



APPLICATION OF SIMULATIONS AND VISUALISATIONS IN ROAD TRAFFIC

Zdenko Lanović¹, Željka Žagar¹, Tomislav Salopek¹, Silvio Žagar²

¹ *Elipsa - S.Z. Ltd., Croatia*

² *Telematika Ltd., Croatia*

Abstract

Present software contributes to quality and speed of design and to project presentation by 3D digital models that help designers to verify the solution functionality in real time and space. In addition to significant advantages of 3D simulations, which are slowly being transformed to 4D models (entity integration with time and all the three spatial dimensions), there are many risks as well. Errors are mainly unintentional arise from lack of information (many pre-defined elements are used which do not match to actual issue) or designer's lack of experience (all possibilities are not fully used).

This paper will present particularities in application of new work techniques by a couple of practical examples in this paper.

1 Introduction

Projects of road construction, reconstruction or regularly maintenance become more complex and good quality presentation – visualisation is in interest of better project understanding. Present software contributes to speed and quality of design by a 3D digital model. Photorealistic visualisations are also obtained that help designers to verify the solution functionality in real space, and give clear picture to decisions makers and public on the proposed design solution.

2 The role of traffic model in road design

In some countries transportation (traffic) engineering is a part of civil engineering, while in other countries, as well as in the Republic of Croatia civil engineering and traffic represent separate scientific branches within the same scientific field. Road construction and road traffic represent two separate and complementary scientific branches which, in most cases, use same scientific methods but different scientific models. On one end, complexity of the issue of road traffic and broad range of applied scientific fields on the other end, enable creation of numerous specialised models of road traffic. Mathematical basis of a model is diversified: differential equations of fluid mechanics, combinatorics for short-term traffic predictions, graph theory as already established theory, application of mathematical programming, fuzzy logic for stratified description of traffic variables and processes, differential equations in cellular models or solving of recursive traffic problems. Simulation models represent tools providing optimal ratio between efficiency and speed of implementation in solving of real traffic issues. Today, tools that will realistically describe actual traffic situation, control traffic, predict potential traffic situation and offer solutions are called for. These requirements require development of a traffic model that will provide integration of time and space; location and time of appearing of each entity in the network will be known at any time.

Traffic model, especially due to capacities of the current simulation models, has the task and possibility of 4D modelling (entities in three spatial dimensions and time dimension):

- 1 three-dimensional realistic modelling of space and structures in space: buildings and civil construction (civil engineering solution of road infrastructure), entities moving along road (pedestrians, bicyclists, vehicles, ...), environment with the purpose of creating a realistic spatial image;
- 2 time component of road traffic flow: mode and speed of motion of individual entities in space.

From the point of view of road traffic infrastructure, aims of sustainable development require development that will preserve the present values of space and observing requirements of community. Efforts are made to achieve it by harmonisation of two opposing goals: to achieve better results in terms of safety and quality of traffic by less usage of the space. Therefore civil engineering solution is of crucial importance, because it determines the level and way of intervention in space and simultaneously it pre-defines other elements that subsequently influence exploitation, mode of management and maintenance. Accordingly, civil engineering solution must satisfy three basic principles: (1) functionality in utilisation, (2) adequacy in maintenance and (3) feasibility in reconstruction.

Traffic model only can meet the principle of functionality through verification of all basic indicators known from the traffic flow theory. In terms of subsequent maintenance issues and the need for reconstruction, traffic model also represents an important factor. Maintenance and reconstruction in reality frequently involve occurrence of certain bottle-necks. Only traffic models in function with civil engineering technology (temporary traffic regulations) give answers to questions how to locate such bottle necks in space and within what time windows in order to achieve sustainable traffic condition (prevention of congestion).

3 Construction of 4D simulation model

Traffic model is integration of three basic values: entity, space and time.

Entity (or population) refers to one or more users of traffic system. Traffic flow theory, or more precisely generic traffic theory, is a scientific discipline that explains the nature and character of movement and occurrence of entities (vehicles, pedestrians, information, media etc.) in traffic system.

The space is represented by Euclidean geometry. In traffic system it can be considered from several points of view: (a) road position in georeference system, (b) form and elements of the road, (c) dimension of an entity moving within traffic system.

Time is considered from several points of view: (a) the physical value of one or more entities, (b) calendar time, (c) occurrence and duration of an event.

In traffic process two basic properties are explained by time values: (a) time from occurrence of one or more entities in space, (b) time during which the observed entities are permitted or prohibition to perform certain action.

