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RESEARCH ARTICLE

Dynamic model of urban controlling based on artifical intelligent methods

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Abstract

To effectuate a consistent methodology for urban planning – taking into consideration the viewpoints of land use and transportation – we need to approach the subject with considering complex social and economical aspects. To handle both of the mentioned urban planning areas together, we shall develop models, which are able to pay attention to all of their restrictive factors within the temporal properties as well.

Keywords

Urban transportation · urban modelling · dynamic modelling · regulated urban process

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1 Introduction

Besides, the increase in transport demand – caused severe imbalances in European metropolitan areas – has to make us to pay also attention to the interests of the users. Congestion, pollution and extensive energy consumption have been identified as key causes for the deteriorating performance of Europe's transport systems in the Common European Transport Policy.

Against this background, it is vital to stimulate policies – based on a developed useful planning method – that can support sustainable urban development without sacrificing either economic growth or the freedom of movement. Sustainable urban policies have to be based on a comprehensive plan and have to involve different sectors and fields of competence, among which spatial planning, regional and industrial policy, public transport policy and policies concerning individual motorised transport. Especially in metropolitan areas, restrictions on car use and parking in city centres, road pricing and improvement of public transport are relevant measures.

The urban transportation pricing, the mobility management and the behavioural change of drivers in favour of public transport are key determinants for the improvement of the living conditions in urban areas and the reduction of traditional problems of these areas such as congestion, pollution, accidents, noise, etc.

To effectuate a uniform, consistent methodology for urban planning – taking into consideration the viewpoints of the land use and the transportation – we need to approach to the subject with considering complex social and economic aspects. To develop a flexible, consistent, and well handleable model, – based on the existing models of urban planning – we shall emphasize the main advantages of the hereinafter given models.

It is important to see that the nowadays applied planning methods generally focus on estimating and comparing the effects of one or two selected measures (e.g. infrastructure investments, land-use or fee-collection possibilities). In contrast to the above mentioned process the assignment of the best solution from a given set of measures seems to be more effective.

Based on this assumption we investigated the development of the optimising methods, because in this way we can extend the method not just to describe individual system components' (e.g. consumers, firms) behaviour but to estimate and compare the social effects of the changed urban environment (based on the investigated set of measures) and to define the optimal solution from a social point of view.

Hereby we will have the possibility to control the urban environment based on the available set of measures (as a part of the controlling method), the object of the individual system components (energy consumption, costs, benefits – as a part of the modelling method) and the selected social objectives (e.g. operational efficiency, summed up social costs, summed up social benefits, pollution – as a part of the controlling method).

We mention here that the controlling criteria's weight usually depends on the spatial, social and cultural environment of the actually investigated urban area; hence in fact the applicability of such a set of weights seems to be relative. Besides, based on the directives of the European Union in reference with the sustainable development we define a possible hierarchic structure of such a set of weights.

2 Dynamic model

The models used at present are static, and are able to define the optimum just to estimate the system equilibrium partly or generally (based on the behaviours of the actors).

If we analyse the operation of an urban area in a time period with a simpler model, perhaps we won't be able to get as exact estimation as with a complex one, but we can investigate the process dynamically (see on Fig. 1), so it can be also calibrated according to the changing parameters of the process (beside it can be also calibrated according to the measured static data).

Another very important part of the dynamically analysed urban process, that after defining the static optimum of the system in one moment we can decide whether it is necessary to influence the process. After evaluating the static situation we can choose the adequate regulation type of the available strategic tools. To build the dynamic model we need to define the structure of the static model which can provide the input data of the dynamic optimization method.

