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Exploring Spatial Patterns of Urban Brownfields Regeneration: The Case of Brno, Czech Republic

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Abstract: Previous studies have demonstrated that the location of brownfields is an important factor affecting potential investor decisions and brownfields regeneration. In this study, the spatial patterns of urban redevelopment are explored, using an analysis of variance model for a detailed database of existing and regenerated brownfields in the city of Brno, Czech Republic. Any general pattern of regeneration – such as 'the closer to the city centre, the better', which would be valid for all brownfields – has not been found. Rather, regeneration seems to be a function of local development potential, local occupier-demand for specific utilities, and planning regulations. Higher rates of regeneration have been detected in densely built-up areas (inner city zones and housing estates), while lower rates are registered for areas with low population density and with a greater supply of green spaces (garden colonies, open spaces, industrial zones and villa residential districts). The factors of centrality and transport links are positively associated with retail and business development projects, but negatively associated with the projects of housing development and construction of civic amenities, for which population density and the socioeconomic structure of the local population are significant positive factors. Important implications for further research and urban planning are formulated in the conclusions.

Keywords: brownfields; urban renewal; spatial patterns; Brno; Czech Republic

1. Introduction

The issues of regeneration and redevelopment of underused, abandoned, derelict and often contaminated lands and premises, or so-called brownfields, remain one of the greatest challenges for urban planners and developers today. As global economic stagnation continues, investments fall, many industries disappear or are moved to countries with lower labour costs – new brownfields emerge, and their sustainable redevelopment is still constrained by many barriers and associated with several dilemmas (Alexandrescu, Martinát, Klusáček, & Bartke, 2014; Frantál & Martinát, 2013; Ganser & Williams, 2007; Payne, 2013; Vojkovská, Vojvodíková, & Macečková, 2013; and others).

The majority of studies that have explored drivers and barriers to brownfields regeneration, to date, have been based on stakeholder surveys (Alberini, Longo, Tonin, Trombetta, & Turvani, 2005; Letang & Taylor, 2012), interviews with experts (Adair, Berry, McGreal, Deddis, & Hirst, 2000; De Sousa, 2003), or assessments of a limited number of local case studies (Coffin & Shepherd, 1998; Dixon, 2007; Nijkamp, Rodenburg, & Wagtendonk, 2002). A rigorous spatial-statistical analysis of comprehensive data has not been applied in brownfields research to date (for exceptions, see Frantál et al., 2013; Novosák, Hájek, Nekolová, & Bednář, 2013, or Sun & Jones, 2013). Effectively, this has been caused by methodological problems, primarily the availability and comparability of appropriate objective data. Mapping and inventorying of brownfields have not been centrally organized in most countries. Detailed inventories with specific locational information or GIS layers are not available, they are inconsistent, or otherwise methodologically problematic (Frantál et al., 2013: 7), and registers owned by private companies and consortia of owners are often protected or provided only with limited descriptive information, without any possibility of publication.

In this paper, we have benefitted from sources utilizing detailed data about successfully regenerated and existing (i.e., not-regenerated) brownfields, collected by the Brno City Municipality in the Czech Republic. The brownfield databases were originally used as supporting data for spatial-analytical documents contributing to the concept of the Brno´s ´Master Zoning Plan´ (the statutory land use plan which guides city's development in the medium term), and – in the form of a best-practice brochure – to "contribute to raising public awareness of brownfields and by presenting successful projects to encourage property owners and investors to follow the presented success stories" (Brno City Municipality, 2013). To date, however, a deeper spatial analysis has not been provided, except for a basic statistical classification of sites according to their previous and current use and their total area.

This case study has an exploratory character: to identify which geographical factors have a significant influence on the objective outcome that some brownfields have become of interest for investors, politicians, experts or other actors, to be selected as profitable or urgent to invest money, time and energy, and therefore to be regenerated, while other sites have been ignored and thus stayed neglected and derelict, or the process of their regeneration has not been successfully completed. These are the key issues for local authorities, urban planners, regional development agencies and other decision makers, who need to effectively distribute limited available resources, time, and energy to those locations and sites where publicly co-financed regeneration is required. In effect, this process identifies those locations where market forces are considered to be weak and some form of intervention to stimulate market activity is required (Adair et al., 2000). This study focuses particularly on location factors; however, we do not question the importance of site-specific factors (such as the level of contamination or property relations) for brownfields regeneration.

2. Exploring brownfields in a spatial context: literature overview

The problems of the evolution and regeneration of brownfields are generally of a multifactor and multilevel character. In large cities – specifically those resulting from transitional economies, such as the cities of post-1989 Eastern Europe – the wider spatial problems are connected with the dynamics of de-industrialization and economic restructuring, residential and commercial suburbanization and re-urbanisation, which resulted in significant migration flows, the expansion of the city into the surrounding countryside, changing built-up and social structures within the inner parts of cities and within the housing estates (Haase, Steinführer, Kabisch, Grossman, & Hall, 2011; Hutton, 2010). Industrial activities, which can be regarded the strongest driving force behind the formation of the original urban structures, naturally gathered around historical city cores, gradually resulting in the appearance of abandoned or underused sites depending on the fluctuations of the industrial business cycle (Bjelland, 2004; Kunc, Martinát, Tonev, & Frantál, 2014; Liu, van Oort, Geertman, & Lin, 2014). Brownfields have constituted barriers to local development, they have become contributors to urban sprawl, burdens degrading the value of surrounding properties, potential hazards to human health and the environment, grounds for neighbourhood crime and other illegal activities (Kunc et al., 2014b, Litt, Tran, & Burke, 2002).

