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Urbanistic aspects in transport modelling: A study of contemporary approaches

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Abstract

Transport modelling has always been closely intertwined with psychology. Even Wardrop's principles have psychological and social elements in their respective interpretations, although they unseemly expect the user to have a perfect rationality rather than a bounded one. It may be the case that this tradition of transport modelling and psychology could be expanded and more closely related to urbanism. Especially in the effort today to rationalise urban mobility and create more compact and functionally balanced cities, urbanistic modification of transport modelling could potentially be a powerful tool for city planners. This study aims to explore contemporary approaches that try to tie modelling to urbanism and to describe the effects of these attempts.
KEY WORDS: *transport modelling, urbanism, urban areas, sustainable urban mobility plans; space syntax; road hierarchization*

1. Introduction

The authors of this paper published an article [1] in which they argued that the road hierarchization process may have significant links to the field of urbanism. Namely, they proposed a new method of road hierarchization that is based on a conflict between the so-called urbanistic and transport-engineering aspects of roads in urban areas. This idea originates from the assumption that transport infrastructure is not only describable from the point of view of transport itself but is also describable as an infrastructure that forms a substantial part of the public space in urban areas and therefore has urbanistic properties. This road duality enables for a more nuanced hierarchization process and a more precise road importance assessment and description of a network.

To help the planning and development process of a city, a variety of simulation and modelling tools may be used. These can optimise and verify the proposed designs in terms of traffic flow and road user behaviour. However, in conjunction with the previous paragraph, traffic models should be expanded by the urbanistic aspects mentioned. This paper focusses on modelling approaches that try to incorporate urbanistic aspects and debates their theoretical applicability. The state of the art section of this paper debates different approaches and methods that have urbanistic overlap. In Section 3, the authors of the paper focus on the space syntax method and its relation to the road hierarchization process. In Section 4, transport modelling is linked to spatial planning and sustainable urban mobility plans (SUMP), and positive as well as negative effects are debated. The last section is reserved for discussion and conclusions.

2. State of the art

The state of the art chapter deals with the definition of current transport modelling approaches that apply in their methods urbanistic aspects. The listed approaches form the basis for the following sections, and both qualitative and quantitative aspects are considered. Simulations and models based on both microscopic and macroscopic methods are taken into account.

A paper by Bernice Liu et al. [2] delves into the usage of simulation methods with a connection to tactical urbanism. The authors of the article utilise the PTV VISSIM software to describe and model the street network of the San Jose downtown area. The calibrated and validated model was applied to evaluate two groups of simulation scenarios. In the first group, one of the main streets was converted from one-way street to two-way street and two variants of base-level automobile travel demand (no change and 5 % increase) were applied. The second group of simulation scenarios considered no change in traffic organization on the main street and three variants of travel demand reduction (30 %, 20 %, 10 %) – this set of scenarios was based on the "stay-at-home" order during the COVID-19 pandemic and is used to test similar situations. The authors then compared the effects of the different scenarios on speeds, travel time, network effectiveness measures (number of vehicles, total travel time, total distance, total delay), and traffic volume. These characteristics were then used to justify the road diet and other measures, such as the use of tactical urbanism to redesign parts of the street. The authors introduced a relatively lightweight method that integrates the fields of transport and urbanism.

An urbanistic aspect can also be seen in approaches that model pedestrian-vehicle mixed traffic flows. For example, a paper by Wang et al. [3] explores a cellular automata approach to simulate pedestrian-vehicle interactions.

The authors of the article simulated and analysed the behaviour of pedestrians and drivers under different circumstances (different speed limits and sidewalk widths). Cellular automata models have a tradition in the field of transport; studies [4], [5], and [6] can be mentioned as an example; however, they are not as often used regarding street design and street profile structure. A different approach to pedestrian-vehicle mixed traffic flow was presented in a paper by Bani et al. [7]. The authors of the study introduced a simulation approach based on a modified social force model. This simulation tool is designed to simulate pedestrian and vehicle trajectories and their interactions in shared spaces. The tool is expected to be used to optimise and verify shared space design prior to implementation. Other studies were conducted on pedestrian-vehicle mixed traffic flows, for example, paper by Laxman et al. [8] or the study [9] on simulation of the interaction between pedestrians and road vehicles at public transport nodes (mainly terminals and interchange stops), in which the first author of this article participated.

