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DECISION MODELS IN TRAFFIC MANAGEMENT

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Abstract. *Decision models in traffic management have not been paid due attention, which brought about the degradation and attrition of the existing traffic network and enormously increased the expenses of the users.*
The paper deals with: The Models for the anticipation of the change of traffic roads conditions; the traffic roads user expenses models with the classification and the importance of the users' expenses and pointing out to the development of the user expenses model with the special focus on the fuel consumption and pneumatics wearing out. At the end, the paper treats the economic decision models in the traffic management systems and states the significance of optimization in these systems.

Key words: *Traffic ways, management, models, decision.*

1. INTRODUCTION

The key elements when making managerial decisions for the traffic roads are the models for the anticipation of the change of traffic road's conditions. The choice of the optimum strategy of managing the traffic roads will mostly depend on the ability and the quality of the model for anticipation of the future condition. Forming and using these models provides the following functions of the managing system:

- Determines the kind of the maintenance works and rehabilitation of the traffic roads, their appropriateness and frequency;
- Provides the knowledge of the consequences of carrying out or postponing the maintenance and rehabilitation works of the traffic roads for the expenses of the users and the society; and
- Provides determination and enhancement of the current efficacy of the regulations, standards and rules for traffic roads design.

There is a small number of researches and results about the assessment models of the condition change of the specific traffic objects, such as: causeways, passages, tunnels, bridges…, as well as the impact of these changes on the users' expenses.

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The traffic roads are the civil engineering objects whose construction has the biggest influence on the investment costs and the users' expenses, and that is why, in the managing systems, the special attention is paid to the research and formulating the condition change anticipation model. They are used in different ways in the managing systems, depending on whether their role is to make decisions at the level of a section or the whole network:

(a) At the level of a section, these models are used in different ways:
- In the designing procedures (the choice of the optimum behaviour during the exploitation),
- During the analysis of the traffic roads condition in various periods of time,
- For the choice of the design variant which would require minimum total construction, maintenance and exploitation costs of the traffic road section,
- For the determination of optimum time of carrying out certain maintenance works,
- For the maintenance of the required condition of the section with minimum costs, etc.

(b) These condition change anticipation models employed at the level of traffic network are used for:
- Providing the technical and economical information which would be used for the choice of optimum strategy,
- For the analysis of the costs and consequences of the usage of different axial loads,
- Determination of the tax value for the usage of the traffic network for the vehicles with the special loads,
- For determination of the tax and fine for possible overloading of vehicles,
- For determination of the optimum ratio of the level of traffic roads condition, maintenance and rehabilitation costs and users' expenses, etc.

2. MODELS OF ANTICIPATION OF TRAFFIC ROADS CONDITION CHANGE

When formulating the traffic roads managing system, it is necessary to form a model for anticipation of the future condition of the traffic roads. In most part, the models of this kind are developed for the change of one condition indicator, which describes the condition of one functional characteristic of the traffic road. That condition has numerous meanings in different models for the change assessment, depending on whether it is used at the level of a section or the traffic network:

(a) At the level of a section, the condition can be defined:
- By the observations of the traffic road damages,
- By the usability index value changes,
- By the evaluations and indices of road-way friction and surface flatness condition,
- By the changes and aberrations in the structure of construction due to the traffic frequency, etc.

(b) At the level of the traffic network, the condition is expressed and defined:
- by the total condition and abilities of the traffic network, and
- by the levels of condition of the traffic network.

The modern systems for managing do not define the notion of traffic road condition uniformly, and they may differ very much in various cases.

There are different kinds of models for the anticipation of the change of condition in the network problems:

(a) ***Models of the general behaviour*** anticipate the basic behaviour of the traffic roads under the influence of the traffic and climate factors of their damages. These models can be theoretical, empirical and mixed;
(b) ***Models of the structural changes*****,** anticipate the change of structure and integrity of the traffic roads (comprising the outside, visible changes);
(c) ***Models of changes of the functional characteristics*****,** anticipate the change of condition of the chosen indicators of the functional condition of the traffic roads which are important for the evaluation of comfort and safety of the traffic roads (friction values, transversal flatness, longitudinal flatness and similar)
(d) ***Models of the traffic surface damages*****,** represent the most common form of the group of the change anticipation models. They are most frequently derived from the single models for the anticipation of the change of the functional or bearing condition indicator characteristics. The damage is defined as the decreasing of the index (or the indicator or value) by which the change of the initial condition is defined; and
(e) ***Models of probability*** are the most developed known models for anticipation of the traffic roads condition changes. The base of the model consists of the matrices which express the probability that traffic roads of the same age and the similar intensity of the traffic frequency would pass from one condition (or usability) to another during the given time period.

