by data refining gathered by satellite snapshots, and trough model which for all data make analysis and forecast. Computer forecast model, provides data for temperature, wind, rain showers, energy and cloudiness.

There are following types of forecasts:

- Three day forecast;
- Numerical forecast for Europe (72 hours)
- Numerical forecast for R. of Macedonia (48 hours)
- Metograms for R. of Macedonia towns

4.1 Meteorological station in R. of Macedonia

Actual weather data are gathered with measurement in sinoptical stations network and further in Metrological department are performed actions which are related to:

- Organization and management the work of performing complete meteorological, climate and agro-meteorological measurements and observations;
- Obrabotka, critical control, archiving, publish and analysis of the results of performed measurements and observations;
- Following of the components of climate system and appliance of its results in science and economy.

Further down meteorological stations on R. of Macedonia territory in relation to transport corridors 8 and 10 will be shown.

- Corridor 8:
  - Direction: East-West
  - Starting point: Vele
  - Ending point: Deve Bair

- Corridor 10:
  - Direction: North
  - Starting point: Tabanov
  - Ending point: Deva Bistra

Figure 1. Meteorological stations in R. of Macedonia in relation to transport corridors 8 and 10

Figure 2. Main station in R. of Macedonia in relation to transport corridors 8 and 10
As it can be noticed, meteorological stations are positioned far from road and transport corridors. This means that such gathered data are not significant and valid for good view of road conditions. Data for wind, temperature and air humidity and visibility type and intensity of rains, also data for ice on road possibility are practically non-existing.

Monthly forecasts have low probability of achieving and most commonly they are only base for expert analysis and representing. Forecasts for present and next day have very basic character, because they are made for large number of different users, and the degree of responsibility for it is very low.

Very short term forecast almost is not available, and they not use climatology analysis necessary for tracing roads and building passive measures for road traffic safety.

4.2 Meteorological data from AMSM

Meteorological information which can be obtained from Auto-Mono-Union of Macedonia (AMSM) is mostly in following form:

- Daily information, which can be also called traffic and not meteorological information, because they are related to way of traffic performance;
- Information for road conditions, mostly for road clearance and throughput and;
- Information for border check points, for example time necessary for passing the border.

Such conditions, calls and obligates to make organization and establishing system for meteorological securing the road traffic in R. of Macedonia. This information system for providing real time information to users should achieve increased traffic safety, efficiency and economic in road traffic.

5. Information system for metrological securing road traffic in R. of Macedonia

For meteorological securing the road traffic in R. of Macedonia it is necessary to:

- Purchase and install automated meteorological stations for measuring meteorological parameters of roads, and especially critical sections and bridges;
- Provide transmission of metrological information to users, which understand forming metrological information center.

By this way will be achieved:

- Analysis of present conditions;
- Definition of road traffic users needs;
- Development of suggestion system for meteorological securing road traffic

There are different configurations of automated meteorological stations. Most simple configuration provides simple installation and programming.

System of this automated meteorology station is contained of:

- Automated station
- Sensors for scanning meteorology parameters: air temperature, humidity, direction and wind speed, quantity of rains, snow depth and direction of sunlight.
- PC software for visualization of data and report creation.

Elements for simplest configuration of automated meteorology station are shown on following figure 6:

More complicated configurations of automated meteorological station, also contains: sensors for level of water on road surface – ultrasonic sensors, sensors for visibility – optical sensors, sensors for height of snow – detectors, cameras, etc.
Further, gathered data for meteorological parameters and conditions, through signs with dynamical messages and other roadside objects and portal are transmitted to users, (Figure 8).

6. Conclusion

Analysis of meteorological securing the road transport network in R. of Macedonia is partial and not enough valid. Meteorological information provided to road transport users is old, non-transparent and unsatisfactional. With installing meteorological stations and forming meteorological information center, also with development of national programme and strategy for road meteorology, scientifically can be increased road traffic safety an economy and also road maintenance. On other hand, expenses for purchasing and installing the equipment are incomparable lower in relation to gains, lower traffic accidents, human losses and material damages, also in saving in road maintenance services.

7. References

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Determination of the Optimal Delivery Supply

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Abstract: This article deals with method of determination of optimal delivery supply of supplier to automotive industry. Today manager’s practice lays emphasis on decrease of stocks. The main issues are considered in this topic: the mathematical stochastic stock model to determine the optimal delivery supply.

KEYWORDS: STOCK, WAREHOUSE, ABC ANALYSIS, SUPPLY, COST

1. Introduction

Nowadays automotive industry develops in the Czech Republic. The modern logistic methods (JIT, KANBAN, etc.) are used in the branch of automotive industry. These methods lay demands on suppliers. Main requirements are quality requirement of supplied components, in time supplies and other. This article deals with method of determination of optimal delivery supply of supplier to automotive industry.

2. Importance of stocks for company

Today manager’s practice lays emphasis on decrease of stocks. Negative influence of stocks is that tie the capital, spend work and means (stocks have to store, consequently energy costs, service costs, costs of repairing, labour costs, etc.), risk of stock depreciation, risk of unserviceableness or risk of unsaleability (possible reason: change of production program or customer preference). Locked-up capital in stocks is short of the technical means (stocks have to store, consequently energy costs, service costs, costs of repairing, labour costs, etc.).