The commute process can be regulated by the short term tools (eg.: traffic control system). Based on the latest scientific results it seems to be possible to consider more and more objects to improve economic-efficiency during the planning and controlling period as well (for example the methodology newly developed by Dr. Tamás Péter applying new approach to describe and control on range large networks using the Ljapunov function method on positive nonlinear systems [11]). The choice of the object of the transport (place motivation) is defined as a medium-term process because it depends on medium-term or longer-term variables (based on habit of the population, eg. change of the chosen recreation area influences the short term decisions as the choice of the commute-route, and depends on the long-term decisions, as choice of residence area). These choices usually can be influenced by the tools of mobility management (eg. education – choice of the closer, but less attractive recreation centre). If we assume that we can estimate the new system states resulted by the system components' choices, we can assume that we can influence the choices according to the objectives. Our objectives can be described with the criteria of the optimization. We can see on Fig. 1 a possible structure of sets of the optimization criteria, whose components can be worked out detailed (e.g. economic effectiveness can contain energy consumption, operation costs – all summed up in reference with the investigated urban system; social justice can contain social costs, pollution – all summed up in reference with the investigated urban system; technical feasibility can contain the technical standards and parameters required by regulations in reference with the given measure e.g. the relation of the maximum speed value and the geometry referring to motorways; environmental effects can contain those influences, which have no direct effects neither on the sociality nor the individuals of the urban area, but have serious effect on the urban environment – e.g. inflection of the landscape).

On Fig. 2 we can see as well, that the above described optimization criteria provide inputs for the controlling processes (traffic, mobility demand and land use controlling). Hence we have to build up our model that it would be able to serve the regulation levels inputs according to criteria with the outputs of the inward decision making processes (commute, transport, place of production and residences). That means, dimension of the optimization criteria and the output function of the inward decision making processes shall be the same (e.g. according to Fig. 2 the given transport network effects the choices – choices result a new system state – from the new system state we can move our system closer to the optimum with a selected measure, e.g. with an infrastructure investment included by land use regulations, which effects the transport system).

The long-term urban process includes the long-term decision process of the firms and the population as well (eg. choice of producing and residential area can be effected by the land-use regulations).

Here we can consider the product distribution process of the firms, as beside labour market, productivity, spatial and network properties; decisions in reference with choosing the place of production are effected by the current production places of the other firms (the static model should be based on general equilibrium models – e.g. firms' and inhabitants' decision making processes, or social equilibrium can be handled by recreation activities; see more detailed by Anas A. and Ikki Kim, 1996 [2]).

To build the described model we have to define the differing term intervals and the expected effects of the regulations (eg. on traffic, on social cost, etc.).

Above we have already mentioned that because of cultural, geographical and economic differences it is difficult to grade the sets of optimization criteria. Although considering the given national and EU directives we can assume that it is possible to define weights or a kind of hierarchy in order of the weights (e.g.

