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CONCEPTUAL MODEL FOR APPLICATION OF SIMULATION SOFTWARE FOR COST-BENEFIT ANALYSIS OF URBAN TRANSPORT INFRASTRUCTURE

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Key words: *conceptual model; cost-benefit analysis; infrastructure; software; traffic simulation*

Abstract: *Evaluating future transport infrastructure projects is a challenge as it requires predicting future traffic demand and tendencies in social-economic development. It also requires monetization of factors such as road accidents, air pollution and noise. This paper aimed at presenting the role of traffic simulation software for the evaluation of future infrastructure projects as well as the role of the software in the process of cost-benefit analysis. In this regard, the role of the traffic software at each stage was presented and a conceptual model was developed as a diagram in this paper.*

1. INTRODUCTION

The problem with evaluating non-existing transport infrastructure is that a model is needed. Computer models are representation of the real world but with limitations. They try to be as close to the real-world infrastructure but they have their limits. However, with the development of computer hardware and software the traffic simulation software is becoming more sophisticated and it capabilities change.

The problem presented in this paper refers to the need of a concept for the use of traffic simulation software for cost-benefit analysis (CBA) of future infrastructure projects.

According to the Guide to Cost-Benefit Analysis of Investment Projects by the EU Commission: "…there is currently no detailed guidance at EU level for the development and application of transport models…"[1].

A transport model according to a definition from the same guide is "a computer-based representation of movement of people and goods (trips) around a transport network within a defined 'study area' possessing certain socio-economic and land-use characteristics".

Computer-aided traffic simulations for urban areas are performed locally (in Bulgaria) and worldwide [2, 3, 4, 5, 6]. Examples for such traffic simulation are to be found in [7, 8]. In the referred papers there are new infrastructures built to meet the need of population in regard to certain public event or increased traffic flow [9, 10, 11].

The decision about the usage of traffic simulation software depends on the effect the infrastructure changes will have on surrounding transport infrastructure. A spreadsheet may

be sufficient for a single intersection of no significant importance. On the other hand, traffic simulation software might be needed for accurate evaluation of infrastructure projects that have profound effect on travel demand. A previous study close to the topic of this paper is presented in [12].

2. MATERIALS AND METHODS

The conceptual model is based on secondary research of papers that present experiments with simulation software. The software is used for prediction of effects of changes in the infrastructure on vehicular traffic in certain urban areas. A significant part of this research was based on a document from the EU commission that concerns cost-benefit analysis of infrastructure projects. The conceptual model was also based on expert knowledge of the simulation software and its features. The content of the Guide of the EU Commission is given on Figure 1. This content represents the stages in the consecutive order that are taken for the cost-benefit analysis of a transport infrastructure.

Fig. 1. Stages of CBA of transport infrastructure [1]

The traffic simulation software that has been available for the study is Aimsun Next [13].

When trying to find the place of traffic simulation software in the process of cost-benefit analysis it is also important to mention at which of these stages the simulation software is applicable and how it can support each stage.

1. **Description of the context** – at this stage the context in which the infrastructure project is developed is presented. The context includes socio-economic trend, political, institutional and regulatory, and existing service conditions. At this stage there is a need for data and statistical information but still no need of modeling and simulation.

2. **Definition of objectives** – the objectives are usually the reason why the infrastructure project is built. At this stage the traffic simulation software could help with evaluation if the objectives of the project will be met. Possible objectives are: reduction of congestion, increased speed, safety etc.

3. **Project identification** - the scope of the investment projects must "be a stand-alone socio-economic and technical unit" [1]. In other words, the traffic simulation software may help with defining the scope of the investment project and help to reveal dependencies with existing infrastructure or other investment projects related to the evaluated one.

4. **Forecasting traffic volume** - sensitivity of traffic to some variables such as demographic changes, socio-economic changes, industrial and logistic structure and developments, elasticity with respect to quality, time and price etc. is also an important factor. In this regard, the traffic simulation software may help with simulating these variables in different configurations. This process happens relatively fast and easy.

5. **Option analysis** - the software allows for fast and relatively inexpensive building of traffic models, and test of different options. For example, if we consider a four-legged intersection that need to be replaced because of high number of accidents two other alternatives can be considered by modelling in traffic environment: roundabout or traffic light regulated intersection.