The stock level should be decreased on the minimum but on the second side it has to ensure sufficient readiness of supplies to customers. It is evident, that both points of view (stock minimization versus high readiness of supplies) are opposed and the company has to choose the compromise.

3. Classification of stocks

Stocks can classify according to many points of view (for example: degree of processing, suitability, function, etc.). Function classification of stocks is the most important from the point of view of operative management.

Function classification of stocks:
- turnover stock
- safety stock
- seasonal pre-stock
- strategic stock
- technological stock
- speculative stock

Turnover stock is the part of stocks which it ensures requirement period between the two supplies. Its level fluctuates during the supply cycle. For that reason it works with the average turnover stock. Its level is half of the supply in ideal case.

Safety stock has the aim to balance stochastic fluctuations partly on the input side to the company (level of supplies and supply interval), partly on the output side from the company (level and interval of draw on stocks).

Seasonal pre-stock balances expected fluctuations in input or output. The company was unable in this period from reason of limited production capacity to satisfy for example strong seasonal consumption of product (for example Christmas). In this case the company begins to make planned stock of product in advance. The company assumes that this planned stock will sell.

Strategic stock ensures function of company during unpredictable incidents (calamity, strike, conflict, etc.).

Technological stock makes in the event of conclusion of production by producer, but the product isn’t able to fill consumer demand because it needs to store before application. Some foods (cheese, beer and vine) have to mellow more time.

Speculative stock makes for purpose of achievement of the extra profit by help of suitable purchase (temporary of reduce a price before expected put up a price, purchase for purpose of advantageous future sale).

4. Differential inventory management

In practise it isn’t possible, not useful, to pay attention to all stock items the same attention. For that reason it is necessary differential inventory management. Pareto’s rule helps to determine the most important stock items. Pareto’s rule says that 80 % consequences follow from 20% possible causes. It means in the issue of stock that 20 % stock items can represent 80 % value of consumption or sale or big part of purchase originates from relatively small number of suppliers. Pareto’s rule means that inventory management should focus on certain number of the most important objects (for example: stock items, suppliers), which they have controlling influence on total result.

On the basis Pareto’s analysis we can classify stock assortment to groups according to the criterions. In practise, stock items classify to three groups. This analysis is called ABC analysis.

The inventory management has to arrange stock items downwardly according to value of monitored statistical index (value of consumption or value of sale) in monitored time. Analysed period should be from 12 to 24 months. Shorter period can be misrepresenting by the seasonal influence, in longer period it gets to change of production program and data lose information capability. Next step is the finding of stock items which represent 80 % and 90 % value of consumption or value of sale.

Category A consists of stock items which make 80 % value of consumption or value of sale. They are the most important stock items which monitor daily. The optimal supply and safety stock is determined individually and as exactly as possible.
Category B represent stock items with 15% value of consumption or value of sale. It means that both categories A and B represent together 95% value of consumption or value of sale. Stock items of category B are monitored as compared with category A less often and simpler methods are used to manage of them. Value of supply and safety stock is usually higher than stock items of category A.

Category C represent stock items with approximately 5% value of consumption or value of sale. Very simple methods are used to manage of them. These methods use estimate of average consumption in preceding period.

5. Stochastic stock model

We will suppose that intensity of warehouse collection - mean value of withdrawal pieces per unit time is \( \lambda \). Stocking products arrive to the warehouse after \( m \) pieces which are the most number of products in the warehouse. If \( K \) is total warehouse capacity then \( m=K \). Intensity of supply is \( \mu \). Impulse for transposition supply into the warehouse is on condition empty warehouse, consequently it replenishes always the empty stock.

The mean time between warehouse collections is the inverse value of intensity of warehouse collection \( 1/\lambda \), similarly mean value between two supplies is the inverse value of intensity of supplies \( 1/\mu \).

By the help of queuing theory derives transition probability. Transition probabilities means that the system goes over from system state \( i \) to system state \( i+1 \) or \( i-1 \) or stays in system state \( i \) (P. M. Morse in work Queues, Inventories and Maintenance deals with model).

Probabilities \( p_i \) of system state \( i \) (the system has just \( i \) system states) were derived on condition stationary distribution.

\[
p_1 = p_2 = \ldots = p_K = \frac{\mu}{\lambda} p_0
\]

\[
p_0 = \frac{1}{1 + K \frac{\mu}{\lambda}}
\]

We will optimise quantity \( m=K \), on condition profit is criterion of optimization. We will suppose that profit per sold unit is \( g \), hold costs per time \( T \) on unit are \( c_1 \) and costs of transposition supply \( m=K \) units are \( c_0 \). If \( K \) is enough high, it is possible that the continuous function approximates development of profit function.

Profit function is:

\[
Z(K) = g \cdot L_s - c_1 - c_0 p_0
\]

where

\[
L_s = T (1 - p_0) = \frac{\lambda \cdot T \cdot K}{K + \lambda \cdot T}
\]

\( L_s \) is average number of warehouse collection per time \( T \).

