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RESEARCHING THE RELATIONSHIP BETWEEN BUILT ENVIRONMENT AND TRANSPORT: THEORY, METHODOLOGY, AND SPECIFICS FOR THE CZECH CONTEXT

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ABSTRACT: The paper provides a theoretical framework and methodological overview for follow-up research on the relationship between the built environment and transport behaviour in the Czech context. Divided into four parts, the paper begins by describing the urgent need for such research. The second part reviews fundamental transport modelling methods commonly used in research on the relationship between the built environment and transport. The methodical concept of Activity-Based Modelling (ABM) is selected for further elaboration through a comprehensive diagram. Individual parts of the diagram are grouped and described. In the third part of the paper, the ABM concept is derived into a quantitative methodology suitable for qualitative research on the built environment and transport. Typical dependent and independent variables are listed. Finally, the fourth part of the paper discusses ABM method limits and requirements in the Czech context.

KEY WORDS: Built environment, transport, theory, framework, activity-based modelling, Czech Republic

Introduction

Despite extensive global academic research on the built environment and transport relationship (Ewing and Cervero, 2010; Hickman et al., 2015; Næss, 2016), only marginal attention is paid to this topic by Czech scholars. There are works focused on issues of transport sociology (Braun Kohlová, 2012; Burian et al., 2018; Kunc et al., 2012), regional transport studies (Hampl and Müller, 2011; Kraft and Marada, 2017; Šťastná and Vaishar, 2017), new infrastructure assessments (Chmelík and Marada, 2014; Maier and Franke, 2019) and time-space geography (Mulíček and Osman, 2011; Nemeškal, Ouředníček and Pospíšilová, 2020); however, none of the listed works primarily focus on the relationship between the built environment and transport. Hence, there is an urgent need for such research in diverse national and regional backgrounds (Ryghaug et al., 2023). Such research should 1) identify the possibilities of urban design in reducing well-documented car dependency negative impacts (Boer, 2013; Currie and Stanley, 2008; Eigenbrod et al., 2011; UNEP, 2014) and 2) empirically evaluate new ambitious urban and planning concepts (Katz and Scully, 1996; Pozoukidou and Chatziyiannaki, 2021; The Urban Task Force, 1999). This paper provides a theoretical overview for following up research filling the gap on the relationship between built environment and transport in the Czech Republic. The paper is divided into three parts. The first part introduces fundamental theories; based on these theories, Activity-based Modelling (ABM) is introduced and described as an effective tool for research on the built environment and transport. The second part of the paper shows the methodology of ABM application to urban research, discussing variables representing the built environment. The last part is dedicated to the Czech context‘s requirements, limitations, and specifics.

Built Environment – Transport Relation Theory

Studying the relationship between built environment and transport, there are two vantage points – "Transport as a law of science" and "Transport as a consequence of individual behaviour". Each attitude consists of theories and concepts created in different eras and for different purposes. Mutual misuse is often the cause of misleading and biased results[1] (Mees, 2010). Thus, both attitudes are briefly depicted and compared:

Transport As a Law of Science

The law of science predicts a range of natural phenomena[2] (Oxford Dictionary of English, 2010). Applied to transport, a new housing estate generates exactly 123 more cars, thus the need for increasing the road infrastructure capacity to accommodate 123 more cars. The derived modelling concept is called the Four-step Model, developed during the 50s to predict future transport infrastructure demand (Mees, 2000). The main issue of the Four-step Model is zonal aggregation; a city is divided into zones with its transport demands (residents moving to work, shopping, etc.). The goal is to saturate transport demand with transport supply (roads, public transport, etc.). Although this attitude is efficient in transport planning and has undergone massive improvement, there are two significant lacks in the case of the research into the built environment and transport. First, the approach works with zones – any specific urban or socio-economic characteristics of neighbourhoods are marginal (Ortúzar and Willumsen, 2011). Secondly, the approach works solely by extrapolating current trends; therefore, any future trend prediction or testing is irrelevant (Ortúzar and Willumsen, 2011).