The substantial part of transport-urbanistic approaches consists of the application of the theory of natural movement postulated by Hillier et al. [10] and associated space syntax configurational analysis. As an example of more recent contributions, research by Koohsari et al. [11, 12], Lerman et al. [13], and Foltête and Piombini [14] can be mentioned. These deal mainly with pedestrians and active mobility; however, the urbanistic overlap of this approach is undeniable. There could be great benefit in combining space syntax methods with more traditional transport-oriented approaches, especially regarding street design. The next section of this paper focusses on space syntax and its potential role in the road hierarchization process.

3. Space syntax and road hierarchization

The authors of the paper proposed in their previous article [1] a new method to hierarchise a street network. The basic idea behind the new method is briefly described in the introduction section of the paper. Some other principles of this new method will be quickly recapitulated here.

The proposed method differentiates between the transport-engineering and urbanistic aspects of roads in urban areas and allows their separate expression. This is done through the index of transport-engineering importance and the index of urbanistic importance. These indices consist of individual subindices that reflect different properties of individual parts of a street network. For example, the index of transport-engineering importance is the sum of the subindex of road class, the subindex of road significance, the subindex of current/prospective intensity, and the subindex of the importance of the mobility function. On the other hand, the index of urbanistic importance is the sum of all existing functions listed in Table 1 [1]. These functions consider the conflict between different modes of transport and reflect functions of a city (residential function, civil amenities, tourist and recreational targets, etc.). The authors argue that the consideration of the urbanistic aspect is essential for a holistic assessment of a street network and its effective operation.

Table 1

Function conflict and index values according to the proposed method

Urbanistic function type	Index [-]		
Transport function with parameter of motor transport	FD_{IAD}	1	Or 0 in the case of non-existent function
Transport function with parameter of public transport	FD_{HD}	1,15-1,3	
Transport function with parameter of bicycle and pedestrian transport	$FD_{C/P}$	1,15-1,3	
Transport and access function towards industrial facilities	FP	1,1	
Residential function	FO	1,2-1,3	
Transport and access function towards civil amenity facilities	FOV	1-1,2	
Transport and access function towards recreational and tourist targets	FR	1,2	

The urbanistic aspect and qualities of a street network and individual streets can be associated with walkability and general accessibility for active mobility. Koohsari et al. [11] used the space syntax method to create a space syntax walkability. Full walkability is based on the principles of 3Ds (density, diversity, and design), more specifically, on net residential density, land use mix, intersection density, and net retail area ratio. The space syntax walkability consists only of gross population density and integration, one of the key space syntax measures used to specify the number of segment transitions needed to reach other street segments from a given street segment. Highly integrated streets are more easily accessible and theoretically have a higher probability of being used by pedestrians. However, there is also an argument that highly integrated streets are central for commercial use (and other amenities) and therefore attract more pedestrians (they function as attraction multipliers) [10]. It can be argued that highly integrated streets represent the local and trans-local urban axis. Such an argumentation can be used to connect space syntax and highly integrated streets to the index of urbanistic importance mentioned above.

The appropriately modified space syntax method could be used to improve the road hierarchization process based on the urbanistic aspect, as the space syntax to some extent reflects the urban form and can be used to calculate some form of index of walkability. The index of walkability could be used as an input to assess individual streets in terms of their urbanistic importance in the entire street network of a given city. The notion that the spatial configuration of the urban grid is the main cause of movement rather than the built attractors is of substantial significance for the index of urban importance and the associated road hierarchization process. This creates an important push toward a more conceptualised perception of roads in urban areas, which should not only be considered in terms of their transport function but also be hierarchised and modelled according to their urban importance. Through links between the space syntax method, the urbanistic importance of roads, and the idea of walking as a primary mode of transport in urban areas, a more holistic and accurate description of the road network may be achieved.

