Transport Development Challenges of Brownfield Investments in the Name of Sustainability

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Abstract. Reconstruction of brownfield sites is part of the EU cohesion policy, a priority area for EU development funding, and a permanent theme for the Committee of the Regions. Redevelopment of brownfield sites is also a solution to ensure sustainable urban sprawl and land management. One of the main advantages of brownfield investments over greenfield investments is, that on the one hand it is not necessary to build the utility infrastructure and road network because it is already built, and on the other hand the development is land-saving, as it is not necessary to declare new undeveloped areas as construction areas. Another advantage can be mentioned: the investment is implemented and the improvement of the environmental conditions, contributing to the appreciation and sustainable development of the settlement. At the same time, the development of brownfields causes challenges during urban planning. On the one hand, an attractive regulatory environment has to be created in the master plans for investors, usually with a high building ratio, but on the other hand, sustainable transport for the area still has to be ensured for the long term. According to our experiences, in order to satisfy the cost-effective investment intention of investors, there is a need to ensure the maximum build-up density of the area, which generates a much higher transport demand than before, which the existing transport infrastructure and services can no longer fulfil, and therefore capacity expansion will be required. However, to ensure sustainable settlement development, the additional traffic demand generated by the brownfield redevelopment must be served following the methodology and criteria of sustainable transport development. Using the experience of a Hungarian case study, the authors present a new brownfield redevelopment model, which can help decision-makers and planners to make the right settlement planning decisions, apply optimal transport planning criteria and methods, and select the adequate, sustainable transport development tools for brownfield investments, during preparation and implementation.

Keywords: Sustainable settlement and transport development · Settlement planning · Master plan · Brownfield development · Sustainable transportation development tools

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1 Introduction

1.1 Introduction of the Brownfield Development Areas

At the beginning of the 1990s, the loss of the Comecon markets [1] and the withdrawal of Russian soldiers caused a substantial paradigm shift in the country's economy and settlement development [2]. As a result, factories were bankrupted, left without function, and barracks were emptied after the withdrawal of Soviet troops (*between 1945 and 1990, the Soviet army used at least 342 sites, in at least 108 settlements*) [3].

These areas that have lost their function, called brownfields, like urban wounds, are disfigured in the urban structure. There are almost 6,000 hectares of brownfields in Hungarian cities. Most of these areas are located in an urban environment [4].

1.2 Sustainability Benefits of Brownfield Developments

The different definitions in Europe, the United States, and Asia describe brownfield sites in a similar way as abandoned or underused properties where the actual or suspended presence of hazardous substances, contaminants, or contaminants requires intervention to ensure beneficial reuse. The health and economic hazards of brownfield sites and the challenges and opportunities for their reuse are addressed in the international literature worldwide [5].

Despite the difficulties and high costs of brownfield developments, their social and environmental effects are indisputable. A research team examined and evaluated 200 brownfield real estate investments in the United States. The study found that socioeconomic factor (income level), green development, and tax were significantly correlated with brownfield renovation [5].

For this reason, European, national and regional development strategies and programs have been set up in recent years to support such developments.

According to the brownfield redevelopment in the EU-conference report (2019), brownfield redevelopment has to be promoted as a solution to limit urban sprawl, land take, and soil sealing. Inspiring policies, good practices, and EU funds have also been explored for efficient brownfield redevelopment [6].

The planning and investment program for the future growth of Hungary's regions, cities, towns, and rural areas is based on the EU Development Plan of Hungary for 2021–2027. The focus areas of the development plan are included in the so-called Operational Programmes. For example, the main objective of the so-called Land and Settlement Development Operational Program Plus is to improve citizens' quality of life. In addition, it is the goal of the integrated urban development interventions local transport, green and blue infrastructure, ICT, and smart settlement, through the brownfield and municipal energy developments, which also serve sustainability and climate protection purposes [7].

One of the most crucial land use recommendations of the National Development 2030 - National Development and Spatial Development Concept (OFTK) is also the economic and well-thought out use of land [8].

Main areas of intervention:

– rehabilitation of brownfield sites with new functions (community, cultural, green space, etc.),
– rehabilitation of rust zones (e.g., family and climate-friendly), including the renovation and utilization of the building stock.

