# A MODEL AND SOFTWARE SOLUTION FOR DETERMINING THE ECONOMIC INDICATORS FOR CONSTRUCTION, EXPLOITATION AND MAINTENANCE OF A TRAFFIC ROAD SECTION

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**Abstract:** Through a multidisciplinary approach, a model which provides efficient evaluation of the economic indicators for construction, exploitation and maintenance of a traffic road section, is proposed. The model is built using hierarchical composition technique – mathematical and statistical modeling of a number of submodels. The software solution reinforces both the efficacy and the usefulness of the model. Computer simulations, as well as some prediction models, which are important to calculating the economics indicators, have been widely used. Customization and choice of a design variant are available through variable model parameters. The proposed model takes into account functional-, investment-, environmental- and multicriterion evaluation.

**Keywords:** traffic ways, economic indicators, statistical modeling, computer simulation

## 1 Introduction

Some of the submodels included in the model for determination of economic indicators of roadway are presented in this work. A roadway is a large infrastructural object with a very high price and great environmental, social and economic influences. The very problem included in the model imposes a multidisciplinary approach. The model has been built according to the principles of the hierarchical composition of submodels. The number of variables is very big, so, it is practically impossible to include all of them. This is one the basic reasons who the model consists of a range of submodels with a big number of mutual influences. The objective of the research has been to create a software solution for the whole model which will make the models practically useful.

The process of evaluation of roadway depends on: economic, environmental, functional and investment evaluation and finally, the ultimate evaluation is found out with a multicriterial evaluation. The need for an efficient estimation of economic indicators is very important in the process of choosing the optimal variant of a roadway. The estimation of the economic indicators is in a significant correlation with the environmental and functional evaluation. In order to simplify the models, and at the same time to keep the quality of reflecting the real appearances, certain hypotheses and limitations have bin made.

## 2 Hypotheses and limitations

1. The hypothesis is that with a additional spending of finances, the negative environmental effects will be eliminated. In the real practise, it is impossible to eliminate the negative environmental influences but they must be reduced bellow the prescribed level. But, as the final purpose of economic indicators is their use in the process of ranking of variants, this hypothesis is acceptable. By additional costs, the negative environmental influences keep the same level. With this kind of an approach, this hypothesis is completely correct.
2. The biggest part of the functional evaluation through its influence over the economic costs and uses is transformed to an influence over the value of the economic indicators. They are: the level of usefulness of the practical capacity (practical capacity used level) , the speed of the vehicles and the speed of the traffic, the presence of a good layout of a distance for a safe talking over, condition of safety in the traffic and the time of travelling of the passengers. We assume that all these influences through the time of travelling and the costs of accidents are quantitatively well reflected through the cost in the economic indicators.

Direct and indirect costs and uses influence the economic indicators. Determination of the direct influences is more easily presented with models which could be useful in most of the cases. Indirect influences are generalized in one model in a very difficult way. The models which are presented in this text mainly refer to the direct influences and their repercussions to the economic indicators. This does not mean that the indirect economic effects are not and could not be included in the models.

Direct costs can be classified in:

- road construction costs
- maintenance costs,
- exploitation costs, and
- costs for accidents.

Road construction costs are taken as a cost of the offered variants of the constructor. Maintenance costs are accepted as costs for each of the offered variants for maintenance. The problem of this research intrudes the need for the space and time to be integrated as important principles.

## 3 Modelling

The space principle in the integrated from three aspects:

- geometrical characteristics of the road which can be embodied in any riad,
- geographical allocation in the sense of the surface where the road is constructed (this specific quality may also be embodied in any road); and
- performances and specific qualities of direct and indirect zones of influences, which is very hard even impossible to be embodied.

As to the time principle, we can say that it is unavoidable because every construction of the roads belongs to the long-term investments. Its exploitation is also a long-term one. Because of these reasons, while determining the economic indicators, a planned period of 20-30 years is used.

Direct exploitation costs of the road are divided into:

1. Costs which direct depend on the use of the vehicles are:

- fuel costs,
- dope costs,
- tyres costs,
- maintenance and repair costs.

2. Costs which partly depend on the use of the vehicle and partly on the time of their use, which most often refer to:

- amortization,
- interests,
- drivers' wages,
- insurance,
- driving licenses and registrations, etc.