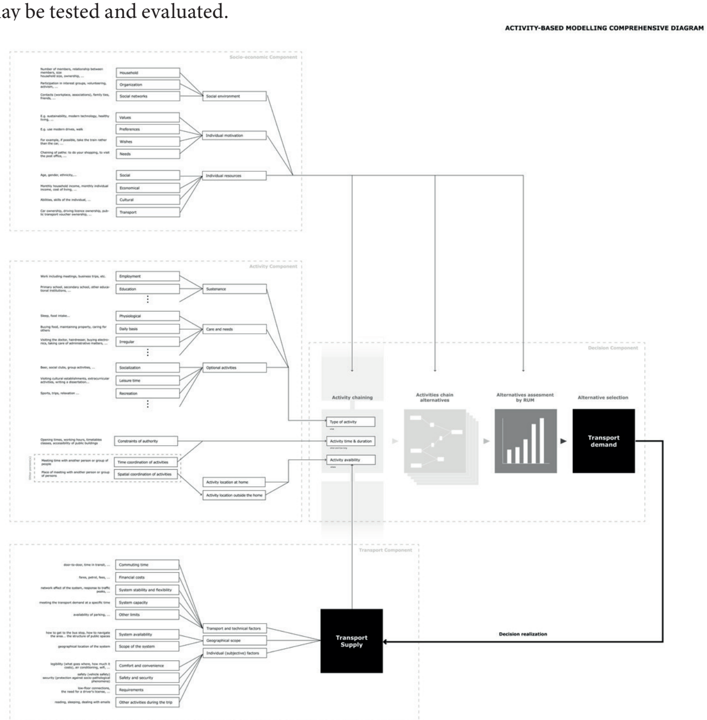
Transport As a Consequence of Individual Behaviour

This attitude stems from Hägerstrand's time-space geography (Hägerstrand, 1970, 1982). The crucial difference to the previous attitude is that the key element is an individual, not the zone of a city. The key element is a person who wants to participate in various activities spread in space and time. However, achieving activities is constrained by personal abilities (ability to walk or drive), institutional regulations (opening times, school schedules) and coordination with others (meeting other people). Combining personal plans, abilities, and constraints creates "space-time prisms". Space-time attitude emphasises individual characteristics with built environment characteristics. Thus, such an attitude is more appropriate for investigation on the relationship between built environment and transport. Simultaneously, more abstract and qualitatively oriented theories emerge, such as rhythm analysis (Lefebvre, 2007), working with rhythms as an abstract repetition time beyond its Euclidian conception (Pospíšilová, 2012b). Later, all time-space and rhythm theories based on the structuration theory (Giddens, 1984) were criticised by phenomenological geographers. The key points of the critique are i) neglecting the individual relationship with place and ii) ignoring necessary activities to achieve movement (Pospíšilová, 2012a, 2012b). However, such a discussion is out of the empirical quantitative scope of this paper.

Activity-based Modelling (ABM)

Combining the econometric background of Four-step Modelling with the individualistic orientation of space-time geographies, a novel modelling technique is established – Activity-based Modelling (ABM) (Ortúzar and Willumsen, 2011). ABM applies standard demand and supply relationships to individual choices. Like time-space geography, ABM works with a person (agent) who is trying to participate in various activities spread in time and space. (Axhausen, 2008). Besides Hägerstrand's classical constraints, individual choices and preferences come into play. The whole model works with a synthetic population of agents, each having an individual preference trying to achieve places for his/her activities (spread in space and time) by transport. Each agent tries to maximise his/her utilities by participating in preferred activities at preferred times, using preferred transport means, lowering travel times, etc. Mutual agent interaction (e.g., traffic jams, full trams) is also considered and evaluated. The ultimate goal is to maximalise the sum of all agent utilities by numerous repeating agents' iterations (Braun Kohlová, 2012; Button, 2008).