1.3 Legal Framework

The 'Building Act LXXVIII of 1997' consists of planning and protecting the built environment, the essential requirements, means, rights, obligations, and related tasks. The 'Act LXIV of 2019' amended the previous one and established basic rules for brownfield sites. The Building Act also requires that, if there is a brownfield area in the administrative territory of the local government, the local government is obliged to define the brownfield in the settlement planning tools (e.g., master plan, land use plan, and zoning plan) and to ensure the possibility of redeveloping the brownfield sites during the planning of the settlement development concept and strategy [9].

Brownfield areas so defined in the local master plan, which includes analysis, recommendations, and proposals for the site's population, economy, housing, transportation, community facilities, and land use. Currently, the Master Plan defines the construction concept of the brownfield redevelopment.

The zoning plan is part of the master plan, which includes detailed rules on how the brownfield area can be used. The building code of the zoning plan specifies the standards for constructed objects, such as buildings on the brownfield, focusing on the building's physical features, including characteristics that affect accessibility and safety.

According to the current practice, a brownfield redevelopment project starts with studying the building regulations. Then, it continues with the analysis of the relevant parameters of the settlement planning tools (master plan and zoning plan) and then the review of the installation parameters (building code).

Feasibility studies such as the analysis of urban architecture, environment, and transport are done as second steps. Finally, the building program of the brownfield is developed after the feasibility studies, but it is usually based on the urban architecture feasibility.

2 Case Study

Szechenyi Istvan University (SZE) is at the gate of large-scale development. A Science and Innovation Park will be built on the former Biscuit and Waffle Factory site in Gyor as a brownfield development project, which will be one of the eight science and innovation parks planned in Hungary.

The establishment of science parks in several countries plays a major role in the functional change of brownfield sites.

According to the experiences of a Czech study, renewable brownfields are morelikely to be found in settlements with higher local development potential, proximity to the regional center and the main road network and high quality of local infrastructure [10].

Technology-oriented businesses have settled in these parks, formerly located in industrial and military areas, typically near university and research bases. It was the first time in Hungary in Budapest that science or technology parks were established in brownfield areas (In-fopark, Graphisoft Park) [11].

The Szechenyi Istvan University owns this 3.6 hectares development area. The development area is within 5 min walking distance from the university campus and 10 min from the city centre. The planned investment is divided into three phases. In the first phase of the investment, a 6000 m^2 building will be renovated for R&D and education use (pink marking in Fig. 1). In the second and third phases (marked with green and blue), new buildings will be established for enterprises, research organizations, research groups, start-ups, spinoffs. Altogether 47,000 m^2 net floor area is planned to be constructed.

Fig. 1. The site of the former Biscuit and Waffle Factory and the planned Science Park

2.1 Urban Development Tools

The redevelopment of brownfield sites within urban areas is considered a sustainable land use. The use of a methodological approach to brownfield redevelopment should be based on an assessment of the existing context, the external context of the site and the use of local indicators [12]. The redevelopment of the brownfield of the former biscuit factory for science park was examined in the context of the valid settlement development decisions, such as the 'Long-Term Settlement Development Concept of the City of Gyor (2014–2030)' [13], and the 'Integrated Settlement Development Strategy of the City of Gyor (2014–2020)' [14]. The existing urban planning tools were analysed as well, in detail: the changes in the process of settlement planning, the current legal environment, the master plan of the City of Gyor [15], and the relevant provision of the local ordinance for the protection of the settlement 'Building Regulations of Gyor Decree of 39/2021 (XI.30.) [16].

2.2 Analysis of Urban Architecture

The urban architecture feasibility study focused on the requirements of the building law according to the brownfield plot, the built environment of the district, and the aspects that influence the installation possibilities [17]. The results of the urban architecture analysis have been defined the installation plan of the brownfield. The results of the analysis on the urban architecture are assumed in Table 1.

Table 1. Feasibility study: analysis of urban architecture

Analysis of indicators	Conclusions
Plot size	The average plot area in the district 500–1500 m; building plot 3.6 Ha
Built-up density	The average built-up density in the district 20–45%; building plot 60%
Building height	The average building height in the district is 7–7.5 m; 'Cube building' 25 m; max. Building height 21 m
Morphology	The construction character surrounding the project area shows a very mixed picture

At the time of the Master plan of 2006, the buildings of the former biscuit factory were still standing, and the zoning plan still considered the use of the plot as a 'commercial service' area. However, the area was converted to 'mixed land use' in 2010 for better market sales. With this action, the city captured its vision of changing the function of the brownfield area.

The utilization of the original parts of the Biscuit Factory related to the university's research and development activities was included in the 2006 large-scale development plan only at the level of proposals.