It has been suggested by previous studies (Bacot & O´Dell, 2006; De Sousa, 2003; Dixon, Otsuka, & Abe, 2011, and others) that the crucial ´success factors´ for redeveloping brownfields are clear property relations, decontamination and regeneration costs and acceptable return rates for investors, government incentives, focused urban development policy and political leadership, strong place branding, and local stakeholders’ involvement and collaboration. It has been also demonstrated, however, that – in addition to political, economic and procedural factors – geographical factors play an important role. In other words, the location of brownfields matters! (Frantál et al., 2013).

Brownfields do not exist by themselves, independently or in a vacuum, but they are products of the interrelationships between places and social and ecological processes (Bjelland, 2002). Brownfields are placed and rooted in a certain geographical space and time, which is hierarchically and functionally structured, and a product as well of the vagaries of time: the spatio-temporal attributes of brownfields are a principal concern in any interpretation of their nature and status. The geographical environment and driving forces acting within it have resulted in the formation of brownfields, and at the same time the actual existence of brownfields affects the environment in a dialectical manner (Harvey, 1996). Therefore, brownfields have to be perceived in their spatial context and we should take into account when assessing and prioritizing those (Chrysochoou et al., 2012), not just site-specific attributes but also contextual factors acting at higher hierarchical levels. This ´area wide approach´ to brownfield regeneration, which reflects a wider community or geographic area of brownfields, can be regarded as an alternative to the previously more common ´site based approach´ (Haberle & Wernstedt, 2006).

With respect to brownfields regeneration, the location factors can be regarded as local development potential or area competitiveness, which result from a complex expression of environmental conditions, economic potential and social capital (see e.g., Coombes, Raybould & Wong, 1992). Longo and Campbell (2007) analysed revitalized brownfields in England and found that sites located in more prosperous regions (London, the South West, and the South East) are more likely to be regenerated compared to sites located in other regions. Their analysis, however, did not reveal a significant influence of population density on brownfields regeneration, nor a significant difference in the redevelopment of sites in rural versus urban areas. Lange and McNeil (2004) reported that brownfield sites in the United States, which have been located near airports, close to the central city, or close to rail access, get developed faster. Frantál et al. (2013) empirically verified that regenerated brownfields are more likely located in municipalities with a higher development potential, which is determined by spatial peripherality (measured as the distance of the municipality from the regional centre and the distance from main road networks), the rate of local business activities (measured as the number of entrepreneurial subjects per capita), and the quality of local infrastructure.

The above-mentioned national or regional studies implicitly demonstrated that site-specific factors (such as the size of brownfields, type of previous use, land contamination, etc.), may not be determining barriers for regeneration for those brownfields which are located in prosperous and attractive areas (with high redevelopment potential) or in areas with a demand for particular projects (e.g., lack of retail or office spaces), and provided that their ownership relations are not complicated. In this paper, we attempt to contribute to current knowledge about the relevance and significance of location factors for brownfields regeneration by providing an analysis at the level of the city, which has not been realized to date.

3. Geographical context of the study

Some countries, for example the US, Great Britain, France and West Germany, have long-term experiences with the problems of brownfields, which had emerged during the 1970s as a result of massively declining mining, heavy industries and textiles. In comparison, in the post-socialist countries (such as the Czech Republic), brownfields appeared in large quantities only after the collapse of socialism and the return to a market economy, with the restructuring of traditional industries, and following globalization trends during the last decade of the 20th century (Stejskal, 2005). The evolution of brownfields in post-socialist countries, their spatial distribution and functional structure are characterized by some specific factors, such as the large occurrence of agricultural brownfields resulting from the decline of socialist agricultural cooperatives (Skála, Vácha, Čechmánková, & Horváthová, 2013), and military brownfields as relics of the military sector restructuring (Hercik, Šimáček, Szczyrba, & Smolová, 2014). Industrial brownfields, however, are considered the most pressing problem to be resolved within the urban context (Kunc et al., 2014b; Vojvodíková, Potužník, & Buergermeisterová, 2011).

The city of Brno is the second largest city of the Czech Republic, with approximately 370,000 residents, and a greater metropolitan area of approximately 800,000 residents. It is the geographical and administrative centre of the South Moravian region, which borders Austria in the south and Slovakia in the south-east. Brno can be regarded as a typical example of 'mono-centrically' expanding cities. Intensive industrialization throughout the 19th and most of the 20th century has been the leading factor of urbanization. While in the late 19th century Brno was called the "Austrian Manchester" (from the large concentration of textile industries), during the following periods of industrialisation (1918-1989) other industrial sectors such as machinery engineering and chemical industries started to play more important roles in the urban economy (Mulíček and Toušek, 2004).

Brno is a post-socialist secondary city, which has been facing more specific problems and challenges in comparison to the capital cities (Stanilov, 2007). Brno's urban development during the era of socialism (1948-1989), was determined by the centrally planned economy, which supported development of preferred sectors, including heavy and engineering industry, railway transportation, the military sector, collective farms, and an intensive development of prefabricated housing estates (Musil, 2001). Accordingly, the processes of deindustrialisation were delayed in comparison with western societies. After the return to the market economy, the system of post-socialist cities went through a rapid and complicated transition, which was characterized by fundamental changes in all socio-economic structures (Sýkora and Bouzarovski, 2012).