Most of the costs depend on the profile of the speed, road damage (in cases when maintenance and repair works are not in time) and the structure and the age of the motor pool. As the repair works which are not on time can not be located in the models according to their time, it is assumed that the road repair works will be done in time and damages on the road won't be a limiting factor for the speed of the vehicles.

The interaction of the model of the road, the vehicle and the driver is very important for determination of the speed profile. The basic concept of this model is shown on figure 1.

Complexity of this model is solved by determining the speed profile in a free traffic low. After the speed profile is determined in this way, we additionally implement the influence of the other vehicles in the traffic. The number and the structure of the vehicles is determined according to the model for the prediction of the next traffic flow. In order to determine the speed of the free traffic flow it necessary to make an interaction of the model of a driver, a roadway and the vehicles. The behavior of an average driver in the model is used according to the researches done by Prof. Dr. Dragorad Damjanovich, and, if there conditions, the speed in a free traffic flow is expressed in this equation:

$$V_{SL} = 34.37 \cdot \log R + 15.42 \cdot S - 0.66 \cdot K - 47.80 \ [{}^{km}\!/_{h}]$$

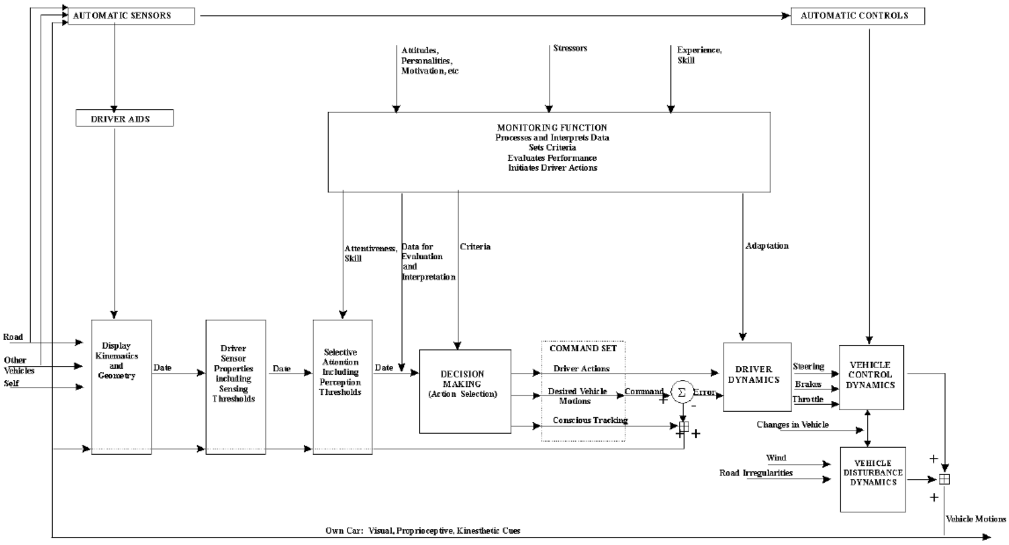


Figure 1: Generalized Block Diagram of the Car-Driver-Roadway System

But, the speed profile depends on the vehicle and its possibilities. The model of the vehicle is implemented with its static, driving and dynamic characteristics the most important of which is the traction diagram of the vehicle. The roadway model is made by segmenting in into equal segments, for example $\Delta l$, which means that linearization of the roadway is made. Each of the segments is characteristic with appropriate geometrical features like: length, width of the lane and longwise and across inclination. The interaction of the model on average driver behaviour and the model of the vehicle and the roadway gives the speed profile in a free traffic flow. With the use of this model and the fuel consumption declared by the producer, we can estimate the costs for: fuel, dope, tyres and maintenance of each vehicle from the traffic structure. Using complementary information about the average number of already passed kilometres, the structure of the traffic in vehicle categories as well as the traffic in vehicle, we can determine amortization costs, interest, drivers' wages, general administration costs, insurance, driving licenses and registrations. To complete the costs, it is necessary to predict the future traffic according to the vehicle categories. It is done by considering the traffic trend or by solving the Fratar model:

$$t'_{ij} = k t_{ij} \frac{P'_i}{P_i} \frac{A'_j}{A_j}$$

where, $t'_{ij}$ - marks the change of the future traffic, $t_{ij}$ - current traffic, $k$ - constant, $P'_i$ - trevellings from the "i" – zone, $P_i$ - change of travellings from "i" – zone, $A'_j$ - attractiveness of "j" – zone, $A_j$ - change of attractiveness of "j" – zone.

