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Research Article

Mobility impacts of urban development in the agglomeration

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Abstract: The paper introduces the connection between land use functions and transportation, presenting their necessary integration in certain planning phases in the Hungarian urban planning and development practice. It emphasizes and explains the role and significance of zoning plans in cities. Zoning plays a significant role in preventing disadvantageous consequences of urban developments and the sustainable operation of city life. Even in the preparation phase of zoning plans, expected transportation effects of certain developments must be estimated, and necessary criteria must be determined. The aim of the paper is to introduce current differences between the principles of sustainable development and the implementation of projects that are (theoretically) well prepared and have anticipated consequences, as well as justify the need for integrated urban development and transport planning. Detailed examples for transportation effects of location and size of different land use functions are shown in metropolitan areas. A complex and integrated method of Land Use and Transportation Planning is shortly introduced. Suggestions are made for possible prevention methods of the adverse effects of planning, lacking integration. The main conclusion is that providing urban infrastructure that supports the planned land use functions must be a priority during urban planning and development. The solution to transport development issues (accessibility, network connections, parking) is a criterion for success in the complex urban development process.

Keywords: Urban planning; Land Use; Sustainable Transport

I. INTRODUCTION OF THE ISSUE

Transportation directly influences living quality. This is especially true in the case of urban transportation, where spatial location (urban structure) and accessibility of different land use functions (residential, work, education, services, recreation) form a complex system within the framework of the urban transport system.

This system is susceptible to any change, like the presence of new land use functions, modification in the public transportation network, parking or traffic management systems. Urban planning strategies (placing/determining the location of land use functions to lower daily mobility needs) are among the most important tools to decrease the number of journeys within the city. Suitable urban planning principles must be transferred into practice to reach this goal.

Development of a new area is often determined by aspects of transportation and accessibility; land use functions are defined by these factors. In most cases, these aspects are principally about private car use, whether the number of parking places can be considered provided or the accessibility criteria. To decrease mobility needs, stopping the area growth of cities ("urban sprawl") has to be a general objective.

In international practice, the research on the issue has become essential in the last 20 years. A new organization was established in 2008 to coordinate scientific work (World Society for Transport and Land Use Research) [1]. Several publications in national and international literature deal with the connection between land use (urban zoning) and transport development. Simulation models were also introduced in the interest of helping the integration process [2].

Many papers deal with the environmental and economic characteristics of urban design. Main findings are the following:

- land use patterns affect travel demand,
- addressing land use patterns can reduce demands on roads and public transport systems [3],
- integrating land use and transport issues reduces the cost of travel and lowers energy consumption (there are some examples in railways [4-6]).

- Intelligent Transport System and Smart City technologies bring new dimensions to research [7],
- urban planning must provide favourable conditions for sustainable mobility [8, 9],
- Cities must be compact, their development should be transit-oriented, the importance of public transportation systems, traffic simulation for large-scale developments, assessment [10]
- more integrated land-use and transport policy packages are needed [11-14],
- accessibility is a key element [15],
- the major challenge is bridging the gap between research and planning practice [1].

In Hungarian urban design practice, zoning plans showing the city's structure and location of existing and planned land use functions for the whole city were a compulsory part of regulatory plans for many decades. These plans indicate the cities' most probable future mobility habits and give information about the expected further improvements (land use functions) near the development sites in case of every development. The consequences of the new construction activity, especially transportation impacts, can be estimated more easily and punctually since planners have the appropriate information when checking the zoning plans. This is not the case anymore, as it will be introduced in Section II.

Based on building investment practices of last years, it seems that although almost all types of land use functions were constructed, residential and commercial developments represent high ratios of building activities. These projects have significant effects socially, environmentally and on the city management as well. The consequences on infrastructure systems are among the most disadvantageous. The magnitude of impacts and consequences depends on the type, size, as well as exact location of the developments.

In the following sections, this paper attempts to explain the important role of zoning plans and other types of planning by showing examples of three land use functions where location and the type of function make it easy to estimate how the function will be accessed, together with other transportation consequences. Further research methods include introducing other urban and transportation plans, showing a strong connection between the two planning areas.

The objective of the following article is to introduce current differences between the principles of sustainable development and the implementation of projects that are (theoretically) well prepared and have anticipated consequences. Transportation results of developments of certain land use functions will be shown and briefly analysed, presenting causes and possible methods of preventing adverse effects.

Due to the extent of this article, only some examples regarding effects experienced in the urban agglomeration area of the Hungarian capital will be introduced.