The space syntax method breaks down streets into axial lines, straight sightlines and directly accessible paths. This can lead to a gap between the perception of the street by pedestrians and its representation on an axial map. The discrepancy is obvious in geometrically non-regular grids – curved streets with pronounced shape function as one street but are represented by several axial lines. Using space syntax with the index of urban importance could potentially function as a kind of control mechanism. For example, in Fig. 1 is a map of the urbanistic importance of roads in the Czech city Poděbrady. The streets of the city were indexed according to the proposed method [1] and divided into four groups according to their urban importance. However, some of the roads with the highest index of urban importance have an irregular curvy shape, yet they are important for pedestrian traffic. Breaking down these streets into several segments limits their association with urban importance. However, linking urban importance and space syntax may lead to a more holistic view of the network and to mitigation of some shortcomings.

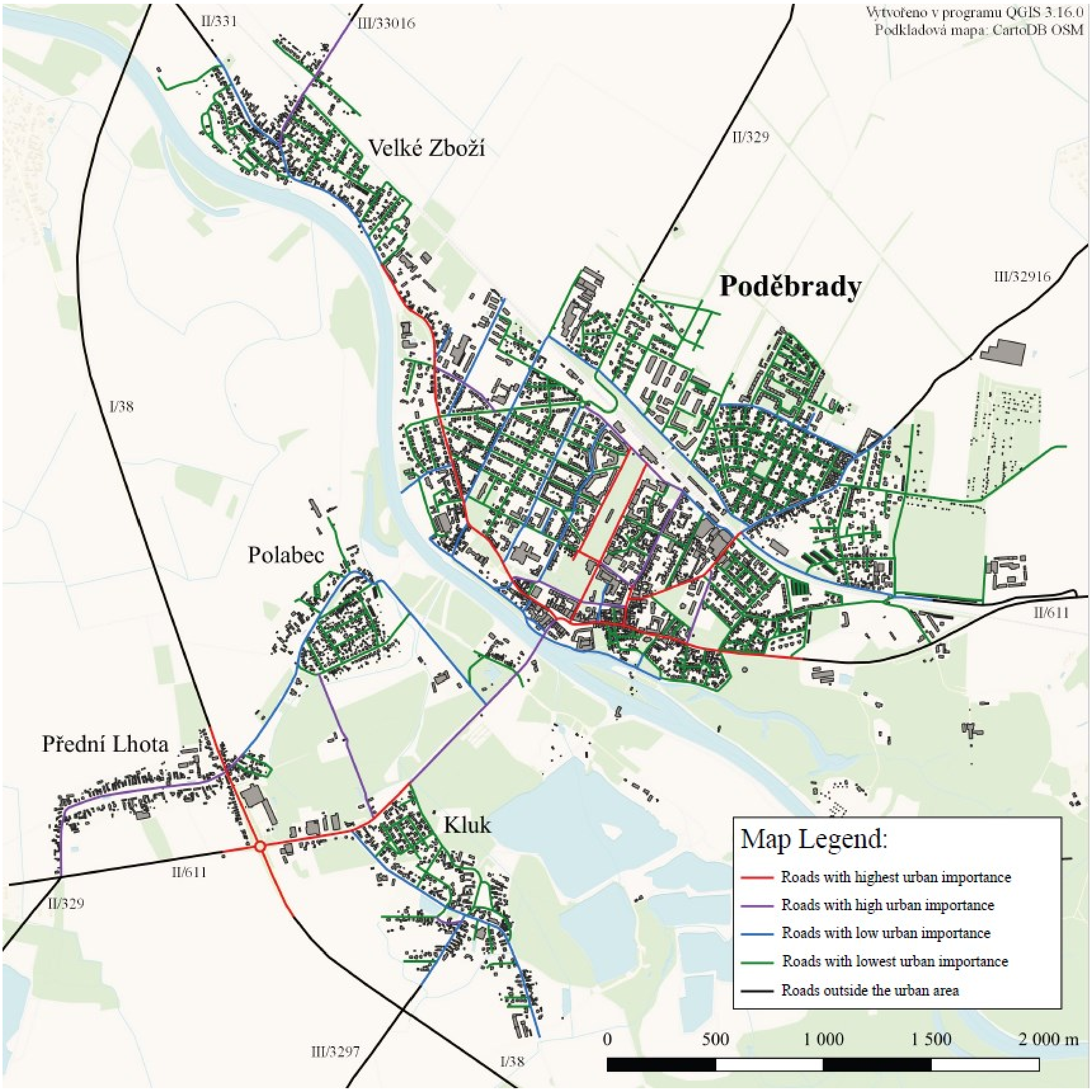

Fig. 1 Map of the urbanistic importance of the roads in the city of Poděbrady

4. Transport modelling, spatial planning and sustainable urban mobility plans

Traffic planning can be divided into three levels:

1. Planning of transport infrastructure – spatial planning, traffic master plans, traffic studies…
2. Planning of transport systems – primary and secondary accessibility by public and personal traffic
3. Planning of mobility – SUMPs (also traffic master plans and studies)

Transport modelling may occur at all these three levels with both positive and negative effects.

Spatial plan is a legally binding document that defines policies and rules for the planning and development of the area. Its main objective is to organise and manage the use of land, the construction of infrastructure, and development of zones, considering the needs and sustainability of the area. It is mainly an urban planning document. Transport planning appears in spatial plans rather secondarily. The results of transport modelling can therefore be reflected in the zoning process (zones can be residential, commercial, industrial, recreational, etc.) and consequently in the transport infrastructure layout. The resulting effect may also be reflected in the street profile structure.