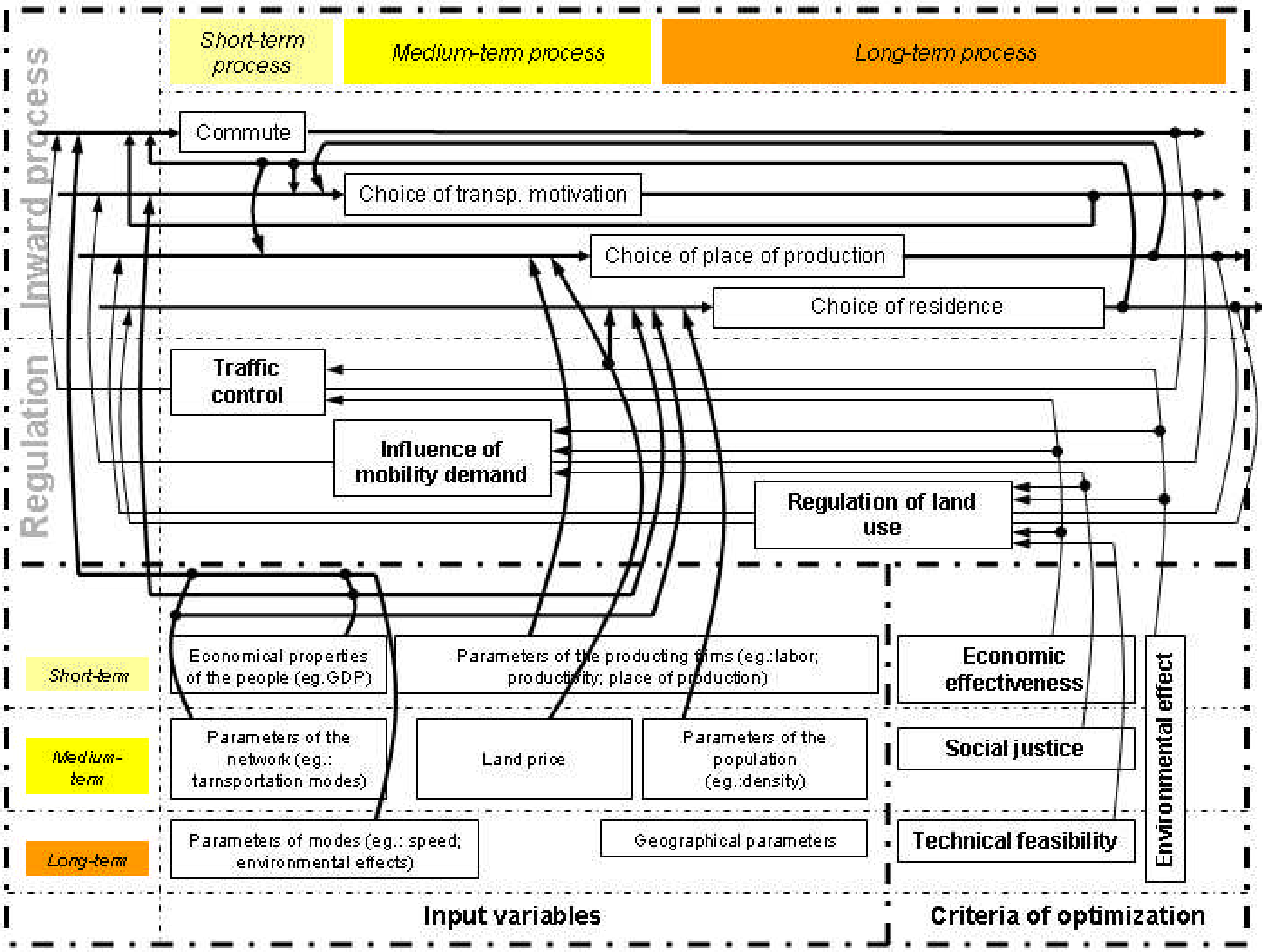

Fig. 1. Dynamic model for the regulation of the urban environment

1. technical feasibility, 2. economic effectiveness, 3. social justice, 4. environmental effect), but it is more likely to be defined as interval thresholds, which can not be crossed by the output function of the inward processes during the estimation and the controlling process. Here should be mentioned that when criteria are not marked out, then the model more resembles a region development rather than just a transport system model.

3 The controlling method

The above described controlling method should involve several different object functions, which must be considered together to find the most useful solutions from the point of view of the urban environment. The groups of optimizing criteria include the object functions which should be taken into account. The different interests of investigated social-economical urban system can be covered with high efficiency based on the external cost functions described by K. Tánczos and Z. Bokor in Közlekedéstudományi Szemle, 2003 [6]:

Economic effectiveness:

1 Cost of infrastructure

2 Cost of transport service

Social justice:

3 Cost of the users

Environmental effects

1 Cost of accidents

2 Cost of pollution

3 Cost of noise

Where the economic effects consider the basic monetary effects, the social justice should focus on the expenditures caused by the transportation system of the different user levels considering the cost of available transport modes, the environmental effects should take into account the hardly monetizeable environment depleting impact of transportation.

The problem of the control system based on the above mentioned components is that it is not possible to define the importance of the effects. In those case, where neither a hierarchic nor a preference based control system can be used the usage of a fuzzy control is suggested.