The transformation period was accompanied by serious problems, such as the bankruptcies of many companies, unemployment growth, labour migration, and also the emergence of brownfields (Mulíček and Toušek, 2004). In spite of these concomitant circumstances, Brno has been transformed quite successfully, especially in regard to the development of new industrial sectors, universities, technological parks, innovation centres and other spheres being supported under the 'knowledge city' brand. This successful development has been important from the brownfields regeneration point of view, since the redevelopment of previously-used land is most difficult in shrinking cities, which are affected by collapsing industries and strong depopulation processes (Rumpel, Slach, & Koutský, 2013). Brno is not currently a 'shrinking city', and its progressive urban development creates relatively feasible opportunities for brownfields regeneration.

4. Data and methods

To identify which geographical factors are significant drivers of brownfields regeneration, we have applied spatial and statistical analyses to relatively 'objective' data sources, in comparison to the majority of previous studies, which classified success factors of regeneration according to stakeholder surveys or assessments of a few case studies.

Our analyses were based on the following data sources:

(i) Database of existing brownfields - provided by the Brno City Municipality (2013) consisting of 124 non-regenerated brownfields. The database (in table and GIS layer formats) includes basic site characteristics such as location, name and description of a site, area size, information about the original use, current use, property relations, estimated extent of contamination, available infrastructure, etc. The database covered brownfield sites with an area greater than 0.5 hectares and with the utilisation rate of up to 30%. A few existing brownfields have been partially used for some provisional activities (e.g., some parts or buildings of larger post-industrial complexes are utilized as warehouses, stores or premises for small manufacturing). These temporarily utilized facilities, however, cannot be regarded as regenerated brownfields, since no remediation and regeneration have been exercised.

(ii) Database of regenerated brownfields - provided by the Brno City Municipality (2013) consists of 63 successfully regenerated brownfields. The database (in table and GIS layer formats) includes basic site characteristics such as location, name and description of the site, area size, information about the original and current use, and the year of regeneration. Only brownfields after complete or almost complete remediation and regeneration were included in the database.

(iii) Data related to the location of brownfields – a database of selected socioeconomic indicators for the city's basic settlement units (BSUs) or city districts (CDs), representing locations of brownfields, has been compiled by the researchers. Data from the 2001 Census (CSO, 2001)) as the time prior to brownfields regeneration, as well as some more recent data for specific indicators, were used. These included information about population density, unemployment rate, economic activity, educational level and housing development. Also, the property prices in the location can play a significant role in the potential investor's decision making. Therefore, data about the average price of a standard flat, provided by the Institute of Regional Information (IRI, 2009) were included in the analyses. Finally, proximity of brownfield sites to the central train station (representing the functional centre of the city), and proximity to the arterial road network were calculated in ArcGIS. Since the inner structure of the city might affect the process of brownfields regeneration, we

have also divided the city into morphogenetic zones (see *Fig. 1*), which were delimited according to the original concept of Mulíček (2007), adapted by Podhrázský (2012), who defined Brno's zones according to morphological characteristics (age and density of buildings, integration periods, and prevailing socio-economic function).

The selected indicators (see *Table 1*) have been chosen as factors potentially affecting brownfields regeneration; however, the selection was also determined by the availability of statistical data for the level of basic settlement units.

Table 1: Selected indicators used in statistical analyses

Indicator	**Measure**	**Spatial level***
Zoning	Location of brownfield within city morphogenetic zones	city level
Centrality	Proximity to central train station [km]	city level
Transport links	Proximity to the arterial road network [km]	city level
Population density	Population per km^2	BSU
Unemployment	Unemployment rate [%]	BSU
Economic activity	Economically active population [%]	BSU
Education level	Population with university degree [%]	BSU
Property value	Average price of standard flat [millions of CZK]	BSU
Retail saturation	Total retail sale area [m^2]) per capita	CD
Housing development	Number of constructed flats (200-2008) per 1000 population	BSU

*Notes: * Basic settlement unit (BSU) is the smallest statistical unit used for the processing of Census data. City districts (CD) are the main administrative units of so-called statutory cities (cities with over 40 thousand inhabitants), which have their own autonomous councils. Brno is divided into 29 city districts and consists of 202 basic settlement units.*