The costs of accidents are also an important item for the total costs. There are various approaches for the prediction of the number of accidents. In this model, the following equation/expression is used:

$$\hat{N}_r = 0.237 + \frac{6499}{PGDS^{1.3}} + 0.064 \cdot e^{0.12 \cdot D_h}$$

where $\hat{N}_r$ - number of accidents, $PGDS$ - an average annual daily traffic, $D_h = \frac{S_{\hat{V}}}{\overline{V}_{SL}} \cdot 100\,[\%]$ is dynamic homogeneity, standard deviation of the regression $S_{\hat{N}} = 0.49$ interpreted variance $R^2 = 67.74\%$, correlation coefficient $R = 0.823$.

This expression/equation is a result of the assumption that $\hat{N}_r = \varphi(D_h, PGDS)$ and the experimental data made on 16 roadways in the Republic of Macedonia.

According to the data we get from this model, we can determine the following economic indicators which are important for the evaluation of the economic justification for construction of roadway:

- economic costs for realization of the project,
- economic costs for the use of roadway net in a certain period,
- total economic costs,
- economic benefits expected from the exploitation of the realized project in a certain period,
- internal rate for return,
- net present (future) value,
- economic profits/economic costs relationship,
- net present (future) value/economic costs relationship,
- economic benefit in the first year/economic costs relationship,
- net income of the commercial exploitation of the roadway,
- net income in the first year,
- the period of exploitation necessary to repay the invested capital in the realization of the project,

In all previously mentioned indicators, the time factor has been implemented through the price of the capital.

## 4 Software solution

Economic indicators in this solution are important in the process of making prefeasibility and feasibility studies for roadways. Software representative of the model will be presented in block diagram.

The input parameters of the models which are adjustable are an important moment for this software solution. The input data are competent vehicle of different categories, traffic structure, PGDS for the last period, a roadway, the price of the competent vehicle, the average annual mileage for each category of the vehicle, the price of registration, the insurance price the average wages of the drivers, daily allowances for the drivers etc. Geometry of the roadway is roadway is read on a standard data pool prepared by PLATEIA – a software for roadway projecting in AUTOCAD.

Software solution consists of a number of modules. Some of them are shown in the figures 2-10.

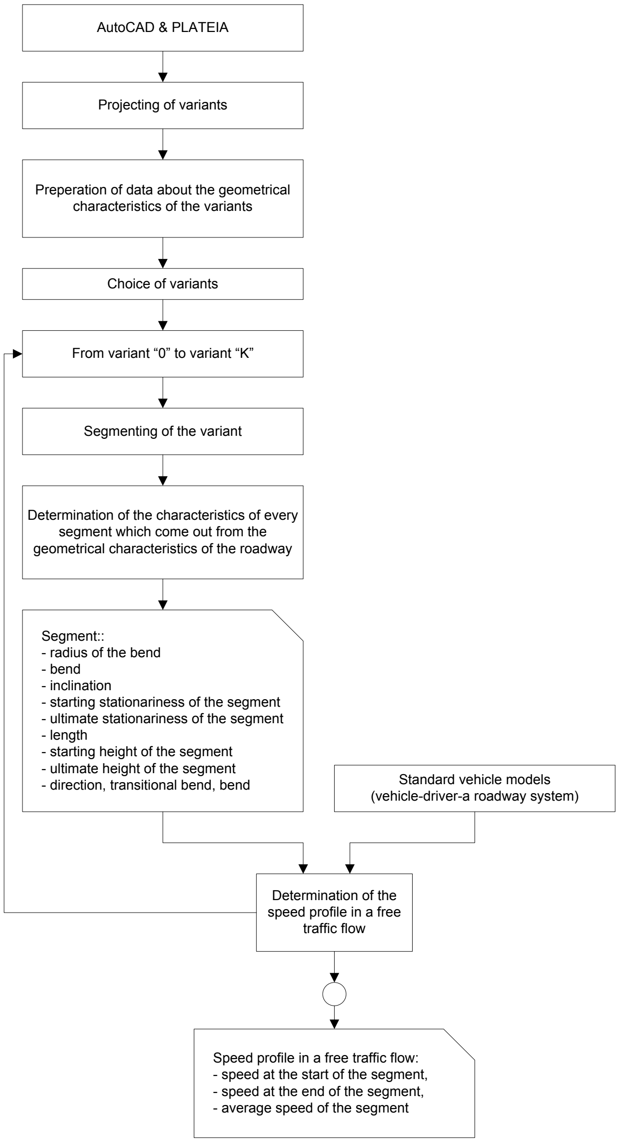


Figure 2: Block diagram of the module for determination the speed of free traffic flow