We can calculate the average stock:

\[
I = \sum_{n=0}^{K} n \cdot p_n = \frac{K^2 + K}{2(K + T \lambda)}
\]

After appointment:

\[
Z(K) = \frac{g \cdot T \cdot \lambda \cdot K - \frac{c_1}{2} \cdot (K^2 + K) - c_0 \cdot T \cdot \lambda}{K + T \cdot \lambda}
\]

First derivative of profit function is zero for the determination of maximum profit and then we can deduce level of supply:

\[
K_{1,2} = -T \cdot \lambda \pm \sqrt{(T \cdot \lambda)^2 - T \cdot \lambda + \frac{2c_0}{c_1} \cdot T \cdot \lambda + \frac{2}{c_1} \cdot g \cdot (T \cdot \lambda)^2}
\]

Because the positive solution is convenient to the problem and other quantities are negligible in relation to \( c_0/c_1 \) a \( g/c_1 \) it is possible to simplify the relation. We will suppose that minimum size of warehouse equals the optimal supply. We can determine level of supply \( m \) and warehouse capacity as follows:

\[
m_0 = K_0 \approx \frac{2T \lambda \cdot g \cdot T \cdot \lambda + c_0}{c_1}
\]

In case that criterion of optimization is minimization of hold costs so cost function is following:

\[
N(K) = \frac{1}{2} \frac{c_1(K^2 + K) + c_0 T \lambda}{K + T \lambda}
\]

Optimal level of supply \( (N'(K)=0) \) will be in the same case as optimal criterion of profit:

\[
m_0 = K_0 \approx \sqrt{\frac{2T \lambda c_0}{c_1}}
\]

Till now we supposed the condition empty warehouse, consequently it replenishes always the empty stock. In practise it isn’t always possible. We have to define number of units in the warehouse, where stock level mustn't drop it like safety stock \( D \). Impulse for the supply will be achievement of safety stock. Then we order \( m=K-D \) units to replenish stock in the warehouse on level \( K \).

We deduce forms of probabilities for the stationary distribution of system probabilities (by help of queuing theory).

\[
2 \mu p_0 = \lambda p_1 \quad 0 < n \leq D
\]
\((\mu + \lambda)p_n = \lambda p_{n+1}\)
\(< \lambda \leq 2\)
\((\mu + \lambda)p_D = \mu p_0 + \lambda p_D\) \quad D < n \leq m

\[\lambda p_n = \lambda p_{n+1}\]
\[\lambda p_n = \lambda p_{n+1} + \mu p_{e-m} \quad m < n \leq K\]

\[p_K = \mu p_K - m\]
\[\sum_{n=0}^{K} p_n = 1\]

If \(\mu = 1/T\), we can determine probabilities of system state:
\[p_n = \frac{2}{T\lambda} \left(1 + \frac{1}{T\lambda}\right)^{n-1} p_0 \quad 0 < n \leq D\]
\[p_n = \frac{2}{T\lambda} \left[\left(1 + \frac{1}{T\lambda}\right)^D - \frac{1}{2}\right] p_0 \quad D < n \leq m\]
\[p_n = \frac{2}{T\lambda} \left[\left(1 + \frac{1}{T\lambda}\right)^D - \left(1 + \frac{1}{T\lambda}\right)^{n-1}\right] p_0 \quad m < n \leq K\]
\[p_0 = \frac{(T\lambda)^{D+1}}{2m(1+T\lambda)^D + (T\lambda + D-m)(T\lambda)^D}\]

On condition profit function we can determine optimal level of supply \(m_0\), if first derivative of profit function is zero according to \(m\). If the warehouse capacity is \(K\) then \(K_0 = K - D\) is the optimal warehouse capacity over safety stock.

1) We will optimise quantity \(m = K\), on condition profit is the criterion of optimization.
\[m_0 = K_0 = \sqrt{\frac{2\lambda c_T}{c_1} T \cdot \lambda + c_0} = \sqrt{\frac{2 \cdot 100 \cdot 1200}{35} + 100 + 15} = \sqrt{85714.71} = 282 \text{ pcs.}\]

2) We will optimise quantity \(m = K\), on condition minimization of hold costs is the criterion of optimization.
\[m_0 = K_0 = \sqrt{\frac{2\lambda c_T}{c_1} T \cdot \lambda + c_0} = \sqrt{\frac{2 \cdot 100 \cdot 15}{35} + 3000} = \sqrt{8571} = 27.026 \approx 10 \text{ pcs.}\]

7. Conclusion

The stock level should be decreased on the minimum but on the second side it has to ensure sufficient readiness of supplies to customers. It is evident, that both points of view (stock minimization versus high readiness of supplies) are opposed and the company has to choose the compromise. It was proposed the mathematical stochastic stock model to determine the optimal delivery supply.

Note: The article is published within solution of research proposal VZ-MSM 0021627505 “The transport systems theory”.

8. References


NANOSTRUCTURED COMPOSITE COATINGS FOR THE PROTECTION AND RESTORATION OF PRECISION FRICTION PAIR PARTS

Abstract: The paper deals with the creation of fundamentally new functional multicomponent coatings applying the technologies of ion-plasmous sputtering. Developed a restoration technique for the precision pairs of hydro fuel equipment. The obtained coatings are peculiar because of their enhanced wear resistance, low coefficient of friction, and good adhesion with basic material.