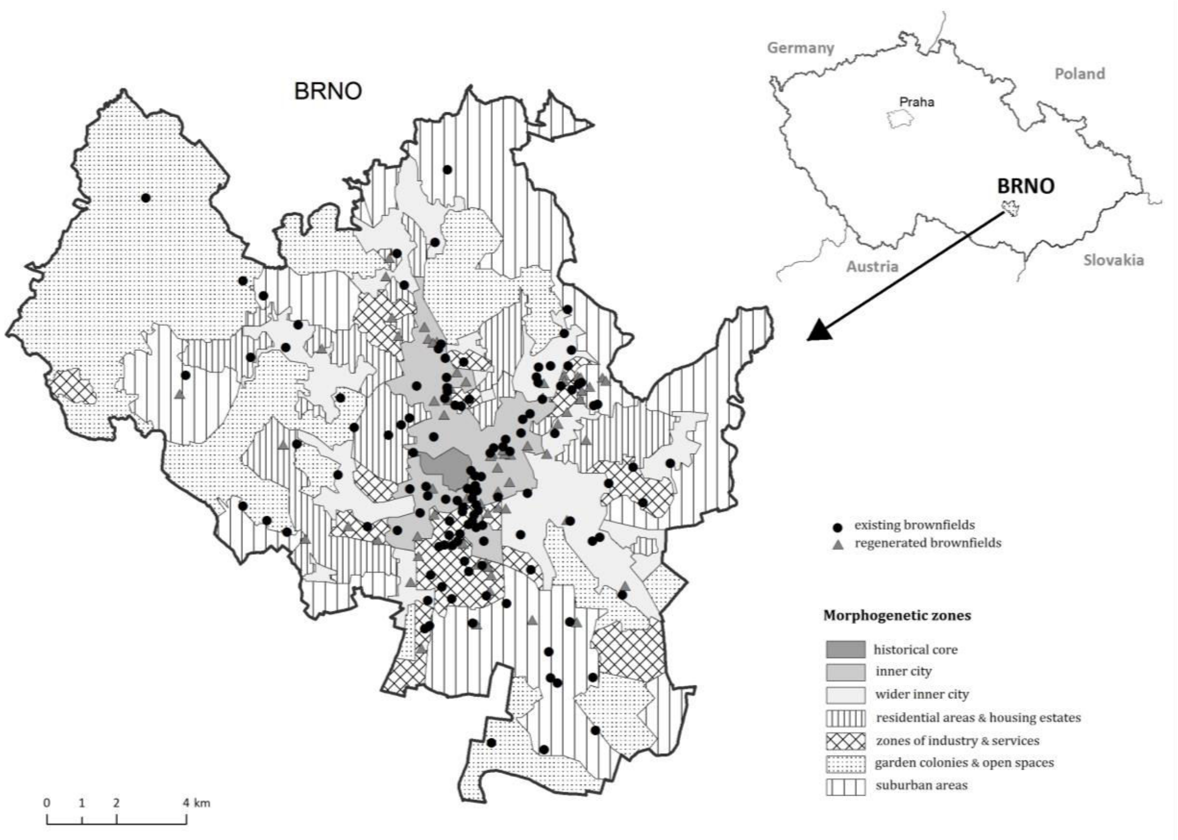
The analyses presented in this paper consisted of several steps. *First*, we investigated the spatial distribution of existing and regenerated brownfields according to their original use, area size, and their current use. *Second*, we assessed the extent of functional change of regenerated brownfield sites (from the original to new use) both in the city as whole and within specific morphogenetic zones. *Third*, we carried out a statistical analysis to investigate the possible occurrence of significant differences between socioeconomic characteristics of areas with existing brownfields and areas with regenerated brownfields. Considering the exploratory nature of our case study and the relatively small sample size, we attempted to keep a balance between the quantitative analysis and the qualitative discussion of the patterns found. Thus we put less emphasis on the complexity of the analysis and more emphasis on the interpretation of its statistically most evident findings. Thus, we used the analysis of variance (ANOVA) instead of logistic regression, which could be also suitable for our data analysis (i.e., in predicting regeneration or not). ANOVA matches the exploratory nature of the analysis presented here, as it is computationally elegant and a substantive illustration of whether or not the mean values of local socioeconomic indicators for groups of regenerated and non-regenerated brownfields, are equal or not.

5. Results

5.1 Spatial distribution and functional structure of brownfields

According to the City of Brno (2013), there are 187 brownfields located in the Brno City area, of which 63 were successfully regenerated, while 124 sites stay for the time being derelict or they are underused without regeneration. The regenerated projects represent one third (34%) of all brownfield sites, but only 26% of the total brownfield area. Brownfields originally occupied almost 2.5% of total city cadastral area (230 km^2). The total area of regenerated brownfields is now 150 hectares, while existing brownfields still occupy about 418 hectares (1.8% of the total city area).

Fig. 1: The Spatial Distribution of Brownfields: Brno City Morphogenetic Zones



Data source: Brno City Municipality (2013). Graphic elaboration by authors.

The distribution of brownfields is spatially uneven, i.e. more brownfields are concentrated in some urban districts, with respect to morphogenetic zones (*see Fig. 1 and Table 2*).

Table 2: Spatial distribution of all brownfields within Brno City morphogenetic zones