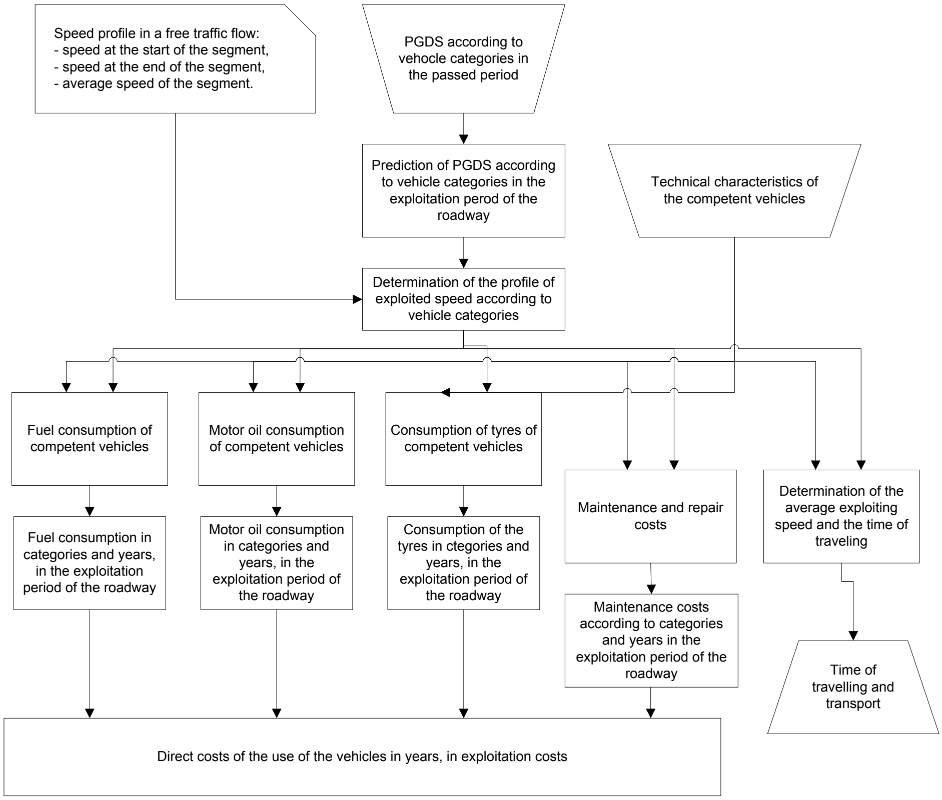


Figure 3: Block diagram of the module for determination of the direct exploitation costs of the roadway

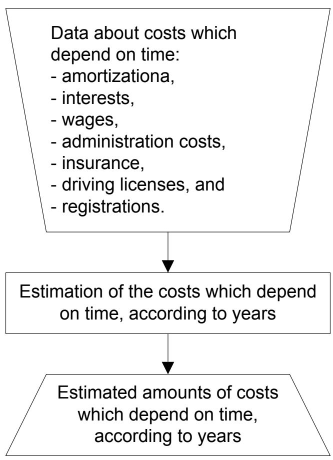


Figure 4: A block diagram of the module for determination of costs that depend on time

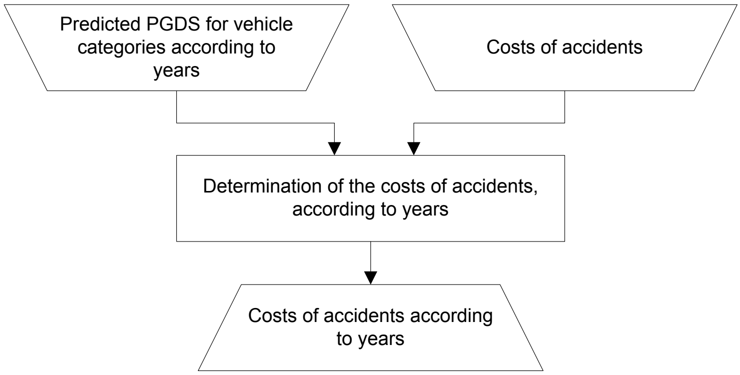


Figure 5: A block diagram of the module for determination of the costs of accidents