Finally, the Municipal General Assembly approved the current valid master plan in 2013, with the 194/2013. (IX. 27.) decree. This decree sets out the current standard construction rules for the area, such as maximum building ratio 60%; minimum green area ratio 20%; maximum floor area ratio 3.0; maximum building height 21 m.

2.3 Transportation Analysis

The primary purpose of the transportation analysis [18] was to design and determine the traffic needs generated by the planned installation.

Table 2. Feasibility study: transportation analysis

Aspects	Conclusions
Location in urban space	Neighborhood district of the university and the city center, close vicinity of the river Moson-Danube
Modal-split	Expected to be similar to the city's: 40% private cars, 30% PT, 20% walking, 10% cycling
Transport needs of the inner city	Inner city's transport needs are reasonably fulfilled

(*continued*)

Table 2. (*continued*)

Aspects	Conclusions
Transport needs of the outer city	The site is accessible from outside the city
Existing road network	The transport infrastructure network is appropriate, but there is a shortage of capacity in peak hours
Intersection's capacity	The four roundabouts of the access road are exhausted
New transport investments in the wider environment	Western bypass and the construction of a new bridge are in progress
Travel plans	Not available
Bicycle facilities	The site is connected to the expanded bicycle network
Pedestrian facilities	Sidewalks surround the site, but parking cars often hinder walking
Electric charging, micro-mobility	A charging station is in short distance
Current bus service	The excellent bus network, but the frequency is not sufficient

The results of the transportation analysis are presented in Table 2 and Fig. 2.

Based on traffic counting and forecasting of the examined area, it was concluded that its capacity reserves are currently exhausted, and significant congestion is observed, especially along the main axis. Expanding the Radnoti street for a 2×2 lane road would result in a capacity reserve, but it would involve narrowing or abolishing pedestrian, bicycle, and parking facilities. Nevertheless, the width of the two-lane Jedlik bridge cannot be increased as well.

Furthermore, the traffic flow in the four roundabouts along the main access road is being restricted in peak hours. Implementing turbo roundabouts would increase their capacity 1.5 times, however, the built-up density and the short distance of the junctions do not allow it. Installation of traffic lights would also have insolvable territorial limitations.

2.4 Impact of the Proposed Development on the Transportation

In order to satisfy the generated transportation needs of the Science and Innovation Park, the following measures were proposed (see Table 3).

The impact of the planned measures on the traffic volume is referred on the current traffic volume of the Jedlik bridge, 23000 PCU (personal car unit)/day, which is the highest in the neighbouring road network.

Among the highest transportation-related risks, the current overload of the road network and the future skyrocketing traffic demands of housing investments are the most considerable.

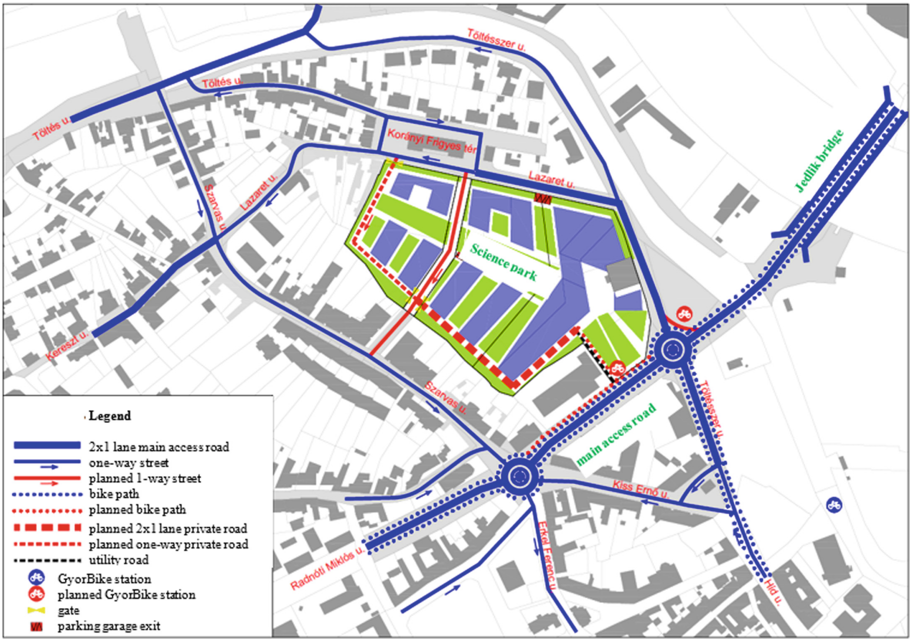

Fig. 2. Road network of the neighbouring area

In the first phase of the project, increasing bus frequency, introducing parking fees in the area, and expanding the public bike system GyorBike will be implemented simultaneously with the renovation of the existing cube building and construction of the inner roads.