KEYWORDS: PRECISION FRICTION PAIR PARTS, MULTICOMPONENT COATINGS, ION-PLASMOUS SPUTTERING

1. Introduction

Reliability of diesel and gas turbine power plants and water power devices of different functionality to a considerable degree depends on failure-free operation of friction pairs having the functions of sensitive elements of automatic control units, distributors of hydraulic tracking drives, and other critical units. The majority of failures including hydraulic unit failure occur due to the malfunction of control units and distributors as well as plunger, piston, and vane pairs of pumps and hydraulic motors.

Movable couplings of different construction and purpose with the parts having radial or plane coupling surfaces created with high accuracy and degree of surface smoothness are attributed to precision pairs (PP).

The type of damageability of PP elements considerably depends on the type of pair, loading conditions, purity, and the properties of operating fluid, which may contain some abrasive particles as well as reactive reagents (water, sulphur, phosphorus, chlorine etc.). The spectrum of wear types is very wide – from systematic abrasive cutting that worsens adjustment characteristics to local and avalanche seizure, and jamming, which result in aggregate operation failures.

At present, in the process of fuel hydraulic aggregate repair, the majority of PP is replaced by new ones because of the loss of the performance characteristics. This circumstance leads to a considerable growth in expenses for equipment repair, because, as a rule, it is necessary to replace the whole unit due to the malfunction of one subunit.

Thus the development of new enabling restoration techniques for worn-out PP part surfaces is a topical problem.

Wear of internal PP elements (valves, plungers, pistons, etc.) can be compensated by creating restoring coatings deposited by method of ion-plasma sputtering [1].

2. Experimental Equipment and Technique

Ion-plasma sputtering was implemented using a vacuum plant; its diagram is presented in Fig. 1. The basic element of the plant is a vacuum chamber for sputtering 9 with sources of material being sputtered 2 and a turntable where the parts being processed are fastened 5. The plant is supplied with a vacuum-pumping system, a working gas feed system, a cooling system, and a power-supply system.

Fig.1. Diagram of vacuum ion-plasma sputtering plant: 1 – plasma, 2 – cathode (arc evaporator), 3 – circular anode, 4 – gun, 5 – parts being processed, 6 – material being sputtered, 7 – focusing magnetic coil, 8 – stabilizing magnetic coil, 9 – vacuum chamber

In order to sputter fine metals and their alloys argon is fed to the chamber to obtain, for instance, nitrides, carbides – reaction gas (nitrogen, methane, etc.). Thus, in argon environment with titanium evaporator, pure titanium in the form of atoms and liquid drops of metal deposits on parts. When nitrogen is present in the chamber, there occurs a plasma chemical reaction, which results in the formation of titanium nitride compounds forming the coating.

The process of sputtering occurs under pressure in the chamber in the range from 10^{-3} to 1.0 Pa at the temperature of the sputtered part surface from 300 to 700°C.

In order to extend the plant performance capabilities its modification was created – instead of one of the arc sources there was installed a planar magnetron sputtering device and added a special system of gas feed.

The advantage of the magnetron sputtering is the absence of a drop phase, the possibility of sputtering a wide spectrum of materials, high utilization of the material, “good” adjustment characteristics, high density and homogeneity even of thin coatings. However, the magnetron sputtering technique has some drawbacks too – poor efficiency when depositing some kinds of materials as well as low effect of ion bombardment. In this case, when sputtering the compounds, a separate feed of the working and reaction gas is also desirable.

The possibility of combining the arc and the magnetron sputtering methods, which appeared in connection with the plant modification, allowed to partially diminish the drawbacks of the both methods using their basic advantages at the same time. In particular such technique gave the opportunity to diminish the drop phase without any substantial decrease of the effect of ion
3. **Subject of Research**

A plunger precision pair of locomotive diesel high-pressure fuel pump with a nominal coupling diameter of 17 mm (Fig. 2.) was chosen as a subject of research. PP consists of an internal element – a plunger and an external element – a barrel.

The plunger (Fig. 3.) has an initial hardness of 59…63HRC.

4. **Basic Research Results**

For the creation of the restoring wear-resistant coating the coatings on the basis of Ti – Al - N (titanium-aluminium-nitrogen) was researched as the basic ones (Fig. 4).

In the process of sputtering Ti was used as the first evaporator, Al – as the second evaporator, also Al – as a magnetron cathode material. Constant sputtering parameters:

- current of the first evaporator - 40A,
- current of the second evaporator - 70A,
- reference voltage on the parts being sputtered - 60 V,
- argon pressure in the sputtering chamber - 1,5·10⁻³ mm Hg,
- nitrogen pressure in the sputtering chamber 2·10⁻³ mm Hg,
- time of sputtering - 20 min.,
- current of the focusing coils of evaporators - 0,3A,
- current of the stabilizing coils evaporators - 0,7A,
- voltage across magnetron- 300 V.

Magnetron current changing in the range from 0 to 10A was chosen as a variable parameter. The results of microhardness research depending on current change across magnetron and, subsequently, the quantity of aluminium in the coating are presented in Fig. 5.