The fuzzy control systems' flexible properties seem to be quite advantageous in strategic decision making planning methods. A possible way of the realization of the above described

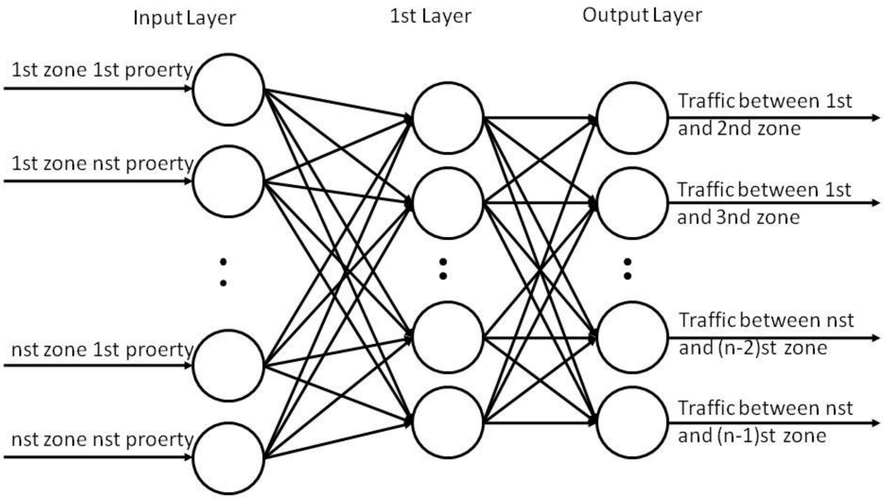

Fig. 2. A possible neural network structure to estimate mobility demands

controlling task to order a utility function (a kind of membership function describing the satisfaction caused by the changing of investigated criteria function). Then the object of the controlling method is to maximize the summarized social satisfaction of the urban system as it is suggested in the paper of Transportation research board of the national academies [5].

4 The estimation method

Nowadays it is used to apply the general equilibrium economical methods [1] to model such a complex economical systems. In our case it is quite difficult because the available sets of the statistical data are really narrow in the point of the described time interval. Since it would be fairly uncertain to determine the coherency levels based on such a short available time interval, the usage of neural networks developed to statistical estimation in reference with urban time series seems to be beneficial.

Since most of the criteria functions described in the previous chapter based on traffic level it is suggested to create a network structure, which has traffic level on its output. We can see on Fig. 2 a possible neural network structure zone property can be eg. population, number of employees, income levels, number of vehicles:

Our approach seems to be applicable, since another study by Abdulhai [10] used an advanced time delay neural network (TDNN) model, optimized using a genetic algorithm, for traffic flow prediction. The results of the study indicated that prediction errors were affected by the variables pertinent to traffic flow prediction such as spatial contribution [5].

5 The optimization method

The optimization method in a dynamic approach causes a hardly superable problem. The control process affects the estimation method, so the outputs of the system, hence the dynamic optimization cover an infinite set of solution in time. So the absolute enumeration seems to be impossible to realize.

In such cases where the number of variables, the complexity of the objective functions and the sets of criteria make the analytical and some of the numerical optimization methods too difficult, the genetic algorithm can be used with good result.

Although the mentioned dynamic optimization problem was not tried to be solved with genetic algorithms until this time there are several good examples of the usage of genetic algorithm in similar transportation problems:

1 Kruchten (2006) used genetic algorithms to estimate appropriate parameters so that within household interactions were incorporated in the mode choice phase [7].

2 Cevallos and Zhao (2006) used a genetic algorithm to minimize transfer times in public transit networks [8].

3 Jeon (2006) used a special genetic algorithm to ease the computational complexity of the discrete network design problem [9].

6 Conclusion

Although we plan to continue the research of the described method's numerical validation there can be defined undeniable further advantages. Although the dynamic models are much more complex than the static models even so the following properties can prove us the reason, how the temporal modelling ensures a higher reliability level of estimation [3].

1 Beyond the static relations (e.g. counted traffic – estimated traffic) it is possible to consider temporal trends (e.g. verifiable trends of traffic's temporal changing).

2 It results more possibility to detect bottlenecks (more detailed temporal analysis let us identify peak times).

3 The regularities of the temporal changing of the urban environment let us control the process, which controllable process can be ordered toward an optimum state according to the socially accepted aspects.

Concluding the paper, the efficiency of urban transportation is getting more and more important because of the increasing rate of mobility demand. To plan, control and organize urban transportation in the most efficient way, we also need to consider the aspects of land use. To handle both of the mentioned urban planning areas together, we shall develop models, which are able to pay attention to all of their restrictive factors within the temporal properties as well.

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