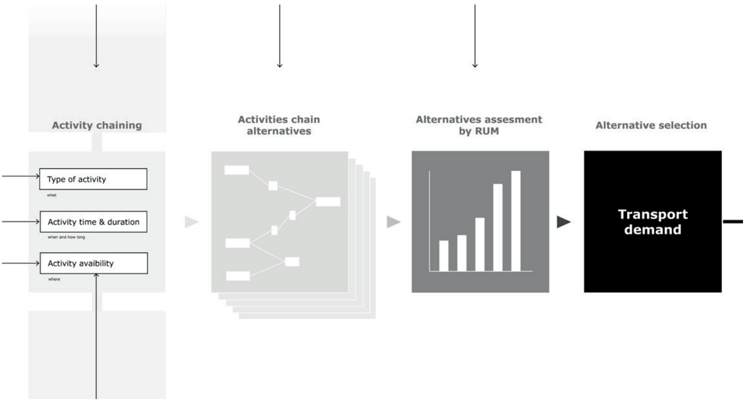
It is the distribution of activities and transport infrastructure that represents the built environment in the ABM. Any change to distribution of activities or transport infrastructure may (or may not) change the transport behaviour of each agent (e.g., change from car to public transport, lowering travelled distances, etc.). Such change could be quantified and compared (Kagho, Balac and Axhausen, 2020). Thus, the ABM brings a new toolkit for urban research due to its detailed focus on the built environment and socio-economic characteristics of agents. New urban concepts, policies, and scenarios may be tested and evaluated.



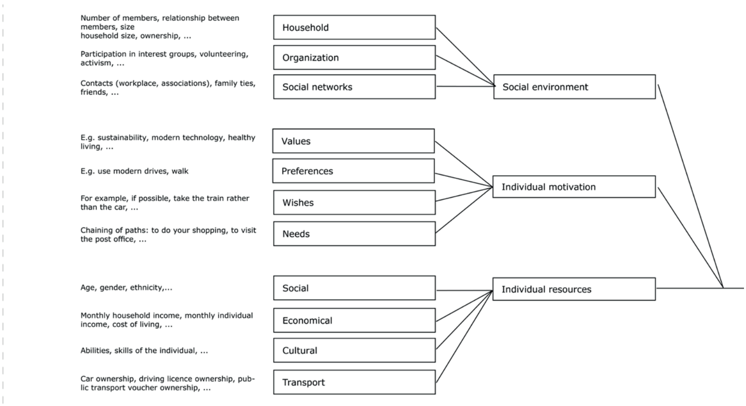
Picture 1

The whole ABM is depicted by a comprehensive diagram in picture 1 based on the Næss framework (Næss, 2016). The diagram consists of four components: decision component, socioeconomic component, activity component, and transport component. Each component is zoomed in and described in the following paragraphs.

The key to the ABM is the balance between transport demand and transport supply. Each agent journey loads the current transport supply and vice versa. To achieve transport demand, three phases are regarded in the first component (see picture 2 – decision component). At the start, each agent‘s activity is characterised by its type, time, duration and availability (e.g. work from 9 to 5 at Thakurova 9, commuting by tram). The day of an agent typically consists of several activities. Such activities are chained in phase two. Activities may be chained in numerous combinations (jogging-work-shop--pub / work-jogging-shop-pub / work-shop-jogging-pub, etc.). In phase three, the agent assesses his/her utilities of each combination. The final decision is made, and transport demand is generated.



