CAPABILITIES OF MODELLING IN SUPPORTING THE MANAGEMENT OF PUBLIC TRANSPORT SYSTEMS

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Abstract

The pursuit of an efficient approach to the design of transport systems declares the need for the use of modelling and simulation methods. It is advisable to establish the input conditions and procedures for dealing with the problem. The paper presents the basic postulates of such an approach and points out the conditions for applying modelling in the field.

Keywords: public transport, modelling, system approach,

Introduction

The transport system represents one of the most significant characteristics of the maturity of any city. In order for it to work in practice and to serve the inhabitants of a given locality well, it is necessary to manage, coordinate and plan all transport processes and related activities taking place in it. Simulation is a numerical method that experiments with a mathematical model of real (mostly dynamic and stochastic) systems on a computer. Simulation is understood by the author as a procedure by which the process under study, or its steps in time, is generated based on the properties of the parameters of the system being imaged.

The basic idea of simulation is based on the direct imitation of the individual steps of the system´s behaviour under study. More precisely, then, the simulation mimics the behaviour of processes occurring in a real system.

Elements of simulation

A simulation model is a mathematical technique consisting of:

- Constructing a set of mathematical and logical relationships expressing the basic functional or other characteristics of the elements of a system,
- Incorporating random effects into the model in the form of probabilistic techniques,
- Incorporating time into the model in the form of a representation of all changes that occur in the system over time,
- Sequential computations with different input data, thereby mimicking the real-time behaviour of a real system.

In terms of the inclusion of the time factor in the model, we can distinguish between static and dynamic simulation. In static simulation, we generate the state of the system at a specific point in time. On the other hand, in dynamic simulation, we model the evolution of the system over time. In terms of the inclusion of random effects in the model, we can distinguish between deterministic and stochastic simulation. In deterministic simulation, we do not consider random influences.

In contrast, in stochastic simulations, we model random factors by including random variables in the simulation model.

A simulation model is a de facto program whose computation represents the behaviour of a system. By varying the input data, we can experiment with the system and find the best possible way to control the system being modelled by successive steps. It can be written and implemented in both standard programming languages and standard programming systems such as spreadsheets. For more complex tasks, a specialised object-oriented programming language is then usually used.

System dynamics

System dynamics began to emerge as a distinct discipline in the 1950s. The American professor Jay W. Forrester is traditionally regarded as its founder and pioneer. An important component of system dynamics is systems thinking. Its implementation tools are primarily computer simulations and the simulation models generated by them.

The most commonly used:

- CAD, or computer-aided design, or computer-aided drafting, is closely linked to the use of advanced computer programs. It is a form of graphical information (vector drawings). The CAD software applications offered can be divided into 2D (surface) and 3D (volume) tools.
- GIS (Geographic Information Systems) and digital maps are currently experiencing a real boom. GIS are computer-based information systems that serve the most commonly used digital mapping surface. They differ from other systems in that they can work with the location of individual objects. These objects can then be assigned other properties in addition to coordinates, depending on the purpose of use. Digital maps are the most commonly used.

Spatial planning and urban planning

All transport must be considered in relation to the area being addressed. In this context, spatial planning and urban planning are important.

Definition of spatial planning and its instrument - spatial planning is a specific type of planning, sometimes referred to as environmental change management. Its emergence is closely linked to the concentration of population in cities and urban areas. It focuses primarily on changes in the physical components of this territory. It systematically and comprehensively addresses its functional use, determines the principles of its organisation, and coordinates construction and other activities affecting its development in terms of substance and time.

Transport Engineering

Traffic engineering is a scientific discipline that deals with the study, research, analysis and forecasting of phenomena and regularities in transport from the point of view of traffic communication. Its purpose is to provide the basis for road design, planning and traffic solutions, both of an immediate nature (traffic management, organisational and implementation measures) and a forward-looking nature. I mention this discipline here because traffic engineers are the main user group of the modelling products I have analysed.

Transport modelling

The field of transport planning, management and optimisation is now almost unthinkable without the use of appropriate computer support. The transport planner creatively uses his expertise and the necessary routine mathematical operations are carried out by the computer system on his behalf. If he or she modifies an existing public transport system according to specified requirements (e.g. by inserting a new stop, modifying the route of a line, changing the timetable, etc.), the corresponding automated modelling system can determine the consequences and impact of such changes on passengers and transport operators. For this purpose, however, it is necessary to have a model that also simulates the behaviour of the actual users of the network, i.e. the passengers, and this will usually allow it to create a different functional component of the product.

There are several reasons for using computer simulations in transport. First of all, they allow the user to obtain a range of important information before carrying out the actual physical implementation of the transport solution in the field (e.g. it helps him to determine the necessary number of transfers on a given line or the desired frequency of connections). Other reasons are then primarily financial, time, safety and technological.