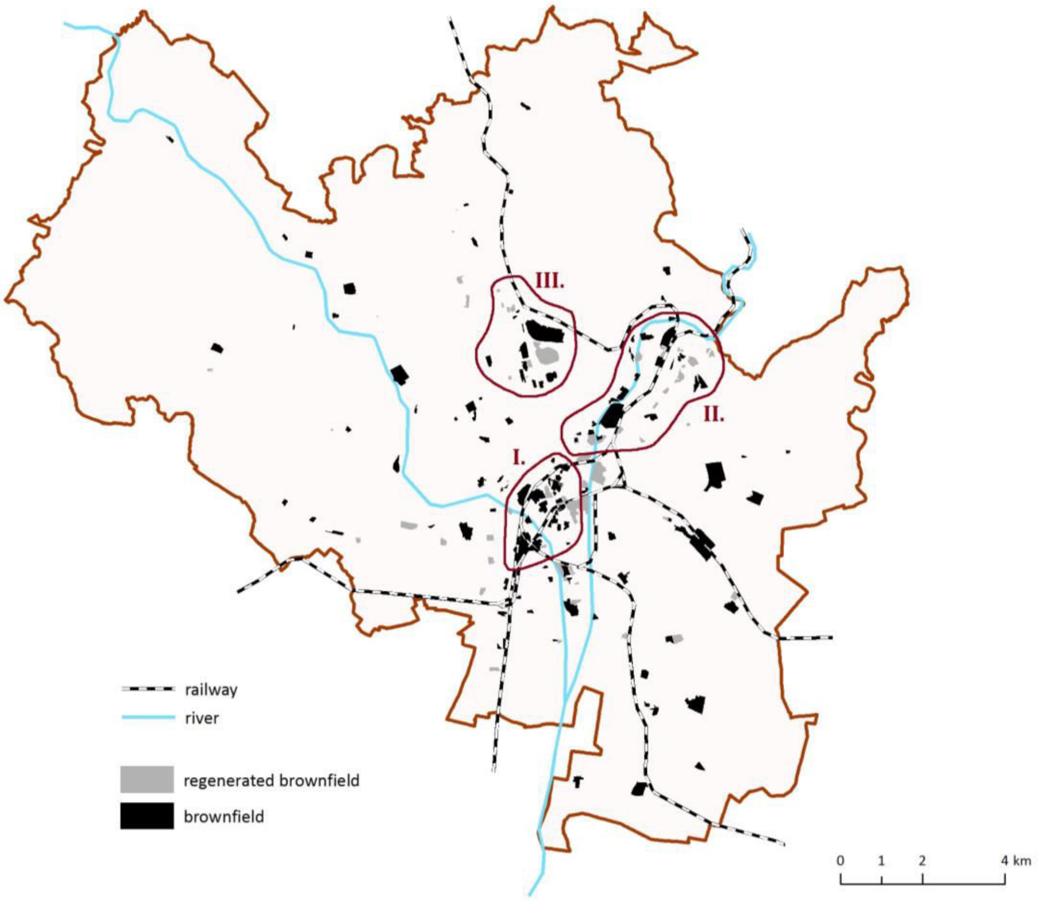
Morphogenetic zone	**Number of brownfields according to its original use**						**Total area** (ha)
	Agriculture	Industry	Military	Railway	Civic	Other	
Historical core	0	1	0	0	0	0	0.9
Inner city	1	40	5	1	11	6	156.3
Wider inner city	2	38	2	2	9	3	182.2
Residential areas and housing estates	2	1	2	0	7	2	33.7
Zones of industry and services	8	12	0	1	3	3	127.0
Garden colonies and open spaces	7	10	0	0	3	2	67.9
Suburban area	0	0	0	0	0	0	0
Total (%)	**11 %**	**54 %**	**5 %**	**4 %**	**17 %**	**9 %**	**568**
Centrality (km)	**4.3**	**3.3**	**3.4**	**1.1**	**3.8**	**3.7**	**3.4**

Data source: Brno City Municipality (2013). Descriptive statistics: computed by authors.

The highest concentration and the largest area of brownfields are within the inner and wider inner city zones. Brownfields located within the zone of industry and services represent approximately 14% of the total number, but over one fifth of the total brownfield area. The distribution of brownfields in Brno is an example of a ´dispersed spatial pattern´ (Filip & Cocean, 2012), which is characterized by the insular distribution of brownfields, which are grouped into several clusters generating a specific urban fabric. The brownfields are located both inside the built-up area and at the city periphery, thus affecting areas with highly important urban functionality (residential, recreational, open urban spaces).

The distribution of specific types of brownfields reflects the historical development of the urban settlement and functional differentiation of Brno's space, particularly the dislocation of industrial factories, which were tied to the rail network, water sources (rivers) and the common supply of steam and energy. In this sense, three main clusters of brownfields can be identified (see *Fig. 2*): (i) an area located south of the central city, which is intersected by rail tracks (characterized by a mixture of different types of brownfields, including industrial, transport, warehouses, agricultural, etc.); (ii) the Posvitavská industrial zone (textile and electro-technical industrial factories located along the Svitava river): and (iii) the area located north of the central city (the Královopolská machinery factory complex and different military facilities). While the post-industrial and railway brownfields are located mostly within the inner or wider inner city areas, the brownfields of agricultural origin tend to be located at the periphery, where facilities of peri-urban agriculture had been widely developed during the socialist era.

Fig. 2: Spatial distribution of brownfield sites in Brno with three main clusters delimited



Data source: Brno City Municipality (2013). Graphic elaboration by authors.

The functional distribution of existing and regenerated brownfields is presented in Tables 3 and 4. About one-half of the existing brownfields is still represented by previous industrial sites and vacant factory complexes (*Table 3*). The second most frequent type is represented by derelict buildings of previous civic amenities (i.e., educational, sport, cultural and other community facilities). The third most frequent type is post-agricultural brownfields represented by facilities of abolished socialist agricultural cooperatives. A significant proportion of existing brownfields in the city is also represented by post-military structures (training grounds, barracks, hangars, etc.), which are evidence of Brno as an important centre of the Czech army (with a large Military Academy). The category 'other' includes different types of objects, from previously-used parking lots and garages, scrap-yards, and unidentified facilities. Post-agricultural and military sites occupy on average the largest areas, while the smallest ones are sites of abandoned civic infrastructure structures.