Picture 2

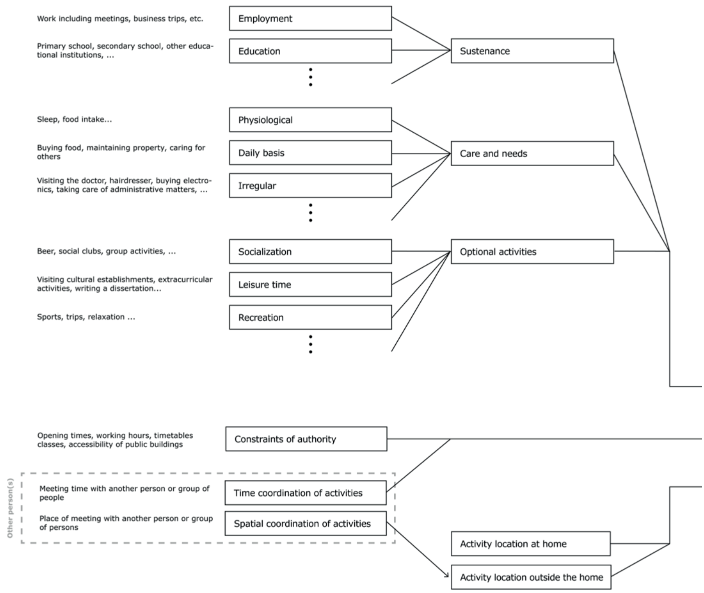


Picture 3

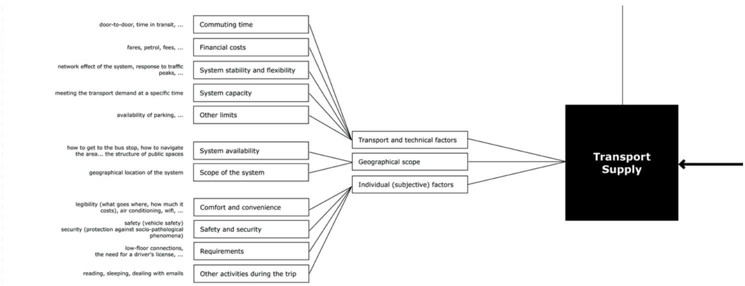
Although the ABM focal point is in the agent‘s travel behaviour (generating transport demand), three more components directly influence his/her decision.

1) First of all, the agents‘ socioeconomic background is reflected (see picture 3 – socio-

economical component). Typically, personal values and preferences (car vs. bike, active lifestyle vs. comfort, etc.), demographic characteristics (age, gender, etc.), individual resources and skills (ability to drive, public transport pass ownership). All these factors influence not only the type of activities to participate in but also their chaining and later assessment (Headicar, 2015; Næss et al., 2018).



Picture 4



Picture 5

2) The next component determines the form of each activity (see picture 4 – activity component). According to (Ortúzar and Willumsen, 2011), each activity type could be categorised into three groups: sustenance (job, education, etc.), care and needs (sleep, food, etc.), and optional (socialisation, sports, etc.). Almost every activity is constrained

by time (start and duration) and often by coordination with another agent. If the activity is not located at home, the location of the activity, in combination with transport supply (next component), creates activity availability (accessibility).

3) The last component is composed of elements determining transport supply (see picture 5 – transport component). The first fundamental factor is transport infrastructure geography (in simple words, where does each transport mode go). Secondly, there are transport infrastructure technical factors, such as transport mode journey time, cost, and system stability capacity. The last factors group is about individual (subjective) level, considering "soft" measures such as comfort and convenience, safety and security or special requirements (Hickman et al., 2015; HiTrans, 2005)

Each element in each component plays a vital role in the overall individual (agent) transport demand. The next chapter aims to describe the methodology investigating the influence of the built environment factors (activity location and geographical transport supply) on individual transport demand and, thus, transport behaviour.

ABM Applied to Built Environment and Transport Research

ABM is a fully developed modelling method dealing with various urban research questions. In Europe, one of the most influential research units working with ABM is the Urban Planning and Transportation research group at Eindhoven University of Technology (EUT) in the Netherlands. The pioneering works of Timmermans (and others) dealing with the ABM methods from the 90s (Oppewal, Louviere and Timmermans, 1994; Timmermans, Arentze and Joh, 2002) established a fundamental methodology framework for current urban and travel research. Nowadays, ABM is being applied to numerous topics, from the level of outdoor activities of older adults (Liu, Kemperman and Timmermans, 2021), dynamics in household car ownership (Gu *et al.*, 2021), impact of the street-scale built environment (Liu *et al.*, 2020), and elderly travel pattern scenarios (Arentze *et al.*, 2008) to wide population exposure to air pollution (Beckx *et al.*, 2009) or complex tasks such as the modelling of whole metropolitan areas (McNally and Rindt Craig, 2008).