There is continuing interaction among three basic values and they offer a series of possible analyses, research, scenarios and defining of traffic events. For example, functional consideration of entities and time in space-invariant shows what changes should be made in character and structure of traffic demand and/or traffic management to achieve specific goals in the traffic infrastructure.

The accuracy of traffic simulation model depends mainly on accuracy of presentation of interactions of entities in space. Namely, driver's behaviour depending on traffic situation by so-called psychophysical model of driver's behaviour should be taken into account. Models based on constant vehicle speed and equal time duration of driver's reactions prevent seeing of complete picture of actual traffic situations. With the aid of software tools, and by application of simulation with actual drivers' behaviour on the road complete photorealistic visualisation is obtained which undoubtedly reveal possible problems and/or their solutions.

Technical properties of a vehicle taken into account in simulations and visualisations are: dimensions, expected speed intervals and standard speed changes, maximum and minimum acceleration and deceleration, position in traffic network, current speed and acceleration depending on service level, density etc.

In addition to drivers' behaviour and technical properties of vehicles there are the following interactions as well: position of a vehicle in front and behind and in the neighbouring traffic lane, position related to the next intersection, position related to (distance, speed) signalized intersection, desired movement direction, i.e. need to move to other lane to realise the intended destination of travelling etc.

All above elements should be related to the space, i.e. civil engineering solution of a road. The simplest and most frequent solution is to use the road capacity manual which contains pre-defined coefficient of individual road structures. The American *Highway Capacity Manual* is most frequently used in Croatia, and in some cases its usage is mandatory. The most recent edition was published in 2000, which includes methodology for 13 different and specific road facilities (from pedestrian traffic, through various types of roads and intersections, to movement of sub-systems of public traffic).

Author's experience shows that strict application of predefined elements introduces an error to the capacity calculation of 5 to 16 %. As the capacity is the main indicator, it is obvious what is the importance of knowledge and experience of civil-engineering and traffic professionals in solving of actual construction and/or traffic problems.

These are the most frequent errors in use of different software tools (because they are certain indicators) that do not match the actual problem, are applied automatically. Software producers offer broad range of models which can be more faster adjusted to local conditions (for example, various modules of movement and behaviour of pedestrians for American, European or Asian conditions etc.), but know-how and experience of traffic-, civil- and other engineering experts related to road traffic will be the keys in development of reliable engineering solutions (Figure 1).

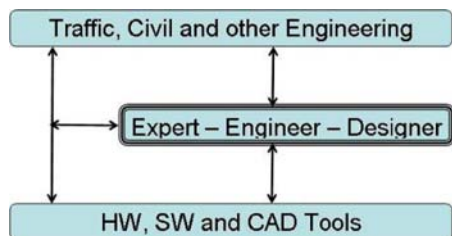


Figure 1 Key role of the expert

4 Case studies

Some advantages and possibilities of the current software tools for simulations and visualisation will be demonstrated by several examples, as well as problems that could encounter in their use.

4.1 Slavenska avenija in Zagreb

Basic design should provide a solution for lowering of Slavenska avenija to -1 level, linkage of existing underpasses in the streets Savska cesta and Hrvatske bratske zajednice. The corridor traffic significance and traffic demand, location and scope of intervention, costs, desired long life of solution, volume and importance of utility installations placed in the zone of intervention, urban significance of the space and other aggravate complete understanding of

the project complexity, its preparation and presentation in standard 2D form. Therefore, the project presentation has required completely new approach. There are more than 30 various utility installations (Figure 2) in the corridor and traffic and infrastructure solution depended largely on the reconstruction solution and relocation of existing utilities, as well as on new utility installations. Simulation package was used to create photorealistic actual situation to show solution of penetration into urban structure of the city. This project is specific for creation of 3D model of communal utilities.

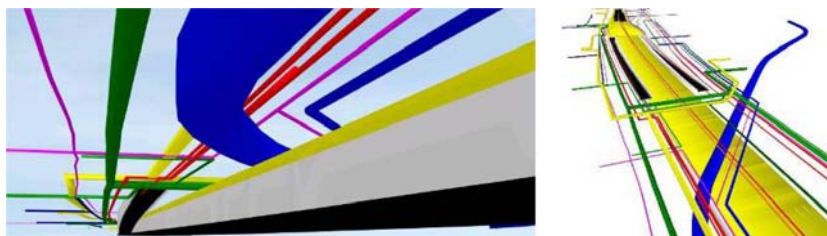


Figure 2 3D presentation of utilities



Figure 3 Virtual 4D model of Slavonska avenija

Project development conditioned preparation of 4D simulation model using VISSIM software tool (Figure 3). Using the model various forms of solutions were tested and the best one was chosen, and then traffic and visually realistic simulation of selected solutions was produced.