II. CONCEPT AND SIGNIFICANCE OF URBAN AGGLOMERATION

Urban agglomeration means an extended city or town area comprising the built-up area of a central place and any settlement attracted by and linked to the central city. Inhabitants of the agglomeration area have a strong and daily connection with the central city, including cultural, economic and community aspects. This way, the functioning of the urban agglomeration creates numerous issues to be solved, regarding social, economic and transportation connections. Extent of the urban agglomeration depends on size, regional functions and job types offered by the central city, as well as the transportation connections of the area.

In the case of Budapest, usually a 30-50 km distance around the capital is designated as expansion of the urban agglomeration area, but since the pandemic experienced by the world in 2020, this radius could even be 100-120 km, due to the new habits and possibilities remaining [16]. Today, the size of the urban agglomeration depends on the feasibility of working online (home office) and the rail connection or motorway connection towards the capital city. (**Fig. 1** shows the City of Sólymár with the railway station and P+R parking area.)

***Figure 1**. City of Sólymár, railway station and P+R parking area*

According to the data provided by the Central Statistical Office, the number of inhabitants in Budapest's urban agglomeration area increased by 8-29% in the last ten years [17]. Raising the ratio of built-up areas and growing population causes social and infrastructural problems in the towns of the agglomeration. Social conflicts are usually present due to the inadequacy of the local institutional system. Some towns declared that they could not accept any more population growth. At the same

time, valid zoning plans still show that new residential areas need to be developed (see **Fig. 2**).

***Figure 2**. Zonal Plan, City of Vác*

As a consequence of the above-mentioned factors, towns of the urban agglomeration are facing two significant transportation problems:

Traffic and needs of commuters: Due to the characteristics of the urban agglomerations, regional institutions, workplaces and services are concentrated in the central city, which is why the number of daily commuters travelling to work and study is significant. Interestingly, the qualification level of people commuting to Budapest is higher than the average level in the agglomeration (46% hold a university degree, and 37.5% are high-school graduates). This is a group where higher "home office" activity is expected; this way, the rate of daily commuting could even be less.
Transportation problems caused by commuters in the towns of the urban agglomeration are shown in the traffic volumes using roads passing through town centres and access roads leading to railway stations. The choice of public transportation instead of private cars is in the interest of the towns and the entire region. This is why developing a sustainable transport system to access bus and railway stations by alternative transportation modes must be a priority.
For example, the Railway Strategy for Budapest Urban Agglomeration Area introduces a detailed analysis of possible developments regarding railway lines, stations, P+R and B+R in the area's towns.

Traffic within the town: Due to the increased number of inhabitants in the towns of the agglomeration area, the allocation of new, extended institutions, commercial and service facilities must be solved. Transportation habits in a town are formed by the types of existing and new land use functions, their location within the city structure, and local traditions and possibilities (including the families' financial situation). Therefore, the location of planned facilities and functions should be chosen carefully during urban planning phases so that they can be accessed and provided well by infrastructural means. The construction of the necessary infrastructure needed for sufficient co-functioning of land use function and the rest of the city must be a criterion for realizing the new development. Zoning plans represent an important urban planning phase in Hungary, since they show areas of certain types of existing land use functions and planned developments within a city structure. In the year 2022, a new legal regulation ("419/2021. (VII. 15.) Government Ordinance about contents, process of preparation and ratification of urban plans") was issued, removing zoning plans from the urban planning process and introducing the so-called Developmental Plans. Developmental plans (unlike zoning plans) only show important and usually short-term developmental areas within the city. In the case of zonal plans, by analysing the type and location of the planned land use functions, future transportation habits were well predictable. However, examining the current situation, it can be stated that in many cases, infrastructural projects ensuring a sufficient transportation system were not constructed for certain developments.

III. DEVELOPMENT OF LAND USE FUNCTIONS AND THEIR CONSEQUENCES

Development projects in urban areas can be classified into several categories:

- development (strategic plans) of regions,
- development of transportation projects (connected to urban developments),
- development of urban functions (infrastructure development is necessary).

In the following section, general problems and conflicts will be introduced through examples regarding three frequently built land use functions:

- low-density residential areas,
- institutes of education,
- commercial-industrial function.

The examples are introduced in the following section represent a general problem; other projects could also be shown.

1. Residential developments

Residential developments represented significant building investments in previous years, especially within metropolitan areas (agglomerations) and around important touristic destinations in Hungary. Since residential areas could generate large traffic volumes in morning and afternoon peak hours, providing suitable transport connections toward the city centre is crucial or checking their existence and capacity. In most cases, this (should be) criterion is only considered regarding private car use.