However, its principle may also be utilised for less complex tasks – such as measuring the influence of the built environment on transport by statistical reasoning. In the case of the described diagram (pictures 1 to 5), the built environment is represented by activity location in the activity component (picture 4) and by the geography of transport systems in the transport component (picture 5). Transport is then covered by transport demand[3] in the diagram.

Density	Residential density Jobs density Commercial FAR
Diversity	Land-use Mix Jobs-residents ration Local amenities count
Design	Street intersections density Cul-de-sac density
Destination accessibility	Jobs within one mile Amenities within one mile
Distance to transit	Closest mass transit stop

Table 1 based on (Stoker, Petheram and Ewing, 2015)

The most popular method for the built environment and transport quantitative research is regression modelling – for linear prediction (such as total travelled distance), linear or generalised linear model (GML), and choice probability (such as travel mode choice) logistic regression. Regardless of regression type, all models stand in three variable groups – dependent (a.k.a. responding variable), independent (a.k.a. explanatory variable) and control variables (filtering out interference)[4].

Beginning with the dependent variable (transport demand), the value typically describes i) transport volume and ii) transport mode share. Transport volume is measured mainly by the total distance travelled per person per day and mode share by the total distance travelled by a person by one transport mode (primarily by car to distinguish between car-dependent and sustainable transport means).

Unlike the dependent variable (transport), defining the independent variable (built environment) is a more complex task. First of all, it is necessary to consider the research focus and scale[5]. Secondly, only uncorrelated, independent variables may be selected to represent researched components of the built environment. Since the built environment is a complex structure containing multiple levels, its reduction to a sole independent variable may result in misinterpretation of the results. Thus, the built environment is also included in an aggregated set of control variables, usually grouped into "5D" developed from the original "3D" (Cervero and Kockelman, 1997)

Other control variables are extracted from the rest of the diagram. These are mostly socio-economic variables such as gender, age, income, and household members (including children); less often, transport measures such as transport reliability, flexibility, security and comfort[6] (Næss, 2016).

The regression analysis works with two layers of data: travel survey and GIS analysis. The travel survey is used for extracting information about individuals (agents) with their travel behaviour and socio-economic characteristics. According to their activity location, a GIS analysis is conducted to extract built environment and travel infrastructure characteristics.

Regression modelling based on ABM is a commonly used method and can be found across European built environment and transport behaviour research works:

- Scandinavia (Cao, Næss and Wolday, 2019; Helminen *et al.*, 2012; Tiitu, 2018)
- Netherlands (Dieleman, Dijst and Burghouwt, 2002; Schwanen, Dieleman and Dijst, 2001)
- Denmark (Jensen, 2015; Næss and Jensen, 2004).

Discussion: ABM Limitations and the Czech context

ABM also shows its limits in the case of longitudinal implementation. On a global scale, the next built environment and transport research work will be focused on changes over time (Næss, 2022). Although some longitudinal ABM studies consider changes in built environment and transport over time, the methodological framework has not been fully developed to cope with challenges such as strong path dependencies (Oakil *et al.*, 2011). Overall, the Activity-Based Modeling (ABM) framework represents an innovative approach to investigating the relationship between built environment and transport in the Czech context. Compared to global research, the Czech research in this field is over a decade lagging and, thus, the generally discussed longitudinal limitation of ABM is not relevant at the moment.

Speaking about current problems in the Czech planning and research context, there are many issues which could be diminished by ABM. The issues are grouped into four fields and explained in the next paragraphs: general background, policy-making, planning practice and extended research.