6. **Financial Analysis** - the financial analysis consists of investment costs, operational and maintenance costs and revenue projections. Here the most appropriate part to use traffic modeling the revenue projection where changes in traffic volume need to be predicted. Sources of revenue can be tolls and other user charges, tickets and subscriptions etc. Essential for the use of traffic simulations here is the traffic forcast.

7. **Economic analysis** - for the economic analysis the traffic simulation software can help with the indicators Travel Time or Total Travel Time. Base on this traffic indicator the Value of Time can be calculated. More detailed information about the Value of Time is presented in the Guide [1].

8. **Risk assessment** – the value of time savings can be more than 70% of all benefits for infrastructure project according to the Guide by the EU Commission. Therefore, it is important to test this variable. The benefit of using traffic simulation software at this stage is that the value of time can be calculated based on total travel time for different scenarios. The rate of increase of traffic over time is another parameter that needs to be analyzed and testes carefully. Again, this can happen with the help of traffic simulation software.

The section "Materials and Methods" presented the eight stages of cost-benefit analysis of transport investment projects. At each stage the benefit of using traffic simulation software was outlined. The next section "Results and Discussion" will present a conceptual model for the application of traffic simulation software in the context of cost-benefit analysis.

3. RESULTS AND DISCUSSION

A conceptual model has been developed based on the "Guide to cost-benefit analysis of investment projects" and expert knowledge about traffic simulation software.

From the perspective of the project management the conceptual model can be used iteratively or linearly. Depending on the availability of information and data the conceptual model can be applied for each stage of the cost benefit-analysis by adding new data and modifying some input parameters. In other word, the work with the conceptual model can be iterative. Otherwise, the model can be prepared after most of the information and data for each stage is available that is similar to a waterfall approach. Although, even by the waterfall approach some later adjustments need to be taken into account.

The conceptual model consists of the following parts that are presented on Figure 2:

- **Information and data gathering**

The information and data gathering part of the model refers to the collection of data in two directions. The first direction is data necessary for the building of the simulation models of the current infrastructure and future infrastructure in the simulation environment. The data needed is the traffic flow detected by sensors or collected in another manner. Surveys can give information about movements of the population in the investigated area. This information is needed for building the O-D matrix (Origin-Destination matrix). The survey data may also be useful in other ways regarding the socio-economic factors.

The data for road geometry is important for building the model inside the simulation environment of the present and future infrastructure.

The second direction in which information and data are gathered are statistical data needed for monetization and calculation of the cost-benefit of the future project e.g. the average wage for the country per hour of work. This information can be used to estimate how difference in travel time between the present and future infrastructure can affect the population.

- **Input**

The input part of the model consists of the input parameters for the geometry and input parameters for the traffic flow. The present infrastructure can be imported form internet service as OpenStreetMaps. However, the data of the geometry of the future infrastructure need to be taken from the authorities or the contractor in charge of the project.