3. THE REGULARITIES OF THE TRAFFIC ROADS CONDITION CHANGE

In order to make the traffic roads change anticipation models real, it is necessary that the regularities of the condition change be real. For these reasons, a special attention ought to be paid to the researches of the condition changes regularity, which consists of:

(a) ***Research of parametres*** is most often aimed at the determination of the regularities and the formulation of the damage condition change models and the characteristics of the traffic roads. Most frequently the following parametres and indicators are researched:
- Environment parametres influence: traffic frequencies, climate (temperatures and precipitation), geometrical characteristics of the traffic road and the relief, the chosen strategy of maintenance and rehabilitation of the traffic road (technical measures, available material, finances, mechanization etc.)
- Condition indicators: crevices, longitudinal deformations, transversal flatness, damage, roughness etc.; and
- Indicators of the traffic roads structure.

The different models have the different characterizations and quantifications of the given indicators. The most common classification is the one in which the condition is

classified in: good, average and bad. The more complex classification is the one which contains a great number of the damage types, which are evaluated from 1 to 10.

b) ***Experimental researches*** of the condition change models are used for the definition of the own results. The manner and procedure of forming the condition change model in the system of management depends on the aims of the system and the type of the model which is defined. Firstly, the possibility of application of the existing models is considered, then the own model is formed using the experimental researches for that purpose.
   - Methods of researches of the traffic roads consist of the determination of the traffic roads condition at the specially built testing ranges. The researches are conducted in the real conditions, under the influence of the given climate conditions and simulation of the traffic frequency. These experimental researches are very expensive, and with the accelerated traffic in a shorter period of time than it is during the exploitation of the traffic roads, we cannot achieve a completely objective finding.
   - Methods of research at the traffic network, consist of the statistical processing of the obtained data at the traffic network in exploitation. Two approaches are possible there:
     – The researches at the certain sections of the traffic roads, which comprises the choice of the representative sections in the frame of the traffic network and systematical observation of the certain indicators, since opening the section for exploitation;
     – The researches at the samples of the traffic network, comprise the choice of the representative sections, by the parametres of the traffic roads structure, by their age and characteristics of the traffic frequency.

c) ***Principles of model forming*** have to be obeyed when forming any condition change anticipation model. If the curved line of the damage (condition indicator) is in function of the number of traffic frequency repetition, the boundary conditions of model forming can be defined as follows:
   – The initial value of any damage (condition indicator) is equal to zero;
   – The initial inclination of the damage curve line can be different (zero or some value) and it should be determined in every separate case. For instance, the initial inclination of the curve line of the crevice damages is zero, while with the transversal and longitudinal flatness of the road-way the condition indicator curve line inclination has a concrete value
   – Almost all the damages tend to grow in function of time.
   – It is necessary to introduce independently variable values in the equation of the damage change, because the majority of the damages is liable to the climate factors influence;
   – The final inclination of the damage curve has to be zero (horizontal tangent to the curve line) with those damages where the final value cannot be higher than 100%.For example, the crevices. At some damages, the final inclination of the damage curve line has a concrete value (it is not a zero).

– The maximum value of the damage is limited with those damages where the final inclination is zero, while the rest of damage does not have its maximum value limited.

When forming an equation, which will be used for the interpretation of the data which were obtained by the experimental researches, it is necessary to obey certain principles, which are known in the mathematical statistics. The models formulated in this manner are applicable in those terms which were dominant during the research of the dependence of the model condition change, in all other cases these models have to be carefully applied with a previous adjustment of all the data which were the basis of the definition. Each managing system uses its own solutions, using mostly the presented procedures and principles.

4. MODELS OF THE TRAFFIC ROADS USER EXPENSES

The complex managing systems, when making decisions, take into account, directly or indirectly, the expenses of the traffic roads users and the maintenance costs. Knowing the maintenance costs and exploitation costs of the traffic network represents a very important piece of information for anyone who manage the network. This information provides the optimum technical measures with the available finances. The maintenance costs may include the costs of traffic accidents, traffic pollution prevention measures costs and similar.