As a bad example for planning and operation, the case of the town Mogyoród can be shown. The town is located 20 km from Budapest, has a regional railway connection and a strong motorway connection with the capital city. Due to its good

accessibility and green, natural location, the town is preferred among people looking for a quiet place to live but commuting to Budapest to work and study every day.

For the need of residential units, new communities (residential areas) were built 2-3 km from the town centre, on the outskirts of the built-up areas. Unfortunately, these areas are not connected to the town centre by bicycle or foot, and the public transport service is also poor. Although most educational, medical and administrative institutions are within walking distance (about 1.5 km) from the new residential areas, residents mostly use their private cars to reach these destinations, increasing traffic volume within the town centre, especially in peak hours. There are no possible public transportation connections from the residential areas towards schools, the regional train stops, or the bus station. Even the zoning plan of the town shows these residential areas as isolated places within the town's outskirts. No sustainable mobility mode is offered for these areas, and even the building regulations applied to the town area do not contain any information about the necessity of walking or cycling connections. Even when planning these residential areas, anyone could have seen that these areas would only be accessible by private cars. Even though the environment around the residential blocks would absolutely be suitable for providing sustainable mobility connections, none of them was planned. Residents of these areas must travel to the town centre and the stop of the regional railway on a very busy national road connecting several cities to the M3 motorway, using junctions that were not built for high traffic volumes. So, in this case, urban planning created a transport problem, causing environmental and safety issues.

It would be possible to connect the new, isolated residential areas to the town centre on a bypass, a short road for pedestrians and cyclists, leading it across green areas, but at the moment, there is no plan to realise this idea. At the same time, further development of residential areas is on the way without any development of transport infrastructure. No doubt, the outcome will be worsening traffic and environmental conditions.

The rate of green areas in this town is favorable, but in several other cities, the increasing rate of built-up areas results in a decrease in the ratio of green areas.

Figs. 3 and 4 illustrate the new residential areas and the zoning plan of Mogyoród.

***Figure 3**. New residential areas, Mogyoród [18]*

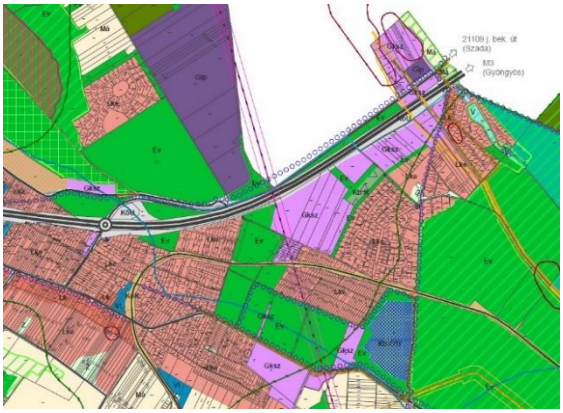

***Figure 4**. Zoning Plan, Mogyoród*

2. Educational institutions

Due to the increasing number of inhabitants and the strengthening regional role of the settlements, institutions were developed significantly in several towns of the agglomeration. In the cities of Biatorbágy and Dunakeszi, large high schools were constructed. Unfortunately, the increase in the built-up areas is so significant within the cities that a suitable size of land for the schools could only be found on the outskirts of the cities. So the location of the schools would require a well-serviced public transportation between the schools and the city centres and/or main railway stations, since they are several kilometres from the city centres and residential areas. Even during the planning period, accessibility and alternative modes of transportation should be a priority. Unfortunately, this usually is not the case. General characteristic of these locations is the difficult accessibility which usually leads to the "normal" situation that (just like in any other school in the country) parents are driving their children to school and in several cases they are driving through residential areas Walking and cycling infrastructure usually is not given or not suitable for a safe access.

In the city of Dunakeszi (**Fig. 5**), a large area has been built up in the last two years, resulting in the realisation of two high schools, a sports facility, other extensive sporting grounds, a swimming pool and a large parking area with 300 parking places. This facility is located on the city's north outskirts, far from most residential areas and about 1.2 km

from the nearest railway station. It can be accessed on a collector road where traffic volume is quite high since this road provides a good connection to the main road No. 2 and the national motorway M2. On this 2×1 lane collector road (having a width of about 6 m), two open cycling lanes are in operation. The parameters of this road are not suitable for accommodating normal-sized public transport vehicles. The new development area is within walking distance of the closest railway station, but only a narrow pavement is provided for pedestrians along the road on one side. Since this high school complex has regional significance, many students and workers arrive by train, but walking to the new complex is unsafe. A cycling road with limited connections has been constructed around the complex. Unfortunately, no traffic study is accessible regarding the originally planned accessibility and transport service.