In what follows, a sputtering mode with 6A current strength across magnetron ensuring the achievement of maximum microhardness of 2200 Hµ was taken as a basic one.

The technique of plunger operating surface restoration by means of ion-plasma sputtering includes the following basic stages:

1. Making the measurements of the part subject to restoration
2. Stabilization thermal tempering
3. Removal of oxidized surface layer
4. Determination of the required size of surface layer being sputtered
5. Ion-plasma sputtering of the first size restoring layer, which ensures good adhesion to the base and levelling of interlayer stresses
6. Ion-plasma sputtering of the second (external) layer with enhanced wear resistance on the basis of titanium and aluminium nitrides
7. After sputtering processing of the part
8. Plunger pair lapping
9. Making control measurements of the restored part

5. **Conclusion**

As a result of the conducted research there was:

- developed a restoration technique for the precision pairs of hydro fuel equipment;
- optimized the modes when sputtering the coating by magnetron current.

The obtained coatings are peculiar because of their enhanced wear resistance, low coefficient of friction, and good adhesion with basic material.

6. **References**

Abstract: The advantages of an unmanned aerial vehicle for the implementation of surveillance and reconnaissance air tasks are obvious. These tasks may include, for instance, ecological monitoring, control of agricultural lands and woodlands condition, introduction of video surveillance and determination of the position of mobile and non-mobile objects, desired route patrolling, etc.

KEYWORDS: UNMANNED AERIAL VEHICLE, MONITORING

1. Introduction

The advantages of an unmanned aerial vehicle (UAV) for the implementation of surveillance and reconnaissance air tasks are obvious. These tasks may include, for instance, ecological monitoring, control of agricultural lands and woodlands condition, introduction of video surveillance and determination of the position of mobile and non-mobile objects, desired route patrolling, etc.

Except the possibility to control it in an off-line mode (unmanned), the main UAV development requirements are its compactness (small size), multifunctional, and ecological safety.

In order to control the UAV in the off-line mode it should be equipped, for instance, with a special radio control system combined with a GPS module.

UAV multifunctionality is meant for the implementation of such tasks because it should carry such useful load as a telecamera, equipment for digital communication and a GPS receiver. Moreover, the obtained information should be transmitted in an online mode as well as recorded onto an electronic media. Outside visibility zone the UAV should pass to an automatic flight mode with GPS system monitoring.

These restrictions make the task of designing as well as the creation of the actual construction of “micro” class UAV especially difficult (with construction weight up to 5 kg).

Another significant problem is to ensure the “ecological safety” of the UAV construction. First of all, this aspect provides for not using the actuator as an internal combustion of the engine. This would make it possible to avoid the emission of harmful combustion residue as well as release from noise, which appear in the process of engine operation. In this relation, for instance, the use of the actuator as a collector-free electric engine is a perspective direction.

In addition the designed UAV should be characterized by high-tech construction, safety, high flight technical and performance criteria.

The design and creation of the UAV corresponding to the specified requirements is an actual and at the same time complex scientifically-practical task.

2. Basic Requirements to UAV Design

The principal task of this research was a creation of an unmanned aerial vehicle (UAV) construction corresponding to the following principal requirements:
- possibility of implementing environment monitoring;
- implementation of the functions of strategic and nature conservation objects protection;
- possibility of determining the exact location of the target;
- possibility of detection and mapping of seats of fire and contaminated environmental zones;
- implementation of patrolling functions to solve the tasks of national armed forces and police;
- implementation of meteorological research, etc.

In addition, in the process of designing, a number of specific requirements is also taken into account, they include:
- performance (the UAV ability to take-off and land in the conditions of runaway absence, the simplicity of maintenance and repair, etc.);
- ecological safety requirements (non-contaminated environment, minimum noise level, etc.);
- effective steerability requirements (possibility of controlling the UAV both in manual and automatic mode using modern navigation systems and communication facilities).

3. Peculiarities of UAV Construction

The aerodynamic diagram of the UAV represents a low-wing aircraft with a normal stabilizer and control (Fig. 1). The UAV construction is peculiar thanks to its design philosophy including the construction of center wing section made in accordance with a longeron diagram with a partially stressed skin. The UAV construction is provided with special useful load compartments (engine, batteries, surveillance camera, control elements, etc.). Outer wings are of V-shaped profile, which ensures a transverse stability of the UAV.

![Fig.1. Aerodynamic diagram of the UAV](image-url)
Such construction gives opportunity to place the surveillance camera far from the engine and avoid unwanted vibration exerting a negative influence upon the quality of the picture being transferred.

A separate video camera is placed into each nacelle. One of the cameras is used for the UAV control and navigation. The picture from the camera is transferred directly to the operator controlling the UAV. The second camera is meant for surveillance and recording of visual information during the monitoring.

Different combinations of polystyrene materials, composite materials on the basis of resin, superlight balsa elements were used to make the UAV. Basic bearing structures are made of extra strong carboxylic tubular members.