4.2 Entrepreneurial zone in the area of interchange Sveta Helena

The task was to research various solutions of traffic linking of new entrepreneurial zone to the east of the interchange Sveta Helena to ensure sustainable traffic status in terms of quality and safety on the A4 highway and D28 state road and adjacent county roads. There are four separate interests: (1) company Hrvatske autoceste d.o.o. (Croatian Highways Ltd.) wants to keep full autonomy and function of the interchange, (2) company Hrvatske ceste d.o.o. (Croatian Roads Ltd.) wants to keep all elements of expressway, (3) Roads administration of Zagreb County manages adjacent roads, and (4) the City of Sveti Ivan Zelina and Municipality of Rakovica want the best accessibility to the area of new entrepreneurial zone.

Two scenarios were analysed. Scenario 1 involves linking of entrepreneurial zones and other facilities through existing county roads in one point – future roundabout. According to Scenario 2, main connection toward entrepreneurial zones is made through expressway and

connections to county roads represent secondary links for local purposes. The advantage of this solution is direct access to entrepreneurial zones through a high serviceability road via an “incomplete interchange” – diamond intersection, with full accessibility from various directions. Mesoscopic model, shown in Figure 4, represents analysis with basic parameter of the link saturation level and collision points of traffic flows.

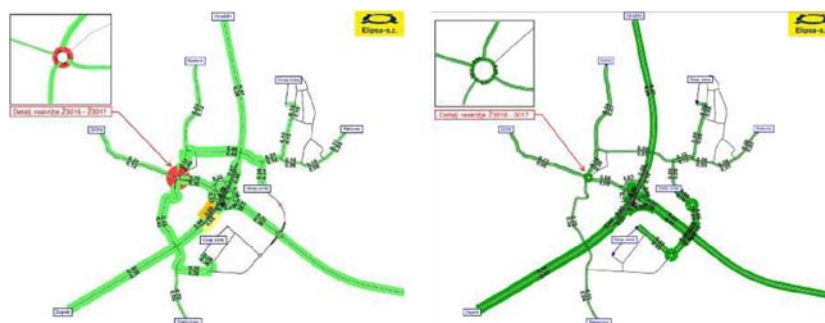


Figure 4 Degree of saturation: Scenario 1 – Scenario 2

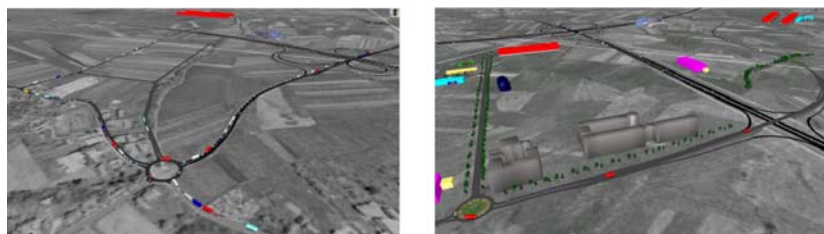


Figure 5 4D Simulation, Scenario 1 – Scenario 2

The magnitude of impact of congestion in the area of future roundabout, i.e. the level of negative impact on the Sveta Helena interchange can be demonstrated and proved only by photo-realistic microscopic simulation as shown in Figure 5.

4.3 Central Railway Station Zagreb

The project task was to prepare traffic analysis and to propose a short-term solution for five pedestrian crossings in the zone of Central Railway Station in Zagreb to increase traffic flow rate, and concept design of pedestrian under-passage as final solution. Due to more than 500 various indicators and factors, simulation imposes as the only possible solution. The crucial problem in such tasks is calibration of simulation model; achieving conditions and traffic parameters as much similar as possible to the present situation. For such a purpose a series of special measurements and surveys were made to determine properties of pedestrian flows in the first place. Figure 6 shows movement of pedestrians over pedestrian crossings, i.e. pedestrian impact on vehicle flow: occurrence time and duration of vehicle stops and queue lengths. The problem nature required analysis of complete traffic process at micro-level. Impact on traffic of large number of pedestrians who have freedom of movement, the scope of intervention and specificity of location that could not be simulated by standard methods and required use of 4D simulation model using VISSIM software tool with addition of a pedestrian module which simulated pedestrians’ behaviour in very realistic manner.