Traffic master plans and studies focus on the analysis and assessment of traffic needs and problems in a specific area. They may focus on a particular mode or selected modes of transport. They propose more specific measures to improve the traffic situation or to fulfil other stated objectives (in contrast to spatial plans). Measures may aim to modify both transport infrastructure and promote specific modes of transport within the framework of urban mobility (for example, to facilitate modal shift). Traffic master plans use the results of transport models as a basis for strategic transport planning in a defined area, in particular to support decision-making on specific transport infrastructure and investment plans.

The SUMP is a strategic document that addresses the mobility needs of people and businesses in and around cities to improve quality of life. The results obtained from the transport modelling are crucial for the development of the SUMP. Both in analysing the current state and predicting the future state, and in proposing strategic objectives, future scenarios, strategies, and measures to achieve the set objectives. Traffic models are important in the analysis to understand the urban traffic situation and to identify traffic problems (causes and consequences) faced by the city. In the context of planning long-term strategies and measures, they allow modelling of traffic situations (including traffic behaviour) in the future. Traffic models can be used to assess the effectiveness and impacts of different measures by simulating the traffic situation during various scenarios.

As can be seen in the text above, transport models can be a supportive tool for urban planning; they are only mandatory in the Czech Republic as part of urban mobility planning, i.e. SUMPs.

Properly set up transport models will help in identifying deficiencies in the transport system, assessing traffic demand, predicting traffic development, and testing different transport planning scenarios. The results can then be used to design measures and strategies for transport infrastructure and car, public, cycling, and walking transport. These measures and strategies can be used in the planning process, both in the development of spatial plans and in SUMPs.

A positive aspect of transport models is that they can consider traffic behaviour. Therefore, if a city has carried out a traffic behaviour survey, it can better set the parameters of the traffic model and better predict future traffic behaviour. Most cities in the Czech Republic conduct a traffic behaviour survey as part of the analysis in the development of SUMP.

The consideration of traffic behaviour is particularly important in the validation and calibration of the model. Evaluating the model outputs against real data and traffic behaviour increases the accuracy and relevance of the model. This will make the outputs of the traffic model more relevant to the needs and preferences of the population.