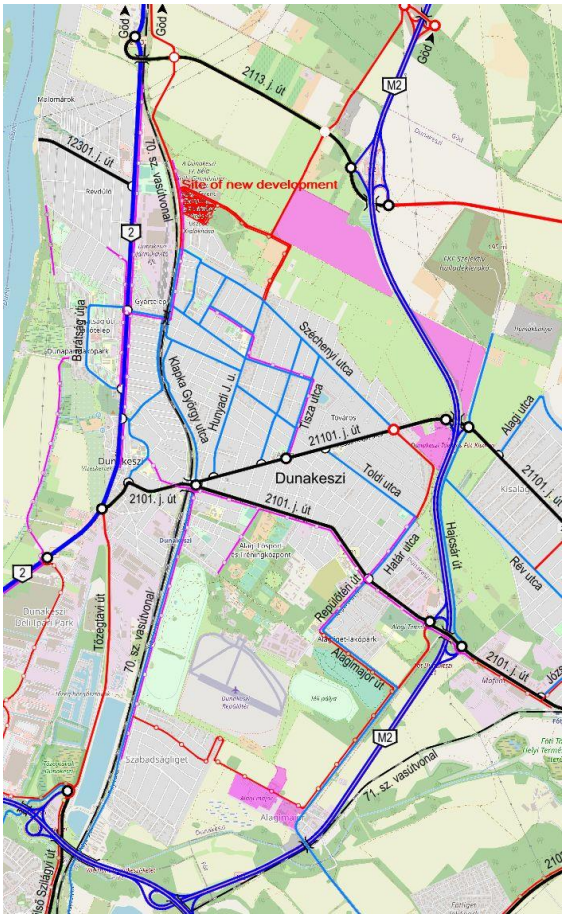

***Figure 5**. Transportation network of Dunakeszi [19]*

3. Development of commercial areas

Development of new, or expansion of existing commercial and industrial areas, is acceptable along national main roads, especially motorways, since these roads have excellent connections towards national and international destinations. Several of these new commercial developments have a logistical function. Regarding the effects of the new developments on the neighbouring towns and cities, the location of these new commercial developments is very well chosen, because the heavy traffic generated by the new development sites will not enter built-up areas (primarily residential areas). At the same time, the capacity and operability of the main road or motorway providing direct access to the new industrial and commercial functions are very much affected by the new developments and many conflicts are experienced during operation. Commercial and industrial functions have a substantial effect on the environment and the transportation network, most probably the highest effect of any land use functions.

A characteristic example could be in Hungary, the commercial zone next to the M1 motorway near Budapest (within a 50-60 km distance). M1 motorway is the most important connection of Hungary towards international areas like Austria, Germany and other countries in Europe, accommodating almost the highest traffic volume on the national road network (average daily traffic volume: 89,744 vehicles/day on a 2×2 cross-sectional road). Looking at the map of the M1 motorway starting point from Budapest, it can be seen that large, built-up areas along the motorway show large-sized commercial and industrial buildings.

The situation is very similar in the metropolitan area south of the city centre, where national main road No. 51 provides the best connection for neighbouring areas towards the M0 ring road. This road is not a motorway, so it operates with a cross-section of 2×1 traffic lanes (except near the M0 ring road). The new commercial developments constructed next to the road generate a high volume of heavy traffic, which has overloaded the road capacity and functionality, becoming critical in recent years.

The following aerial photographs (**Fig. 6**) show changes in built-up ratios around the area between 2005 and 2020. Today's average daily traffic volume on main road No. 51 is 31,479 vehicles/day (including 2,454 heavy vehicles) according to National Road Regulations, the tolerated capacity of the main road is 2,000 vehicles per hour (level of service is just acceptable). This means that traffic volume travelling on main road No. 51 is well over the road's capacity, using 157% of the theoretical capacity. Zoning plans of the cities next to this main road show even more possible development sites along the road. Significant improvement is expected in the near future along the critical section of the main road: cross-section is planned to be developed into a 2×2 lanes cross-section, increasing traffic capacity and hopefully traffic safety (**Fig. 7**). Unfortunately, construction work has not been started yet, but - according to the zoning plans - new

development could be commence next to the main road anytime.