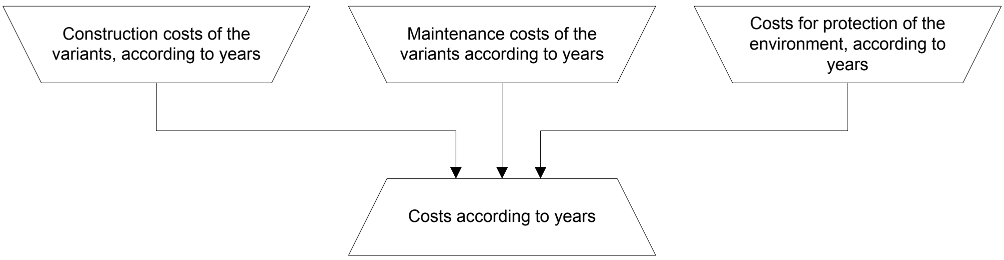


Figure 6: A block diagram of the module where it updates the construction data, maintenance of the roadway and the costs for a reduction of the environmental consequences as well as a protection of the environment.

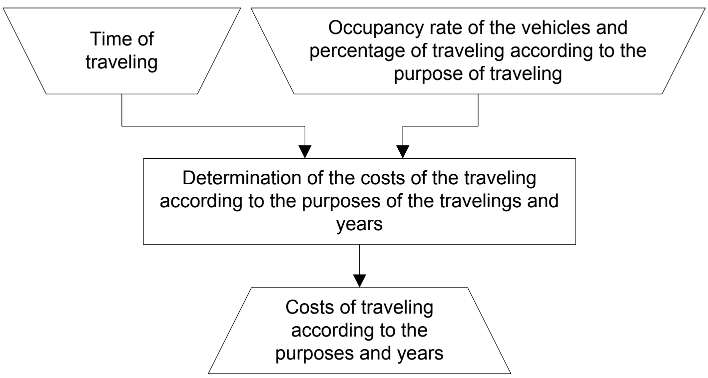


Figure 7: A block diagram of the module for determination of the costs for the time of traveling of the passengers.

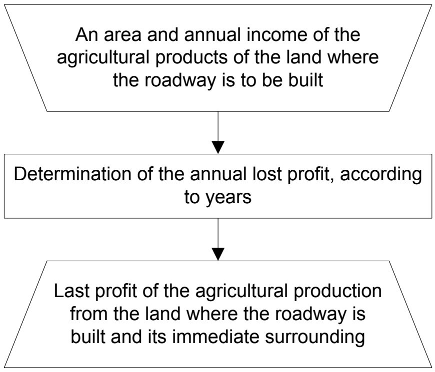


Figure 8: A block diagram of the module for estimation of the costs of the lost profit.

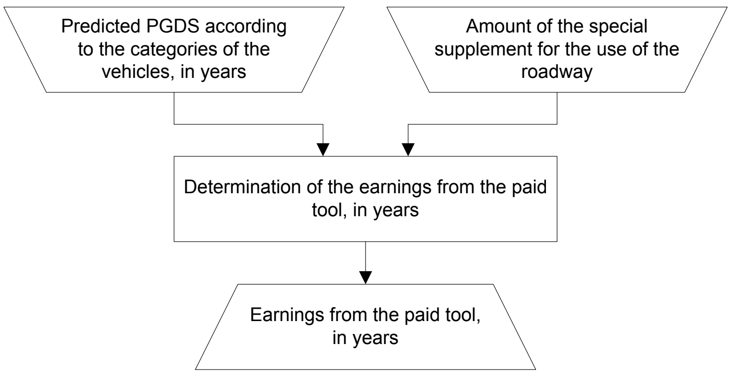


Figure 9: A block diagram of the module for determination of the income from the payment of special taxes for the use of the roadway.