The costs of the traffic roads users are a portion of the total costs which are paid by the users, and it consists of two basic subgroups:

- The costs of the time of a trip, and
- The costs of exploitation of a vehicle (fuel, lubricants, spare parts, vehicle maintenance and similar)

4.1. Classification and Importance of the Users' Expenses

Nowadays, the users' expenses can be classified in: the financial costs, the costs which can be expressed by the financial values, the costs which cannot be directly financially expressed, and the costs which cannot be financially expressed:

- The financial costs comprise the costs of purchasing and exploitation of the transport means.
- The costs which can be expressed by the financial values pertain directly to the time of a drive and can be decreased by shortening the time of a drive. It is, at the same time, one of the main purposes of the technical measures at the traffic network;
- The costs which are not directly financially expressed are made when some of the advantages ought to be quantified and expressed. There we have the costs of reduced or enhanced safety of the users etc.; and
- The costs which cannot be directly financially expressed, represent the values obtained in the changes of the safety of the traffic network users. This includes the profit which is a result of the economic development of the region.

The managing systems which take into account the expenses of the users, base their planning on the reduction of those expenses. The users' expenses are not only analysed at

the moment of observation, but in each year of the plan period. Hence the models for anticipation of the condition change and the models for evaluation of the maintenance and rehabilitation effects represent the basic prerequisite for the calculation of users expenses. With the models and economic methods for calculations of the users' expenses make the most important part of any managing system.

The expenses of the users and transport means exploitation make the largest and the most significant part of total costs of the traffic economy. The costs of exploitation of the transport means in the most part depend on the condition of the road-way of the traffic roads. That is how small savings in maintenance costs bring about the large exploitation losses, and vice versa, substantial investments in the maintenance costs bring about the considerable savings in the costs of exploitation. It is yet another big and significant reason to use the managing systems as a decision instrument in the area of traffic roads.

4.2 Model Formulation

In the recent years, some significant research results pertaining to the fuel consumption and pneumatics wearing out were achieved.

4.2.1 Fuel Consumption

The movement of transport means is opposed by the resistance, as follows: basic resistance (appears on the straight, horizontal road), resistance because of the inclination of the surface the transport means moves across (it is a positive gradient uphill and a negative downhill), air resistance (the drag at the higher speeds), inertial resistance (appears when changing the speed of the transport means), curve resistance (increases with the increase of speed and the decrease of the curve radius).

The formulated models and done researches on the models show that the obvious increase in the fuel consumption on the traffic roads with bigger curve characteristic (a ratio of the total sum of all turn angles on the path with the total length of it). In respect to the fuel consumption on the straight road, those sections of the traffic roads significantly increase the fuel consumption with the increase of speed (with passenger vehicles it can be up to 40% more, with freight vehicles up to 30%). Along with this increase, there is an additional fuel consumption increase due to braking when entering the curve and accelerating when exiting the curve.

4.2.2. Pneumatics wearing out

A pneumatic wears out as a result of friction and snapping, and it occurs at the contact of a pneumatic and a road-way surface. The mechanisms of the pneumatic wearing out in the road traffic were discovered on the basis of extensive researches:

- A pneumatic most often wears out because of the friction with the road-way surface
- Because of the thermo-oxidation processes in the pneumatic itself.
- Because of the fatigue of material in the pneumatic
- Wearing out due to spinning
- Pneumatic damage because of the big irregularities on the road-way surface (impact bumps and holes).

As it can be seen, the influence of the road-way structure and the drive speed to the pneumatics wearing out is big, and it affects the costs of the traffic road users. It has to be regarded when the managing systems are dealt with. To these costs, we may add: vehicle depreciation, traffic roads maintenance costs, traffic incidents cost, environment protection costs and so on. The researches contributed to forming the model which can successfully assess the expenses of the users.

4.2.3 Models of the users' expenses

Users' expenses anticipation models can be used for the economic analyses or within the managing system. The most often used models of the users are: the Drive speed anticipation – time of transport, the Influence of the traffic obstruction, the Costs of vehicle exploitation, and the Costs of the traffic incidents and accidents:

- The Drive speed anticipation model is based on the probability of sustaining the boundary speed depending on the used vehicles (effective engine power of the vehicle and vehicle brake system efficacy), geometrical characteristics of the traffic road (inclination of the traffic road, curvature of the path etc.) and the condition of the road-way surface;
- The travelling time, apart from the speed and the length of the traffic road section which outhgt to be travelled, depends on the time of delay caused by the traffic impeding (due to the maintenance and rehabilitation works);
- The management system, when anlysing the costs of vehicle exploatation, takes into account: fuel consumption, lubricants consumption, pneumatics wearing out, spare parts consumption, vehicle maintenance costs, human labour costs, depreciation costs, bank interest costs etc.;
- Traffic accidents and icidents costs are linked to the road-way surface condition (flatness and roughness), though, in the general models, these costs cannot be defined.