4. UAV Control System

The UAV has a combined control system covering three flight zones (Fig. 4). Within zone 1, there is implemented a radio control of take-off/landing mode and the UAV flight inside visibility zone. The UAV control within zone 2 is implemented by an autopilot according to GPS system with the possibility of flight characteristics change in a real-time mode and flight process control using video cameras. The operator controlling the UAV has the opportunity to set flight modes on the basis of a preliminarily compiled computer program as well. The enciphered data of the drawn flight plan is downloaded to autopilot database. At the same time there is an opportunity of UAV flight realization according to a guided route as well as the opportunity of making some necessary partial corrections to the plan or a complete change of flight parameters. For example, it is possible to interrupt the flight of the UAV at any journey leg, return it to the home position or to direct it according to another route. Within zone 2, the UAV control is implemented by means of autopilot according to programmed flight plan. Moreover, the control of UAV mode is implemented by means of the video camera using new generation 3G mobile communication systems. In addition to the on-line control of flight modes the system gives opportunity to transmit visual data to several independent users not connected with a ground system of UAV control.

Module systems of the UAV flight control make it possible to strictly maintain the altitude and selected flight course, to efficiently correct the UAV spatial orientation taking into account wind force and drift angle.

5. Computer-aided Design

The design of basic elements and UAV constructions in general was implemented in SolidWorks program. Parts and units are designed taking into consideration the workability of UAV assembly. With a high degree of accuracy there are solved the tasks of centring and chosen the optimal diagrams of basic elements and UAV units arrangement. The possibility of computer-aided design made it possible to create the optimal constructions of basic elements and the constructions in general taking into account the aerodynamic properties as well as durability and weight.

6. General Description of the UAV

In the UAV construction there are used different innovative materials – a combination of polystyrene materials, composite materials on the basis of resins, superlight materials on the basis of balsa. The basic bearing structures of the UAV are made of extra strong carboxylic tubular members. The centre wing section has a partially stressed skin, which gives opportunity to increase the strength and rigidity of the UAV construction in general and reduce the weight of basic load-bearing elements.

The designed UAV is characterized by the following key features:

- construction weight – up to 5 kg;
- flight duration – up to 1 hour;
- flight altitude – up to 1 km;
- useful load – up to 1.5 kg;
- actuator type – electric.

7. References

INITIALISATION OF OPTICAL CAR TRACKING SYSTEMS USING VIDEO DATA ANALYSIS

ИНИЦИАЛИЗИРОВАНИЕ ОПТИЧЕСКИХ СИСТЕМ СЛЕЖЕНИЯ АВТОМОБИЛЕЙ С ИСПОЛЬЗОВАНИЕМ АНАЛИЗЫ ДАННЫХ ВИДЕО

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Abstract: In the paper the algorithm of initialisation of video based vehicle tracking systems is presented. It utilises the analysis of chosen frames of the video sequence with the road traffic. The assumption of the algorithm is the usage of the side-view located camera in order to handle all possible locations. As the side-view location can be treated as one of the hardest ones for the tracking purposes, proposed method should be robust to the possible overlapping of the vehicles in many lanes in the analysed video frames.

KEYWORDS: INTELLIGENT TRANSPORT SYSTEMS, IMAGE ANALYSIS

1. Introduction

Optical car tracking systems can be an efficient solution for Intelligent Transport Systems, especially in the situations where classical approach based e.g. on many inductive loops seem to be too expensive. A serious advantage of the optical approach is the ability of multiple car tracking at the same time, often impossible using classical methods.

In our earlier papers [1,5] some applications of Jump Diffusion Markov Chain Monte Carlo for vehicle tracking purposes have been analysed. Presented method work fine but its main disadvantage is relatively high computational cost.

Nevertheless, such algorithms can be assisted with some image processing and analysis methods which are much faster and can be successfully applied for some pre-processing operations and the initialisation of the main algorithm.

In the paper the algorithm useful for preliminary detection and classification of the vehicles based on the video sequence recorded by the side-view located camera is proposed.

2. Vehicle detection algorithm

One of the essential features of Jump Diffusion Markov Chain Monte Carlo method presented earlier [1,5] is the ability to track many vehicles overlapping each other in the video frames. After the proper localisation of each visible vehicle the extraction of the position and velocity information can be performed analysing the differential information between frames (with the proper assignment).

Our faster method of video data analysis should handle the possible overlapping as well without the necessity of using such sophisticated techniques as the MCMC method.

Probably the simplest and widely used approach to image analysis is the processing of the binary images, especially because of extremely low computational requirements. Similarly as in the Jump Diffusion approach the analysis of the image data in our method can be performed after the binarization.

2.1. Background removal

The first step of the algorithm is related to the background estimation and removal. It may cause some problems especially related to the weather conditions (e.g. trees and leaves in the strong wind). However, even if some of the data not corresponding to the moving vehicles remain in the differential frame (the frame with removed background), it can be ignored in the further analysis because of the shape’s mismatch in comparison to the database of vehicles’ contours.

Typical background estimation methods are:
- differential detection
- moving average
- moving average with threshold

Fig.1 Example frames taken by the side-view located camera.
The first one is based just on the differences between two neighbouring frames in the video sequence, similarly as in motion detection algorithms and some video compression standards [7]. Unfortunately the usage of such simple method can cause some problems with the proper background estimation, especially for relatively large surfaces (e.g. bonnet or the top of the moving car), which can be wrongly classified as the background particularly for high frame rate video sequences.