Two side roads (Szarvas and Toltesszer streets) are going to be turned into one-way streets according to the proposal in order to mitigate parking needs and support traffic flow. Additionally, bicycle infrastructure is going to be improved locally.

In the second and third phases of the investments, further measures are essential to maintain an appropriate level of service, such as travel plan, work shift (discouraging work start at school start around 8:00 a.m.), and increasing parking fee.

In addition, in the short term, some independent road development projects of the city will have a significant impact on the transportation system of the science park by decreasing the inner traffic volume of the city, such as the development of road No. 83, Western bypass and Ipar Street bridge development.

Additionally, some barely realistic transportation projects for achieving higher road capacity are listed in Table 3. For instance, road development of the Radnoti street with 2 $\times$ 2 lanes, building a new bridge along Jedlik bridge, reconstructing the four roundabouts into turbo roundabouts or traffic light intersections. A futuristic zip line between the science park and the university and integration of ship transport into public transport would also have an estimated positive impact on the road capacity of the area.

The first phase can be environmentally sustainable by implementing the listed short-term measures. Phases 2 and 3 will be feasible exclusively if more significant transportation developments come true to decrease the traffic volume of the inner city, and a remarkable modal shift will be achieved by implementing sustainable mobility measures. The goal is to minimize the future motorized transport demand of the entire investment.

Generally, it can be stated that the road network's existing and future capacity should be preliminarily taken into account when deciding the building parameters of the brownfields.

Table 3. Transportation development measures and their effect on traffic volume

Measures	Traffic default PCU/ day	Estimated impact on motor vehicle traffic, %	Estimated impact on motor vehicle traffic, PCU/day	Estimated impact on road capacity %
Increasing bus frequency	23,000	-5.0%	-1150	
Shuttle bus to university	200	-10.0%	-20	
Shuttle bus to Industrial Park	100	-5.0%	-5	
Travel plan[1]	365	-15.0%	-55	
Work shift[2]	23,000	-20.0%	-	
Parking fee	23,000	-2.0%	-460	
Public bike development	23,000	-0.5%	-115	
Road 83. development	23,000	-0.5%	-115	
Western bypass road dev.[3]	23,000	-15.0%	-3450	
Ipar street bridge development			-2000	
Road capacity development of the Radnoti str. with 2x2 lanes[4]				320%
New bridge along Jedlik bridge				320%
Turbo roundabouts[5]				150%
Traffic light intersections[5]				200%
Train development	23,000	-1.0%	-230	
Integrate ship transport to PT	23,000	-0.5%	-115	
Zip line between S Park-university	200	-10.0%	-20	
Real estate development	23,000	15.0 %	2500	
Phase 1 additional traffic			365	
Phases 2 and 3 additional traffic			730	

[1] *Based on previous Travel Plan experiences* [19].

[2] *Calculated based on the average reverse capacity of the intersections within the area of the analysis* [18].

[3] *Based on the macrosimulation traffic model of the planned western bypass road* [18].

[4] *Based on the design guidelines of roads* [20].

[5] *Based on the estimated capacity of the different intersection types: turboroundabouts and signalized intersections* [18].

3 Results

According to the transportation feasibility study's results, it can be concluded that the urban planning tools such as the master plan and the zoning plan, which defines the building code, should not be done without preliminary transportation analyses.

The case study indicated that the brownfield redevelopment areas might cause overbuilding in this current valid legal framework, overloading transportation capacities, thus creating unliveable areas.

The construction rules for a brownfield area, such as maximum building ratio; minimum green area ratio; maximum floor area ratio, maximum building height, should not be defined without the consideration of the transportation circumstances of the area.

The urban architecture feasibility study can help define the installation plan and characteristics of the buildings of the brownfield redevelopment projects but should not be prepared prior to the transportation analysis of the area. The reason behind is that the characteristics of the buildings, the morphology, and the size of the plots cannot determine the brownfield's maximum building ratio sustainably without considering the current and future capacity of transportation infrastructure and mobility services.