Table 3: Structure of existing brownfields according to the original use and area

Original use	**Total number**	**% of total number**	**Total area (ha)**	**% of total area**	**Average area (ha)**
Agricultural	14	11	77	18	5.5
Industrial	61	49	236	56	3.9
Railway	7	6	16	4	2.3
Military	9	7	40	10	4.9
Civic amenities	19	15	32	8	1.4
Housing	1	< 1	< 1	< 1	0.8
Other	13	11	17	4	1.3
Total	**124**	**100 %**	**418**	**100 %**	**3.4**

Data source: Brno City Municipality (2013). Descriptive statistics computed by authors.

A predominant type of new use after regeneration is represented by new industrial or manufacturing production, followed by the construction of new civic (medical, cultural, education and research) amenities, supermarkets, shopping malls, and commercial or multifunctional projects (see *Table 4*).

Table 4: Structure of regenerated brownfields according to current use and area

Current use	**Total number**	**% of total number**	**Total area (ha)**	**% of total area**	**Average area (ha)**
Industrial, manufacturing	23	36	75	50	3.3
Civic amenities	18	29	25	17	1.4
Retail, commerce	13	21	41	28	3.2
Housing	6	9	4.5	2.5	0.8
Mixed (housing/commerce)	3	5	4	2.5	1.3
Total	**63**	**100 %**	**150**	**100 %**	**2.4**

Data source: Brno City Municipality (2013). Descriptive statistics computed by authors.

5.2 Functional restructuration of urban space

Almost 40% of industrial and civic amenities brownfields (representing about 35% of the total area within these two categories) have been already successfully regenerated brownfields (*Table 5*). In comparison, only 30% of cases (representing only 12% of total area) of agricultural brownfields were regenerated at the current time. This indicates that fewer large structures have been regenerated than likely so far (the average area of regenerated brownfields is 1.6 hectares, while it is 5.5 hectares in the case of existing brownfields). In practice, a large area of sites with many buildings and facilities means a mixed ownership with more proprietors (i.e., as a result of the restitution and privatization processes) of different concerns, which represents a regeneration barrier. In the case of agricultural brownfields, there is also a significant difference in distance from the city centre -- between regenerated (3.4 km) and existing ones (4.7 km).

At present, no military or railway brownfields have been completely regenerated. It could be caused by the average larger areas (in the case of military sites), low attractiveness (in the case of railway objects), potential ecological burden (contamination), and/or more strict regulations related to the original state properties, which are obviously not allowed to be sold and redeveloped for purely commercial purposes.

Table 5: Functional change of regenerated brownfield areas

Original use	**Regenerated area (ha)**	**Regenerated area (%)**	**Current use**	**Number of projects**	**Area (ha)**	**Functional change (%)**
Agricultural	9.5	12%	Industrial	1	2.3	100%
			Amenities	3	6.1	
			Retail, commerce	2	1.0	
Industrial	123.5	35%	Industrial	21	71.8	42%
			Amenities	8	8.9	
			Retail, commerce	8	36.4	
			Housing	2	3.1	
			Mixed	2	3.3	
Railway	0	0%	-	0	0	0%
Military	0	0%	-	0	0	0%
Amenities	14.4	35%	Industrial	1	0.9	32%
			Amenities	6	9.8	
			Retail, commerce	2	2.5	
			Housing	3	0.6	
			Mixed	1	0.6	
Other	2.7	14%	Amenities	1	0.4	100%
			Retail, commerce	1	1.4	
			Housing	1	0.9	
Total	**150**	**100**		**63**	**150**	

Data source: Brno City Municipality (2013). Descriptive statistics computed by authors.

Overall, there was a functional change of land use on 68.5 hectares of the total 150 hectares of regenerated brownfields, representing circa 46% functional change. Nearly half of the regenerated area continues to be used for industrial and productive activities; however, the specific focus of activities has been changed (small-scale manufacturing and logistics prevail). The most significant functional change is the transition from industry to trade, retail sale, logistics and associated business activities. Kok (2007) emphasizes that the retail sector, in these cases, is a reliable and important source of income and is becoming indispensable in these circumstances as a key factor influencing the feasibility of the regeneration project. Construction is often limited by the surrounding buildings and transport infrastructure, parking places are usually in the basement or on the roof. In most cases, the projects have improved the social, economic, as well as urban environments of originally unappealing industrial parts of city. For some, due to an exposed location within the inner city, the new shopping sites (supermarkets, malls) have become sought-after pulsating organisms in the daily ´rhythm of the city´ (Mulíček, Osman, & Seidenglanz, 2014).

It is interesting as well to take into account the time period when the project of regeneration was implemented. In the first wave (the period from the mid-1990s to 2006), 42 brownfields were regenerated. An insufficient supply of retail networks and services caused these changes predominantly (75%): the former industrial buildings in the inner city were redeveloped for the construction of new supermarkets (35%), as well as amenities and services (25%), while the regeneration of public housing was exceptional (5%). Mostly so-called total regenerations (i.e., demolition of old buildings and construction of new ones) have been realized in most of the cases for retail infrastructure developments. In the second wave (from 2007 to the present), the frequency of regenerations of former civil facilities for new housing increased (40%), while the use of brownfields for new civic amenities (25%) and especially for the development of large format stores (5%) increased. Regeneration for new productive activities (manufacturing, logistics) maintained its stable representation in both time periods (35%).