It is important to recognise that transport models can also have a negative impact on spatial planning, especially if they are not properly set, interpreted or do not adequately take into account the entire planning context and the mobility needs of the population.

Transport models can be complex and technically challenging tools that require expertise and resources to use and interpret them correctly. Because of this complexity, cities often have them developed by an outside firm. Problems then arise in their subsequent use in transport planning, especially in smaller municipalities or cities with limited resources. Yet the correct use and interpretation of transport models results is crucial for urban planning and development. Incorrect interpretation of the results can lead to an inaccurate picture of the actual traffic situation. The consequences may then be the application of incorrect, inappropriate measures (overestimation or underestimation of the need for transport infrastructure, underestimation of the effectiveness of measures, etc.), inefficient investments, and ultimately negative impact on the environment.

Transport models are based on input data such as traffic demand, network infrastructure, demographic information, etc. The limited availability or accuracy of these data can affect the reliability and precision of the transport models. Transport models are often simplified by focussing primarily on car traffic and suppressing other modes of transport. When used in the planning process, this can lead to underestimation, and thus insufficient consideration of other modes of transport, especially cycling and walking, in spatial planning, e.g., planning for accessibility of the area or transport infrastructure (capacity and quality).

Transport models are based on static analyses and on the assumption that the condition will remain stable or evolve according to predetermined scenarios. The models operate with a degree of rationality in traffic behaviour, and thus may struggle to capture changes in traffic behaviour due to unforeseen events (e.g., COVID pandemic, financial crisis, changes in public policy, etc.).

Transport models often focus only on quantitative aspects of traffic (routing and volume of traffic flows) without sufficient consideration of social aspects. These are important not only for sustainability, but also for the measures proposed (different social groups may have different needs) and their subsequent adoption. It should also be recognised that transport also affects social interactions (meeting opportunities, accessibility to destinations, and services).

Incorrect interpretation of the results of transport modelling can manifest itself in the structure of the transport network and its dimensions (it can lead to dispersion of urban space – suburbanisation and thus to an inappropriate distributed modal split), in the assignment of functions and structure of urban roads (allocation of space to individual modes of transport), in consideration of needs of active mobility (inappropriate routing, inappropriate type of measures). It can ultimately affect the 'life' of a city, affecting the overall quality of urban space. Inappropriate transport infrastructure can fragment urban space and separate parts of the city from each other. This can have a negative impact on mobility, fluidity of movement, but also on social interaction and social accessibility.

As can be seen in the previous text, it is important to recognise the limits and challenges of using transport models in spatial planning and transport planning. In order to get the maximum benefit from their use in planning, transport models should be used as decision support tools, but should not be the only source of information in the development of plans and strategies. The results obtained from transport modelling must be combined with other relevant tools and sources of information, interpreted with expert judgment, and compared with the data obtained from communication with stakeholders and the public.

5. Discussion and Conclusions

As can be seen in Sections 3 and 4, there is a connection between transport modelling and urbanism. However, municipalities (at least in the Czech Republic) usually do not have the necessary resources and know how to fully utilise transport modelling tools. This can lead to a misinterpretation of the outputs of transport modelling and to the adoption of inappropriate measures. Some of these problems can be alleviated by using easy-to-use support tools that are applied alongside the transport modelling tools. The appropriate setting of the road hierarchization process can be one of these supporting tools. However, it is important to acknowledge that the hierarchization process must be holistic and address not only the transport function of urban roads, but also their urbanistic function. Using the space syntax method to further support the hierarchization process and transport modelling tools may be a way to improve the current approach of municipalities to the outputs of transport modelling. On the other hand, linking space syntax to more traditional transport modelling approaches may be beneficial in terms of a more complex and holistic view of the transport network and traffic behaviour. This should be a matter of follow-up research.

The authors of the paper would like to focus on the interactions between road hierarchy, urbanism, and space syntax and further explore this topic. Finding links between these could be potentially beneficial in supporting transport modelling efforts, and creating more conceptualised tools for city development is consistent with current urbanistic, environmental and traffic goals.

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