During the preparation of a master plan, before defining the building regulations of a brownfield, a transportation impact assessment needs to be executed, which considers the sustainable urban mobility (SUM) principles.

"A Sustainable Urban Mobility Plan is a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and considers integration, participation, and evaluation principles." [21]. SUMP also requires a considerable change in the planning principles of cities [22]. While traditional transport planning has focused on providing space for the development of car traffic, SUMP places people and their mobility in the centre: it supports public transport, walking, and cycling and, at the same time, reduce car use.

The planning process is carried out by interdisciplinary planning teams with the involvement of stakeholders. It means that the building concept has to be prepared to understand sustainable urban mobility values in cooperation with interdisciplinary planning teams, such as urban planners, architects, and transportation engineers. The primary purpose of the feasibility studies, both the architecture and the transportation feasibility study, is to ensure the long-term sustainable development of the district and the brownfield.

3.1 Introduction of the New Sustainable Brownfield Development Model

Reconstruction of brownfield sites recently has became the mission of governments, communities, environmentalists, scientists and researchers around the world. Several studies have aimed to sets out a new framework for effective brownfield renovations.

The purpose of some of the studies was, to provide a framework for establishing and optimizing the evaluation for brownfield redevelopment projects [5, 23], or monitor their sustainability [24], however none of them was taking into account the transportation issues.

In order to guarantee the sustainable development of brownfield areas, using the experiences of the case study, a new sustainable brownfield development model has been designed. This new model requires a significant change in the national legal policy framework and calculates with the change of the planning principles of local governments. The new model also summarises the cooperation of the interdisciplinary planning teams and the typical project planning.

The 'Transportation impact assessment' has been added as input for the master plan considering transportation aspects as a new process element.

Implementing a SUMP needs to appear earlier in the project evaluation process, following the master plan and the feasibility studies. Previously the SUMP, as the last step, was not able to supply the transportation needs of sustainable transport modes optimally because it did not influence the installation plan.

With this new brownfield development model, the sustainable development of the district is guaranteed, as well as the high-quality environment for citizens and settlers (Fig. 3).

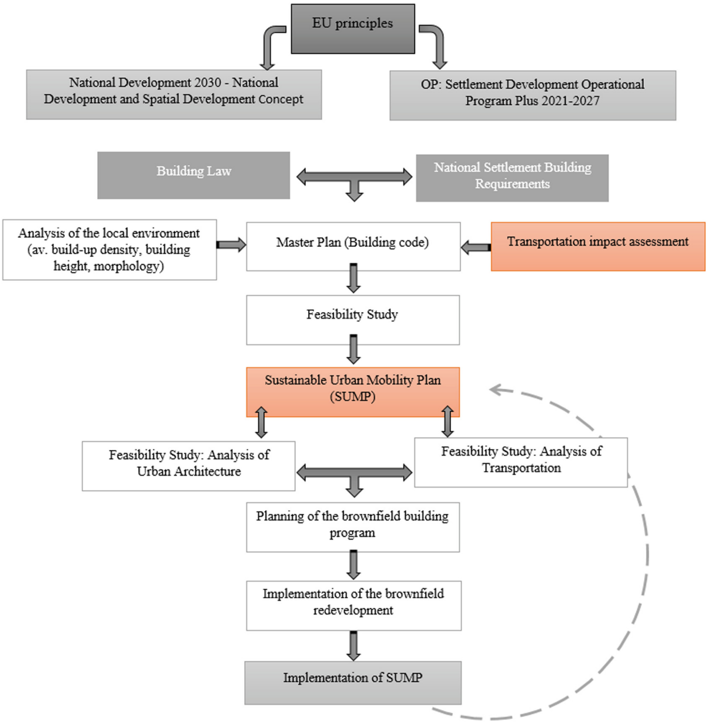

Fig. 3. Sustainable brownfield redevelopment model

4 Conclusions

The rehabilitation and redevelopment of brownfield sites are often less competitive than greenfield sites, especially if their built-up density is economically not optimal for the investors. However, despite brownfield redevelopment's often limited transportation capacity, it has many positive external effects on urban rehabilitation. The European Union funds provide financial support at the international and national levels to implement redevelopment of brownfield sites. However, the rehabilitation can be sustainable unless the transportation aspects are considered during the master planning and if the SUMP appears earlier in the project evaluation process. The proposed model accomplishes the criteria of sustainable settlement and transportation planning additionally ensures the cooperation of the interdisciplinary planning teams and mutual project planning.

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