Table 6: Mean values of selected location variables for different groups of brownfields

Location variables	**Status of brownfield**		**Regenerated – current use**				
	Existing	Regenerated	Industrial	Retail	Civic	Housing	***Eta***
Centrality	3.4	3.4	3.8	2.2	3.5	4.5	*0.35**
Transport link	5.5	5.8	5.7	4.1	6.9	6.7	*0.34*
Population density	2,671	3,015	1,527	2,648	4,150	4,881	*0.51***
Unemployment	10.1	9.8	10.1	10.0	9.6	9.3	*0.24*
Property value	1,947	1,958	1,895	1,940	2,086	1,904	*0.54***
Housing development	64	71	60	47	95	104	*0.39**
Retail saturation	4.4	4.4	5.7	5.7	2.7	3.5	*0.27*
Economic activity	48.8	48.9	48.5	48.8	49.2	49.1	*0.26*
Education level	21.3	21.0	18.3	20.1	24.1	24.5	*0.44**

*Notes: Results of ANOVA, Eta coefficients of association are significant at: **p < 0.01; *p < 0.05*
Data sources: Brno City Municipality (2013), Czech Statistical Office (2001), Institute of Regional Information (2009). Statistical analysis by authors.

5.3 Spatial patterns of redevelopment

If we analyse all brownfields in total (respectively as two groups only, one group of existing, and the second of regenerated brownfields), there are no patterns or regularities in their spatial distribution. Both the regenerated and existing brownfields are on average at the same distance from the city centre (circa 3.4 km) and the motorway axis (circa 5.5 km). Regenerated brownfields are more likely located in areas with higher population density and higher levels of housing development (see *Table 6*); however, these differences are not statistically significant.

If we analyse brownfields separately by type of use, however, certain spatial patterns are emerging. Regeneration projects in the form of retail stores and civic infrastructure are located closer to the city centre (on average 2.2 km), while new industrial developments (3.6 km) and housing developments (4.5 km) are more distant from the city centre. Our analysis has detected that brownfields regenerated into projects of new housing or civic amenities are more likely located in inner or wider inner city zones with larger proportions of highly educated people (with university education), higher population density and generally higher levels of new housing development. The new development projects usually represent more quality and generally more expensive housing in these areas.

We can hypothesize that in urban areas with a higher proportion of highly educated people (with higher disposable incomes and purchasing power), there is a greater demand to re-develop existing brownfields into new civic amenities and alternative forms of housing (such as loft apartments or multifunctional buildings with flats, offices and shops), instead of sustaining their original industrial or productive use. Moreover, highly educated people have generally higher socio-political efficacy and they can be more effective in pushing local policy makers to stimulate redevelopment of underused or abandoned sites (e.g., by investing into so called public-private partnership projects – see e.g., Kalberer, Klever, & Lepke, 2005).

We also found slightly higher levels of unemployment in the areas with existing brownfields, but the differences were not significant. Such findings are in accordance with the results of previous studies realized at the regional level in the USA and England (Lee, 2008; Tang & Nathanail, 2012), which demonstrated that differences in local socio-economic characteristics (including income, employment, education, housing quality, etc.) affect the rate and processes of brownfield regeneration.

Table 7: Spatial and functional distribution of regenerated brownfields

Morphogenetic zone	Rate of regeneration		Current use after regeneration (%)				
	area (ha)	% of total	Industry	Civic	Retail	Housing	Mixed
Historical core	0	0	0	0	0	0	0
Inner city	58.4	37	25	30	27	9	9
Wider inner city	59.7	33	59	32	9	0	0
Residential areas and housing estates*	2.5	7.5	0	20	20	40	20
Zone of industry and services	21.5	17	23	33	44	0	0
Garden colonies and open spaces	8.0	12	50	0	0	50	0
Brno (Total)	**150 ha**	**26 %**	**36 %**	**29 %**	**21 %**	**9 %**	**5 %**

*Notes: *No regeneration has been realized so far within the residential areas (villa districts). All five regenerated brownfields with total area of 2.5 hectares are located within the housing estates areas.*
Data source: Brno City Municipality (2013). Descriptive statistics computed by authors.

The rate of regeneration with respect to the functional structure of regenerated brownfields within the Brno morphogenetic zones is shown in *Table 7*. Generally, the higher regeneration rate was detected in inner and wider inner city zones. Industrial brownfields have represented two thirds of all brownfields located in the inner city zone. Of those regenerated industrial brownfields located in the inner city, only one fourth gained new industrial use while the majority has been redeveloped for retail stores and various civic amenities and housing developments. Similarly, the majority (77%) of regenerated brownfields located within the zone originally designed for industry and services (which is located close to the inner city) has been redeveloped for retail and civic amenities. In comparison, more than one half (59%) of regenerated brownfields located within the wider inner city has been used for new industrial activities. In other words, the most significant functional change of space has appeared within the inner city morphogenetic zone, where industry has been replaced by the construction of stores and amenities.