Figure 7 shows parts of simulation of the existing traffic process at the Central Railway Station in Zagreb during morning peak period.

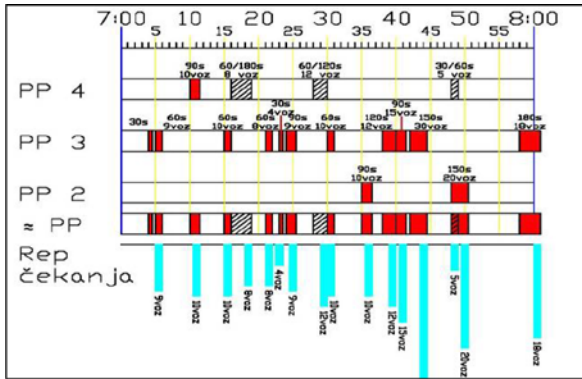


Figure 6 Pedestrians' influence on traffic flow in Branimirova street

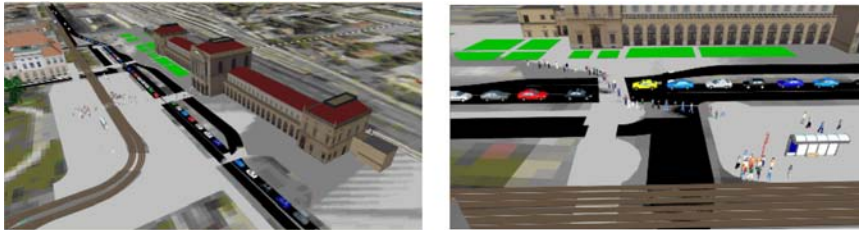


Figure 7 Simulation of existing situation

5 Conclusion

Dynamic analysis of technical problems has existed for more than 60 years, but only in recent years such problems have been solved properly, quickly and most cost-effective by application of specialised CAD tools. Interdependence of three basic traffic values (entities, space and time) can be fully analysed only through dynamic traffic models. In recent years, use of traffic software tools, that involve dynamic traffic models, has been expanding quickly. There are two main reasons:

- 1 in recent period traffic phenomenon is being understood as a unique problem and not as a part of architectural-urban and civil-engineering issue,
- 2 acceptable price remove the exclusive image and operability of software interfaces has eliminated the need for attending by professional teams, affordable only by large companies and public institutions.

Although in the Republic of Croatia traffic and civil-engineering sciences represent separate fields of technical sciences, maybe it is for this reasons that traffic software tools show in the best way that road construction and road traffic are two separate and complementary scientific branches which, in most cases, use the same scientific methods but different scientific models.

Traffic software tools give significant contribution to quality and speed of design and project presentation. There is no doubt regarding popularity and efficiency of 3D digital models that help designers in processes of planning, design and presentation of a solution. 3D models can be relatively easily upgraded into 4D models: integration of observed entities with time and all the three spatial dimensions. Although traffic software tools mean better quality and faster work, they also include numerous risks. Errors are mainly unintentional and caused by lack of information (many pre-defined elements are used which do not correspond to actual

problem) or designer's lack of experience (all possibilities of software packages are not fully used).

Authors' experiences, illustrated by a couple of practical examples, present particularities and difficulties in application of new techniques.

References

- [1] Daganzo, C. F.: Fundamentals of Transportation and Traffic Operations, Elsevier Science Ltd, Oxford, 2000.
- [2] Gartner, N., Messer, C. J., Rathi, A. K. (redaktori): Traffic Flow Theory, Special Report 165, Transportation Research Board, Committee on Theory of Traffic Flow, SAD, Update June 1992.
- [3] Highway Capacity Manual, Transportation Research Board, National Research Council, Washington D.C, USA, 2000.
- [4] Lanović, Z.: Traffic flow model in road management systems, Master's Thesis, University of Zagreb, Faculty of Transport and Traffic Engineering, 2006.
- [5] Salopek, T.: Four-dimensional traffic modelling, Graduate Work, University of Zagreb, Faculty of Transport and Traffic Engineering, 2009.
- [6] Elipsa – S.Z. Ltd: project archive 2006 – 2009.
- [7] VISSIM 5.20 User Manual, Planung Transport Verkehr AG, Germany, 2009.
- [8] VISUM 11.0 User Manual, Planung Transport Verkehr AG, Germany, 2009.
- [9] Internet sources: www.paramics-online.com, www.its.leeds.ac.uk, www.trafficware.com, www.aimsun.com.