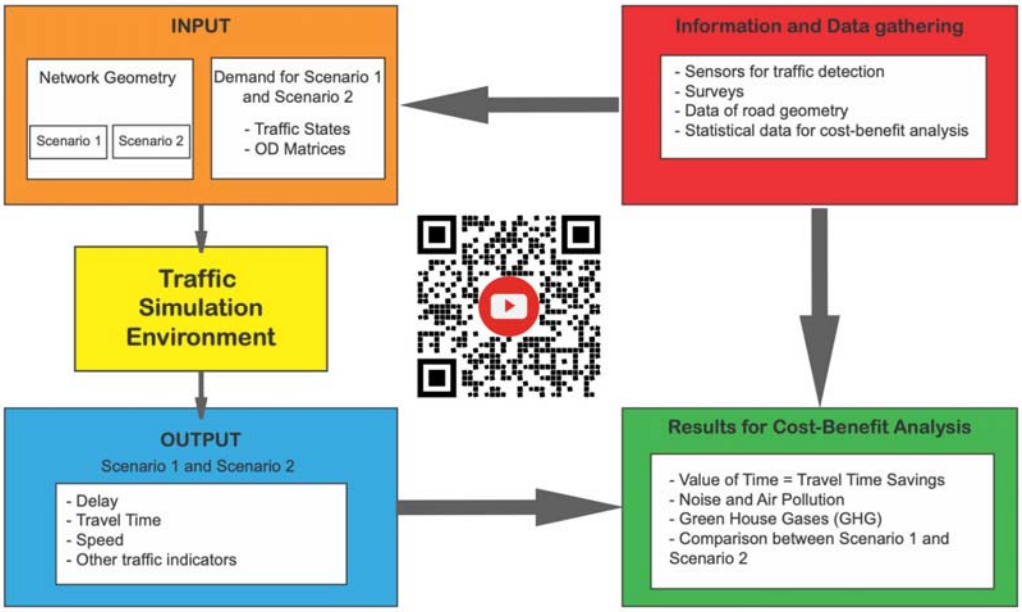

Fig. 2. Conceptual model for application of simulation software for CBA

The input parameters for traffic flow can be entered in the simulation environment as traffic states (the software decides the destination of vehicles in the network) or as O-D matrices (based on a survey the origin and destination of a vehicle is assigned upon its entering in the transport network).

- **Traffic simulation environment**

The traffic simulation environment is the software which is used for computer simulation of the present and future infrastructure. There are at least several popular commercial and free-of-charge software alternatives. The information for them is also

available in scientific papers that compare the different traffic simulation environments [14]. However, describing the features and the suitability of the different software products is out of scope for this paper.

The traffic simulation environment available for the study was Aimsun Next. This software environment gives the opportunity to model and compare a present and future infrastructure. The result is output parameters described as the next part of the model.

- **Output**

There is a list of traffic indicators that are available after the simulation of movement of vehicles in the network finishes. As mentioned earlier, travel time can be used for CBA as it shows if the new infrastructure saved time for the travelers or rather increased the time spend for travel. Among the output parameters there is also information about the air pollution and greenhouse gases. There are also parameters as speed and mean queues that might be considered as well.

- **Results for Cost-Benefit Analysis**

The final part of the conceptual model is the Results for Cost-Benefit Analysis. It combines some information and data gathered at the first part as well as the output date from the traffic simulation environment. In this part monetization of traffic indicators as travel time is done. The cost of air pollution and greenhouse gases can also be calculated based on results from the simulation environment and statistical data for the cost of health and other factors. The final goal is CBAs for two scenarios (without project and with project), as well as their comparison and support of the final decision about the implementation of the project.

The presented conceptual model is a simple tool that describes the process of application of traffic simulation software to cost-benefit analysis of transport investment projects. However, it can be elaborated and further developed. It can as well be customized for the needs of a specific traffic infrastructure project. The conceptual model is a step forward to the use of traffic models as an analysis and evaluation tool.

4. CONCLUSION

Investing in new transport infrastructure requires a detail cost-benefit analysis (CBA). A guide by the EU Commission exists that describes the CBA phases. However, this guide gives only some recommendations for the use of traffic modelling.

The aim of this paper was to give idea about the role of traffic modelling software in the process of evaluation of new transport infrastructure. The function to the traffic simulation software during each phase was presented. A conceptual model, based on expert knowledge, for the process of traffic modelling in the context of CBA was also presented. Further, a more detailed concept of traffic modelling for the evaluation of infrastructure projects as well as an application on potential transport infrastructure will be developed.

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КОНЦЕПТУАЛЕН МОДЕЛ ЗА ПРИЛОЖЕНИЕ НА СИМУЛАЦИОНЕН СОФТУЕР ИЗВЪРШВАНЕ НА АНАЛИЗ “РАЗХОДИ-ПОЛЗИ” НА ГРАДСКА ТРАНСПОРТНА ИНФРАСТРУКТУРА

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Ключови думи: *концептуален модел; анализ „разходи-ползи”; инфраструктура; софтуер; транспортна симулация*

Резюме: *Оценяването на бъдещи проекти за транспортна инфраструктура е предизвикателство, тъй като изисква прогнозиране на бъдещото търсене на транспортна услуга и тенденциите в социално-икономическото развитие. Освен това изисква монетизиране на фактори като пътни инциденти, замърсяване на въздуха и шум. Тази публикация има за цел да представи ролята на софтуера за симулация на трафик за оценка на бъдещи инфраструктурни проекти, както и ролята на софтуера в процеса на анализа „разходи-ползи”. В тази връзка беше представена ролята на софтуера за симулация на пътен трафик на всеки етап и беше разработен концептуален модел като диаграма в тази статия.*