Comprehensive software solutions for transport modelling and in particular their output, a functional dynamic transport model, can in practice act as:

- A tool to introduce long-term transport objectives,
- Optimisation tool,
- Efficiency analysis and evaluation tool,
- Monitoring tool,
- Transport network management tool.

Software tools are generally used both offline and online.

In off-line management, they can be used to test and validate different situations and scenarios in the transport network, e.g. road blockages due to repairs, traffic accidents, as well as extraordinary events in the city, such as the organisation of mass sports and cultural events, exhibitions, fairs, etc., when a large number of passengers are directed in one direction in the network at a certain point in time. Such situations can be addressed by the software, e.g. by designing and integrating signal plans into traffic lights. Likewise, the model is capable of short-term traffic prediction and rapid response to traffic situations by changing signal programs.

As far as on-line traffic network management is concerned, some large software modelling packages include functional modules designed directly for the continuous evaluation of traffic data generated in real traffic.

A decisive element of the quality of a future model is the input data with which the model is populated. Collecting adequate, complete and truly high-quality input data is quite difficult in Slovak practice. The preparation of a portfolio of data needed to build a model of the transport network of a large city can take several months or even years.

These entities then usually procure part of the data themselves, as they also have some, albeit limited, capacity in this field (e.g. they have their unit dedicated to conducting and processing traffic surveys). Other necessary data cannot usually be obtained other than from surveys carried out by specialised, usually private, bodies to which these institutions outsource the relevant surveys for processing on a commercial basis. This service is also a public contract awarded by public tender, the implementation of which entails considerable costs. Once collected, the data must then be structured into a form suitable for input into a given computer application.

Traffic surveys - surveys are one of the most important sources of input data for the development of traffic models. They are generally used to identify the transportation needs of the residents of a given locality. If we know the transport needs of the population, then we can design a new or optimize the existing transport system (e.g. by substituting individual modes of transport, modifying the routing of lines or, for example, the extent and density of the transport network), as well as to develop a forecast of the expected development of the transport needs of the inhabitants of a given locality.

The surveys themselves then aim to find out, in particular, the following data: population momentum (number of trips per capita per period in the respective transport area), origin and destination of the trips, their purpose, means of transport used, timing of the trips (peak or off-peak periods can be defined), passenger structure (child, pupil, pensioner, etc.), and intensity of the traffic flow (the load of a given line or link section by the number of passengers per direction of travel in a given unit of time). On their basis, it is then possible in practice to compile a model of transport needs or passenger movement, to process a transport engineering forecast of the expected development of transport behaviour of the population, qualified proposals for changes in the relevant transport system and the division of the transport space or, for example, calculations of financial flows corresponding to the relevant variant of the transport solution.

Urban Mobility and the European Union

In general, urban transport cannot be said to be directly addressed by any specific EU policy. In this sense, individual Member States generally deal with it separately at the relevant national level. However, several EU sub-legislations touch on it, particularly in relation to transport and its safety, but also in terms of consumer policy and environmental protection.

Green Book: "Towards a New Culture of Urban Mobility" defines the objectives:

- Objective one - Cities with smooth traffic flow,
- Objective Two - Greener Cities,
- Objective Three - Smart Urban Transport: increased application of integrated intelligent transport and payment systems to enable better timing of traffic, higher load factors on the relevant roads and more efficient use of vehicles; the stakeholders, in this case, will be technology provider, transport and infrastructure operator, industry, value-added service provider, digital map contractor, law enforcement authorities and infrastructure user; support of sub-applications by the Galileo satellite system; achieving interoperability of data and information exchange (uniform transmission protocols); interoperability of both standards and relevant functional elements between different modes of transport; creation of a single framework for the use of intelligent transport systems in the EU,
- Goal Four - Accessible urban transport,
- Goal Five - Safe transport.

Conclusion

Modelling of dynamic transport systems is nowadays unthinkable without adequate automated support. Quality planning and efficient organisation of transport processes are then all the more critical in cities, where they affect the lives of tens of thousands, but usually also hundreds of thousands, of inhabitants of a given agglomeration. The current market offers a range of supporting software products, from small programs with partial functionality to complex software packages for transport modelling. The level of functionality of the product used is quite logically determined by the nature of the requirements arising from the activities and expertise of the user´s workplace. Of course, the costs associated with the acquisition of a given modelling product also have an impact, which in the case of really high-quality modelling tools can range up to the order of tens of thousands of euros. This is probably one of the reasons why, in the case of large multifunctional licensed products, it is true that they are implemented and used in a relatively narrow circle of larger and highly professional institutions.

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