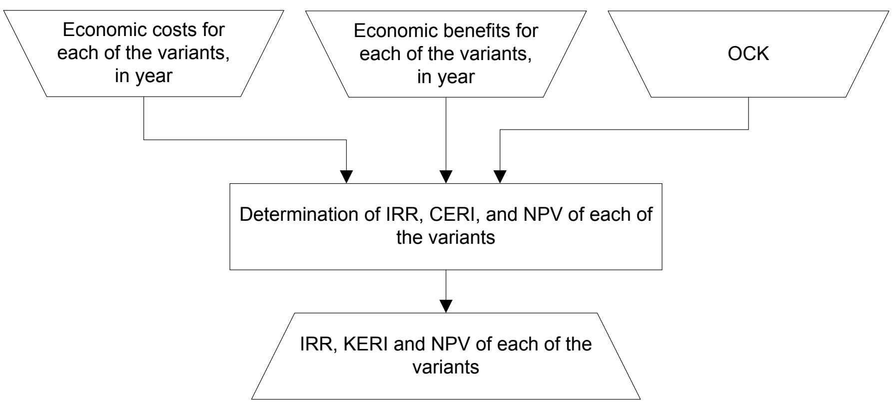


Figure 10: A block diagram of the module for estimation of ISR and NPV

Figures 11 and 12 show two forms for insertion and estimation.

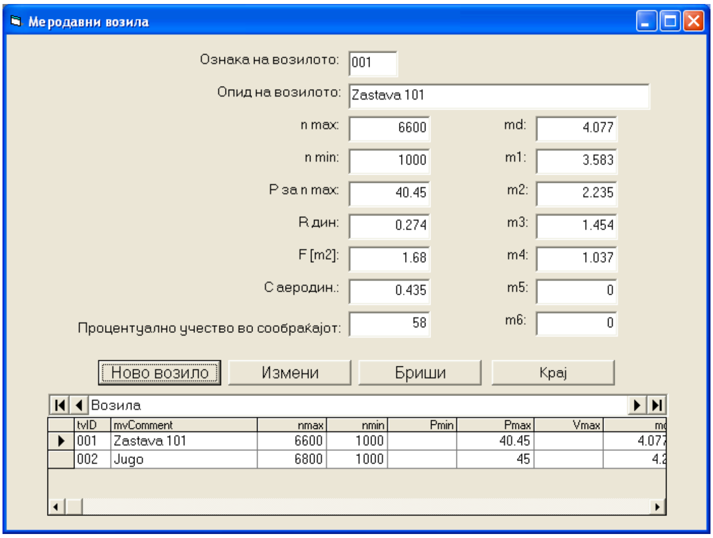


Figure 11: A form of data insertion for competent vehicles

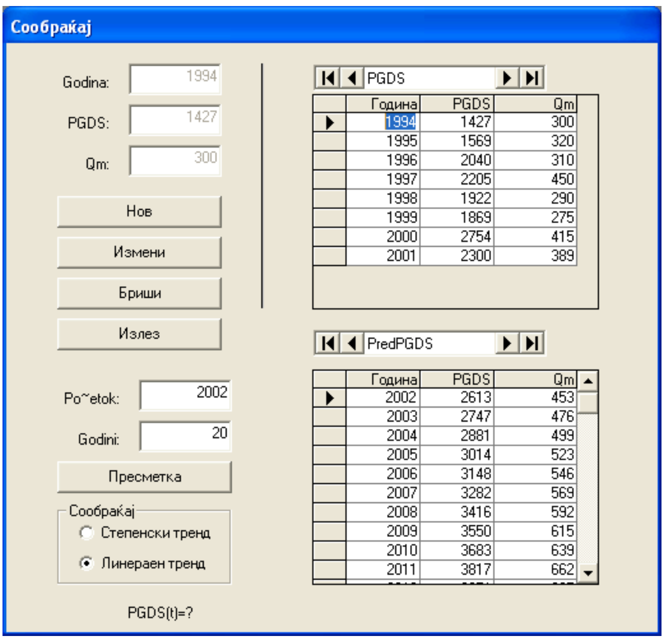


Figure 12: Forms for prediction of the future *PGDS*

## 5 Conclusion

The process of determination of economic indicators which are important in the process of the choice of the optimal variant of a roadway is simplified with the use of this software solution. This model can be applied in the process which should give the answer to the question whether a new roadway is to be constructed. This software solution is suitable to be used while making prefeasibility of feasibility studies for roadways. Adaptability of the software solution provides a wide implementation in a great number of practical cases.

## 6 References


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