In the effect of using Moving Average (MA) algorithm the background information with the presence of some light noise caused by moving vehicles can be achieved. The amount of noise depends on the number of frames in the moving average window. In real applications there is a high possibility of occurring some random disturbances causing the background instability so additional thresholding can be also used for the elimination of slight color changes of each pixel (possible influence of the CCD noise). Nevertheless it requires initialization by the starting background image, which can be obtained by the averaging of the specified number of the first frames.

In order to reduce the computational cost the background estimation can be performed after cutting the images to the area of interest (the fragment of the image where the moving vehicles can appear). Taking into consideration the possible noise caused by the CCD or small moving elements visible on the acquires images (e.g. leaves, flying insects, dust etc.) the background removal algorithm has been supplemented by the image filtering operation using standard low-pass filter with the mask of 5x5 pixels.

The local minimum values of Hamming distance used as the measure of dissimilarity (after additional thresholding) are treated as the positions of the vehicles of the given type (depending on the type chosen from the database). The example results of such calculations are presented in Fig. 6 (darker areas indicate lower values of Hamming distance) in the same order as in Figs. 1 and 4.

As can be noticed especially on the first two images in Fig. 6 such method works fine only for well separable objects. In the case when such separable vehicle, especially differing from the typical ones, appears on the image (in an expected place on the road) it can be added to the database.

The example cut frames of the analysed video sequence with removed background are shown in Fig. 4.
2.3. Processing of the colour difference images

The problems occur when the vehicles cover each other on the image, what is illustrated on the bottom image in Fig. 6. In such case the calculation of Hamming distance for binary images should be replaced by analysis of full colour images using Euclidean distance in the RGB colour space (1). However, the vehicles should be well separated on at least single frame in order to track them directly instead of using the images from the database.

The results obtained using proposed technique are illustrated in Fig. 9. Darker areas indicate higher similarity corresponding to estimated vehicle’s position. As shown in Fig. 9 for the situations where the overlapping is possible using Euclidean distance for searching is a better solution. Nevertheless, the application of Hamming distance for binary images can be also an interesting alternative for well separated objects, especially when the computational complexity of the algorithm is crucial.

In the case when the vehicles are partially separable the algorithm for limited camera’s field of view car recognition systems presented in one of our earlier papers [4] can be used. In the result the combined image can be obtained and further used as the model. The block diagram of the whole algorithm is presented in Fig. 8.

Fig.5 Example results of detection based on Hamming distance.

Fig.6 Example binary mask from the database and the example separable model taken from one of the video frames.

Fig.7 Illustration of the idea of the sliding mask approach – only the values under the black part of the mask are taken into consideration for the specified position of the mask.

Fig.8 Block diagram of the detection algorithm.

Fig.9 Example results of detection based on Euclidean distance in the RGB colour space.
3. Bibliography


APPLICATION OF HUE-SATURATION COLOUR MODEL TO THE REDUCTION OF VEHICLE’S TRACKING ERRORS

УПОТРЕБЛЕНИЕ ЦВЕТОВОЙ МОДЕЛИ ТОН-НАСЫЩЕННОСТЬ К УМЕНЬШЕНИЮ ОШИБОК СЛЕЖЕНИЯ АВТОМОБИЛЕЙ

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Abstract: In the paper some possibilities of utilisation of reduced colour models for the improvement of the vehicles’ tracking accuracy is discussed. Presented results are based on the HSV colour model limited to Hue-Saturation space by elimination of the value (V) channel. Presented approach is especially useful for tracking of vehicles with shining bonnets, particularly in the strong sunshine. Decreasing the colour variance of the vehicle’s fragments on each video frame allows more precise estimation of the vehicle’s location and its velocity.

KEYWORDS: INTELLIGENT TRANSPORT SYSTEMS, IMAGE ANALYSIS

1. Introduction

One of the most interesting aspects of contemporary road transport seems to be the application of Intelligent Transport Systems allowing not only the statistical traffic analysis but also more sophisticated automatic tracking and control. Application of such systems cannot be done without some image processing and analysis operations necessary for the proper work of the detection system.

One of the most advanced parts of the ITS is the video based automatic recognition and tracking system. In some applications it is reduced to simple recognition of the register plates’ numbers often based on the analysis of the single image. Nevertheless, in most advanced applications the video part, allowing also tracking and estimation of some vehicle’s motion parameters and also the geometrical ones, represents a serious fragment of the whole system.

Vision systems are usually sensitive on many factors related to the weather conditions, lighting conditions, smog, fog, dust, noise, blinking street lamplights etc. That is why some errors may occur so the position and velocity estimation may not be perfect. The reduction of the influence of some disadvantageous effects, especially related to lighting conditions, seems to be one of the most relevant tasks for the image processing and analysis part of such systems.