First of all, general discourse regards transport as a solely technical field. In institutional structures, transport is mostly reduced to engineering disciplines fulfilling legislative requirements (road capacities, PT frequencies, noise limits, safety, etc.), mobility plans and strategies are designed by transport engineers (predicting static travel demand and designing infrastructures), and professional public discussion is focused on technical matters (building code standards, etc.). By spreading the ABM interdisciplinarity principles in general, links from transport to other branches may be drawn, such as sociology (travel behaviour, social exclusion), psychology (perceived accessibility), health care (civilisation diseases and transport connection), and, of course, sustainability (modal shift, theory of change – MLP (Geels, 2011)). Applying the ABM interdisciplinarity principles, municipal transport departments may share their concerns with others, mobility plans and strategies could be elaborated by multidisciplinary teams targeting broader goals, and public discussion shall contain questions from other fields.

Concerning the second group, there are several controversial transport policies and projects in Czech cities including congestion charges and car restrictions in city centres, parking fees and traffic regulations, and new transport projects (network of P+R in Prague's fringes, new metro and tram lines, new motorways, or modification of existing ones). All of these policies or projects are often decided by baseless intuition or rigid legislation (derived from an almost century-old transport attitude). If there are any empirical models, only obsolete transport-zoning methods are employed with limited applicability (such as infrastructure validation). By applying ABM, all of these policies and projects may be examined and tested in numerous variants and scenarios. For example, in the case of the congestion charge, predicting which citizens may be mostly discriminated against by the charge, testing effects of different charge levels, finding optimal locations for restrictive zones, etc. Moreover, all features could be observed over a long period with various outer influences (petrol price growth, socio-demographic change, etc.). At the end of the day, new policies or infrastructures may be well evaluated, and the final decision (by its nature always made by politicians) shall be evidence based.

The third group focuses on a specific field – Czech city planning. The current planning legislation considers transport a passive, singular layer of (often very extensive) physical infrastructures. Although land-use plans contain a distinctive transport section, the section mostly focuses on infrastructure capacities. Since ABM perceives transport as a product of the agents (people) trying to fulfil their activities in space and time, and since the activity distribution is directly influenced by urban design, a strong link between urban design (urban form) and transport behaviour may be drawn. Implementing this attitude to the current Czech zoning plans shall concern the urban form and structure as a critical determinant of transport behaviour. Although there are several other factors influencing transport demand, reflecting generated transport behaviour as an integral part of any urban design might impact the mitigation of various contemporary planning problems (e.g. suburbanisation, social exclusion, etc.). On the other hand, the change is feasible only by extensive legislative planning paradigm shift, which is, especially in the Czech system, strongly path-dependent.

Lastly, transport research itself is fragmented between institutions with a strictly defined research scope. Apart from the interdisciplinary framework of ABM, there is a potential to link various researches (such as economy or sociology) by ABM attitude. Thus, ABM may be extended into reality price modelling, customer behaviour, regional studies, etc.

All in all, there is a broad field of potential influence of ABM in the Czech context, from rather general, abstract impact on institutional structures and expert discourse to very concrete planning policies and design evaluation. Moreover, diverse research branches may be linked through agent activities.

Conclusions

This paper explores the methodology for research on the relationship between built environment and transport in the Czech Republic, an area that has yet to be fully explored by scholars. It highlights the use of Activity-Based Modelling (ABM) as a powerful tool for investigating this relationship, taking into account individual characteristics and preferences. It is argued that the ABM may be utilised to create an empirical ground for various planning decisions concerning the built environment and transport. Ultimately, understanding the interplay between the built environment and transport may be beneficial for general urban discourse across fields.

Footnotes

[1] Typically using solely Four-step Transport Modelling to advocate road infrastructure extensions.
[2] When you drop a stone, the stone will fall to the ground surface
[3] Properly speaking, transport demand is reduced to realised transport observed by transport surveys. Real transport demand is available only in the case of full transport modelling.
[4] To learn more about regression modelling, refer to (Chen, 2021)
[5] Research of cities structure influence on transport works with wider, aggregated data compared to research of local amenities accessibility to transport.
[6] Note that all variables must be quantified

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