Figure 6. *Built-up areas along main road No. 51. (Years 2005 and 2020)*

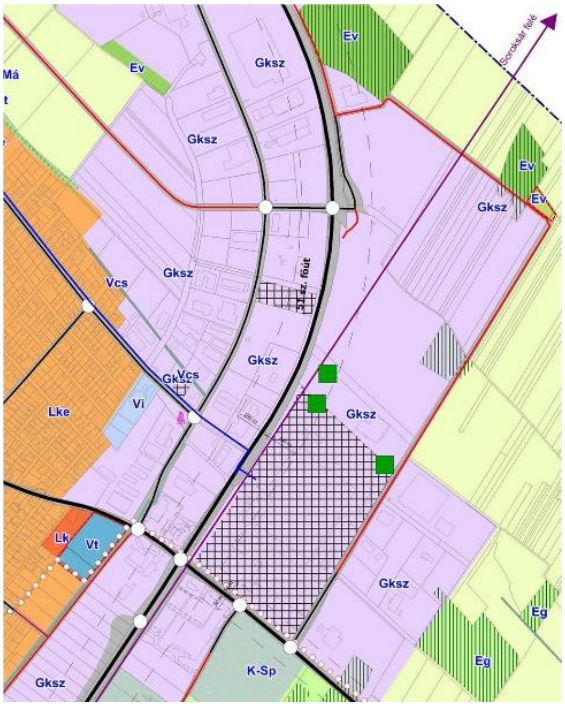

Figure 7*. Built-up areas along the main road*

IV. CONCLUSIONS AND RECOMMENDATIONS REGARDING MORE COMPLEX MANAGEMENT OF LAND USE AND TRANSPORT IN A CITY

Transportation planning is one of the most important aspects of urban planning [20]. The connection between land use and transport is much more important and substantial than it may seem during urban planning. The international research area Land Use and Transport (LUTR) mainly deals with the effects and connections of whole cities or regions. However, single developments (of all sizes) must also be studied, since they affect everyday life in a city.

Required planning process of projects [20]:

- conceptual planning,
- feasibility studies,
- settling study with transportation impacts assessment (defining conditions of the project),
- Development Plan (Structural Plan),
- Master Planning (Local Construction Code), defined conditions should be made compulsory.

In the system of urban development plans (supported by sectorial plans), the individual plan types build on each other, thus providing an appropriate framework for sustainable development. The concept plans determine the directions of development to be followed, for which the strategies provide specific tasks and programs with a toolbox of applicable methods. Land use zoning (development) and regulatory plans are part of the mandatory Local Building Regulations. Individual investments can only be implemented with parameters aligned with the urban development plans, which can be justified by impact studies and settlement studies. If any element of the system is missing or does not fit, the effects of the investment (according to this study, mainly the effects of transport) will be detrimental to the city. In other words, the responsibility of planners, decision-makers and local authorities during the preparation, approval and application of settlement plans is indisputable.

Important transportation issues to be considered during urban development [20]:

- accessibility (by all modes of transportation),
- structure and inner connections of the transportation network,
- parking (system) [21],
- possibilities for sustainable transport development.

The examples above show general conflicts and problems. Urban planning strategies could offer a strong base for a sustainable and well-functioning urban transportation system. Strategies that support reducing the rate of private car usage and replacing it with other, environmentally friendly transportation modes.

Providing urban infrastructure that supports planned land use functions must be a priority during urban planning and development. The solution to transport development issues (accessibility, network connections, parking) is a criterion for success in the complex urban development process. In general, transportation is a service function of urban development ideas. The structure of cities is determined by the functions of land use and their connections. The structure-forming role of the transportation network is clearly visible in urban

development, when land use functions can utilise existing infrastructural advantages and spatial development happens according to them.

Apart from land use functions, accessibility is an important factor in the generated traffic volume of a certain urban area. Access to the main road network in a city, distance from public transportation, size and service level of provided parking possibilities basically determine the generated traffic volume in certain developments.

The role of the developmental and regulatory plan is significant in the evolution of the transportation network, transportation habits, and the sustainable mobility system. Expected transportation impacts of planned land use characteristics must be defined during the work on the zoning plan, such as quantifying traffic generation, accessibility, ratio of heavy traffic, parking possibilities, etc. If this issue is not settled during phases of urban planning, problems can be expected during realisation processes, and unsolved transportation conflicts may cause significant drawbacks during implementation and everyday operation of land use functions.

According to the issues discussed above, urban planning (especially development strategies and zoning plans) plays an important role in the acceptable functioning of cities. This responsibility can be dealt with through careful preparation and evaluation of supporting parts of planning and certain impact studies, and by enforcing construction criteria during every project. A sustainable, smart and compact city is a must in large developments (for example, a residential area for 3000-5000 inhabitants).

Applying and enforcing basic principles dealing with land use and transport development as a complex issue is necessary for sustainable and conscious planning. The main objective of urban development must be creating a liveable city and a good standard of living.

AUTHOR CONTRIBUTIONS

K. Macsinka: Conceptualization, Theoretical analysis, Writing, Supervision, Review and editing.

DISCLOSURE STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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