2. Idea of the vehicle’s detection and tracking

The algorithm used in the paper is based on the elimination of the background from each frame. Estimation of the background can be performed using various techniques described in our earlier paper [3]. After that, each difference frame is screened using the sliding window approach with the shape of the mask accordant to the shape of the sought vehicle. As the measure of similarity of each region with the specified pattern of the vehicle, we can use Euclidean distance in RGB colour space or apply the correlation coefficient. Euclidean distance is calculated as the following:

\[ d = \sqrt{(R_{im} - R_{bg})^2 + (G_{im} - G_{bg})^2 + (B_{im} - B_{bg})^2} \]

(1)

where R,G,B denote the red, green and blue channel’s values respectively. ‘im’ stands for the analysed image and ‘bg’ for the estimated background.

However, obtained results are strongly dependent on the local changes of the vehicle’s colour in each position caused by the changes of the local lighting conditions (visible shining areas with varying locations).

3. Proposed method

Taking into account the fact that observed changes of colour are mainly related to the intensity or luminance, it is possible to reduce such undesirable effects by elimination of the channel related to luminance data. It is impossible in the RGB colour space so the conversion into the HSV model is proposed.

Assuming the RGB values are normalised to the range \(<0 ; 1>\) the conversion can be performed using the following formulas:

\[
H = \begin{cases} 
0 & \text{if } \max = \min \\
60 \times \frac{G - B}{\max - \min} & \text{mod } 360^\circ \text{ if } \max = R \\
60 \times \frac{B - R}{\max - \min} + 120^\circ & \text{if } \max = G \\
60 \times \frac{R - G}{\max - \min} + 240^\circ & \text{if } \max = B 
\end{cases}
\]

(1)

\[ S = \begin{cases} 
0 & \text{if } \max = 0 \\
1 - \frac{\min}{\max} & \text{otherwise} 
\end{cases} \]

(2)

\[ V = \max \]

(3)

where \( \max \) and \( \min \) are the greatest and the least values of R, G, and B channels respectively [6]. The dynamic range of S and V components is \(<0 ; 1>\) and for the hue it is from \(0^\circ \) to \(360^\circ\). The backward conversion from HSV to RGB can be performed as:

\[
[R \ G \ B] = \begin{cases} 
[q \ V \ p] & \text{if } \frac{h}{60} \mod 6 = 0 \\
[p \ V \ i] & \text{if } \frac{h}{60} \mod 6 = 1 \\
[p \ q \ V] & \text{if } \frac{h}{60} \mod 6 = 2 \\
[t \ p \ V] & \text{if } \frac{h}{60} \mod 6 = 3 \\
[V \ p \ q] & \text{if } \frac{h}{60} \mod 6 = 4 \\
[V \ t \ p] & \text{if } \frac{h}{60} \mod 6 = 5 
\end{cases}
\]

(4)

where
In the case of elimination of V channel a constant value should be used (in our experiments V=0.5 has been chosen in order to ensure visual similarity of colours).

Another possibility is using H2SV colour model, which can be also used for tracking purposes [7]. Nevertheless, such approach, based mainly on the conversion of hue from radial to Cartesian coordinates, is not necessary in our algorithm. In our approach the main elements of the conversion are elimination of the V channel and backward conversion from H-S to RGB colour space. Further analysis is performed in RGB colour space with the use of Euclidean distance. The main elements of the algorithm are illustrated in Fig. 1.

4. Results

Results obtained using RGB and H-S approach are presented in Table 1. As we can easily notice some results achieved using H-S approach are inappropriate (they are marked with asterisk in the Table 1). Because of the side-view localisation of the camera only the horizontal positions of the vehicles have been analysed. The images taken from the camera used in our experiments are presented in Fig. 3 while Fig. 4 and 5 illustrate the visualisation of obtained results – dark areas indicate lower values of Euclidean distance.

Table 1. Results obtained using RGB and H-S colour spaces (outliers marked with asterisk).

<table>
<thead>
<tr>
<th>No. of model [no. of image]</th>
<th>Location in pixels (horizontal coordinate)</th>
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Fig. 3 Images corresponding to the results presented in Table 1 (cut to the area of interest).

Fig. 4 Visualisation of the results presented in Table 1 (RGB colour space).

Fig. 5 Visualisation of the results presented in Table 1 (H-S colour space).
In order to compare the effectiveness of using only RGB colour space and the additional conversion to Hue-Saturation model the set of 40 images divided into 10 groups has been used. Each group consists of one reference image (numbered as 1) and three images with the same vehicle visible in some other locations. Each of images has been cut to the area of interest and the pattern of the vehicle has been chosen from the first images in each group so the results obtained for them are usually the best ones. The example reference frame with the pattern cut out from it is shown in Fig. 2.

Nevertheless, using H-S model there may be the situation of inappropriate detection (“outliers” not visible in Fig. 6) so the best solution seems to be using hybrid. For the most of the images with similar results obtained in RGB and H-S colour model the value obtained using Hue-Saturation model is closer to the reality. If the difference between both results is too high, the result obtained using H-S model should be rejected and the value achieved using RGB model should be treated as the final result.

5. Conclusions

Comparing the absolute errors (Fig. 6) achieved for both techniques it can be noticed that for most images application of H-S colour model leads to better results. The size of the circle in Fig. 6 is proportional to the number of images with specified combination of errors expressed in pixels.

6. Bibliography