Numerous researches show that with the increase of the road-way surfaces damages, the users' expenses also increase, as well as the decrease of speed.

5. ECONOMIC DECISION MODELS

The economic analyses in the traffic roads managing systems provide the quantitative indicators on whose basis one can make a reliable decision about what variant should be applied in the managing system so as to facilitate the most efficient financial investment in the maintenance and rehabilitation of the traffic roads. That procedure enables maximum exploitation of the invested finances and gives an answer as to where, when and how those finances ought to be invested to attain the maximum profit with the minimum of investments. The profit is primarily seen in the improvement of the traffic roads condition indicators, improvement of the conditions and the quality of drive, and in the reduction of the users' expenses.

Various kinds of models for the assessment of the efficiency of finances investments: The mean annual expenses models (which combine all the costs made during the maintenance and rehabilitation works for several alternative solutions), the Current cost value models (which take into account all the costs of the tested alternative solution during the

analysis period), the Net profit models (which determine the net profit of the alternative solution, for the entire period of testing [***n*** years]), the Current net value models (the current value of profit is subtracted from the current value of the costs), the Internal profitability rate models (the internal profitability rate is defined as the value of the yearly discount rate where the current net value is equal to zero), the First year profit models (the optimum investment time is determined on the basis of the profit of the alternative solutions in the first year, and the profit and costs ratio models (the best alternative, economically viewed, is the one which has the biggest ratio of profit and cost).

The application of the economic models of decision making in the traffic roads management systems requires a large number of data about the traffic network and their automatized processing by the sections in each year of analysis.

6. OPTIMIZATION

The restrictive circumstances, in which the managing the construction of the traffic roads is conducted, make the production of the optimum programme of management impossible. The most common limiting factors are the insufficient resources in material, means and finances. Therefore, we may consider the traffic roads management as, actually, the management of the available resources. In those conditions, the management system gives possibilities how to manage those resources in the most efficient and the most favourable manner, adapting at the same time to the limiting factors a choice is made; of the maintenance, rehabilitation and reconstruction of the traffic road, choice of the section in want of an intervention and the time of execution. This optimization is aimed at maximum profit with limiting finances.

In the optimization phase, the following questions are answered:

- How can the condition of the traffic road be achieved by the available finances; and
- What finances ought to be provided so as to achieve the required condition of the traffic network.

As the managing systems have two decision levels, the optimization has those levels as well: The level of the traffic network and at the level of the section. A final task of the optimization in the limited financial investments is to determine those works which will achieve the highest efficacy of the investments, ie. maximum economic effect.

7. CONCLUSION

A remarkable place within the traffic roads managing decision models is taken by the: the Traffic roads condition change models, the Traffic roads user expenses models, and the Economic decision models. The quoted modes represent the irreplaceable link in the traffic roads managing system, they are integral part of design governing and construction of the traffic roads as a compact unity.

The frequently asked question is whether an existing section of the traffic road, or a network of traffic roads, should be rehabilitated or should an entirely or partially new one be constructed. The correct decision can be made only by the introduction of the managing systems decision models in the decision process. The introduction of those models in

the decision process is the main assignment of all who deal with the problems of traffic and traffic roads.

By the presented models, one can achieve the most favourable long-term distribution of the finances intended for the needs of maintenance and rehabilitation of the traffic roads in accordance with the economical and social circumstances. On the basis of what has been said, the presented concept of decision should be accepted much faster and applied much more efficiently, so that the new decision making philosophy should yield the adequate positive results.

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MODELI ODLUČIVANJA U UPRAVLJANJU SAOBRAĆAJNICAMA

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Modelima odlučivanja u upravljanja saobraćajnicama nije se posvećivala potrebna pažnja, što je dovelo do degradacije i propadanja postojeće saobraćajne mreže i enormno povećanih troškova korisnika.

U radu se obrađuju: Modeli za predviđanje promene stanja saobraćajnica; Modeli troškova korisnika saobraćajnica sa klasifikacijom i značajem troškova korisnika i ukazivanje na razvoj modela troškova korisnika sa posebnim osvrtom na potrošnju goriva i potrošnju pneumatika. Na kraju se obrađuju Modeli ekonomskog odlučivanja u sistemima upravljanja saobraćajnicama i ukazuje na značaj optimizacije u ovim sistemima.

Ključne reči: *Saobraćajnice, upravljanje, modeli, odlučivanje.*