6. Conclusions

It seems to be widely agreed to by stakeholders and by experts that the location of brownfields is an important factor affecting investor decisions and potential brownfields redevelopment. The very few previous regional studies based on analyses of comprehensive brownfield inventories (Frantál et al., 2013; Longo and Campbell, 2007), have verified that brownfields located in attractive areas with favourable economic development potential and good transport links are more likely to be regenerated than brownfields located in less-favoured peripheral areas. Our analysis of brownfields at the city level, however, has not detected any general spatial pattern or simple equation for regeneration (such as "the closer to city centre the better"), which may be valid for all types of brownfields. Rather, regeneration is a function of local development potential, local occupier demand for a specific utility, and limitations based on the city's planning regulations.

Generally, higher rates of regeneration (over 30%) have been detected in the densely built-up areas (the inner and wider inner city zones). An even higher rate of regeneration (over 50%) has been detected specifically within the zones of housing estates. On the other hand, less pressure on brownfields regeneration has been seen in areas with low population density and with a greater supply of green spaces (i.e., garden colonies, open spaces, old and new industrial zones at the city outskirts, and also within the villa residential areas). The factors of centrality (proximity to the city centre) and transport links (proximity to motorway axis) are positively associated with retail and business development regeneration projects, but negatively associated with projects of housing development and construction of civic amenities, for which population density and the social structure of the local population (e.g., the level of education) are significant positive factors.

The most significant functional change of urban space (perhaps typical for post-socialist cities, as exemplified by Brno) is represented by the transition from heavy, engineering and textile industries, to trade, logistics, retail sale and associated business activities. This functional change is most evident in the inner city areas where the majority of post-industrial brownfields have been redeveloped (often after complete demolition) into supermarkets, shopping malls and other facilities of civic amenities. The regeneration of brownfields for the purpose of new housing development is still quite sporadic and the realized projects have a form of smaller individual structures, not of loft apartment complexes.

Our findings are in accordance with one study from the USA (Lange & McNail, 2004) which showed that, in general, larger brownfields (especially in the case of post-industrial and post-agricultural sites) are less likely to be regenerated and would take longer to redevelop than smaller sites. In this sense, large post-agricultural, post-industrial, post-military sites and railway objects, located further away from inner parts of the city, seem to be the most critical brownfields whose regeneration will be hardly realized without some form of political intervention and/or investment of public monies, to stimulate market activities. This is important information for decision makers who are responsible for the prioritizing and marketing of brownfield sites for the purposes of allocation of limited public resources.

The studies which were based on surveys or interviews with stakeholders (Adair et al. 2000; De Sousa, 2000) demonstrated that the primary reason why the private sector invests in some regeneration areas is the perception of achieving some target rates of return. The private sector is opportunity driven, invests in areas where it is comfortable and where returns are achievable commensurate with the risk taken - in this respect, grant regimes should be used as tools to lever investment. Conversely, the principal reasons for non-investment include the negative image of locality or neighbouring environments, lack of capital (funding) and the perceptions of bureaucratic grant regimes (Adair et al., 2000). Similarly, Coffin and Shepherd (1998) identified four key barriers to regeneration, including legal liability, limited information, limited financial resources, and limited demand for the properties.

The economic, legislative and procedural-administrative issues that have been perceived by stakeholders as general barriers to regeneration, have also been realized in surveys in the Czech Republic (Frantál et al., 2012). This Brno case study contributes to these understandings by detecting the main geographical barrier to regeneration at the level of the city, which is the location of brownfields in areas being more distant from the city centre, being sparsely populated and with a greater supply of developable green spaces, with a limited demand for previously-used properties. In many cases, however, even good conditions (i.e., good location) for brownfields regeneration may not be utilized if there are some subjective barriers, such as weak local political involvement, a deficit of information, poor communication and cooperation among stakeholders – the result is that the key actors are not able to exploit the local potential. On the contrary, "soft factors" such as political leadership and adequate cooperation between stakeholders can turn even insufficient local conditions and low potential into positive results. There are many examples of such so-called good practices of regeneration (Brno City Municipality, 2013), reporting how human factors such as an initiator of brownfields regeneration (e.g., making a good project proposal, gaining local community support, acquiring grant titles, etc.) have overcome location handicaps or modified the characteristics of suitability of area or of a concrete brownfield site according to specific project purposes.

Our case study has fulfilled its main objective - to explore and identify what geographical factors have a significant influence on the regeneration or stagnation of brownfields in urban spaces. Our findings concerning the spatial regularities of brownfields evolution may represent valuable information for all stakeholders (e.g., city councils, urban planners, regional development agencies, etc.) responsible for wider territories (cities, districts) or for clusters of brownfields (portfolios), which need to allocate limited available resources, time and energy to those brownfield sites that are assessed and prioritized as being most practical or critical to address: in particular, for those in locations where market forces are considered to be weak and some form of public intervention to stimulate investors activity is required.

Our study raises some questions for future research, such as: Are the identified spatial regularities in the evolution of brownfields and their regeneration typical only for Brno City, or are they valid for other European cities, particularly for those with polycentric development, and perhaps also for those cities which have experienced post-socialist histories? Are location factors more significant for potential regeneration than site-specific factors, or vice versa? Resolving such issues, however, requires comprehensive and reliable brownfield databases in geographic information systems (Hayek, Novak, Arku, & Gilliland, 2010), which will be provided only in cooperation with responsible institutions, decision makers and site owners, and hopefully will be open-sourced for further research.

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