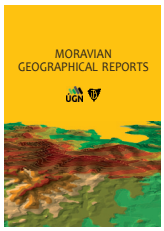

MORAVIAN GEOGRAPHICAL REPORTS

sciendo

The Czech Academy of Sciences, Institute of Geonics
Palacký University Olomouc, Faculty of Science

journal homepage: www.geonika.cz/mgr.html

doi: https://doi.org/10.2478/mgr-2023-0008

Spatial factors affecting the functional diversity of regenerated brownfields: The case of Silesian Voivodeship (Poland)

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Abstract

Until 1990, the Silesian Voivodeship was one of the most industrialised regions in Central Europe. The restructuring of the national economy after the change of the political system, in particular the extensive deindustrialisation, resulted in the emergence of substantial quantity of post-industrial brownfields. During the research we identified a total of 125 post-industrial brownfield sites that had undergone a regeneration process between 1990 and 2019. The total value of these regeneration projects was estimated at over EUR 1.7 billion. About 55% of the projects were carried out by public bodies, 40% by private enterprises and 5% by non-governmental organisations. The EU aid from structural funds was used in 37% of projects. The aim of the paper is to provide new empirical evidence about the role of spatial factors on the regeneration and new functional use of the brownfields. The analysis has revealed that there is a statistically significant relationship between the distance from the city centre and the functions of regenerated brownfield sites: commercial services were located closest to the centre, whereas manufacturing plants and investment zones were found at the greatest distance from the city centre. The research has also shown the crucial role of post-industrial heritage for projects related to redevelopment for public services, which was insignificant for other project types. These results have been interpreted in the context of the rent gap theory and the brownfield redevelopment potential model (the so-called ABC model).

Keywords: *post-industrial brownfield regeneration, rent gap theory, European Union aid funds, Silesian Voivodeship, Poland*

Article history: *Received 21 October 2022, Accepted 10 May 2023, Published 30 June 2023*

1. Introduction

According to one of the most common definitions, brownfield is a term referring to

> "any land or premises which has previously been used or developed and is not currently fully in use, although it may be partially occupied or utilised. It may also be vacant, derelict or contaminated. Therefore, a brownfield site is not available for immediate use without intervention" (Alker et al., 2000, 64).

The term brownfield most often refers to post-industrial sites but may also include areas with other functions in the past, such as transport, military and even agricultural (Ferber et. al, 2006). In this paper, however, we decided to focus exclusively on the issues of the post-industrial brownfields due to limited data availability about other types of brownfield sites in Poland, particularly in the region chosen as the research area. The brownfield regeneration process can be defined as "the management, rehabilitation and return to beneficial use of brownfields" (Franz et al., 2006, 139). Redevelopment is a term often used as a synonym for regeneration (cf. Rey et al., 2022), but it seems to be more related to physical change in the use of space (Ferber et al., 2006). Remediation, in turn, is a term mostly used in an environmental context referring to decontamination of soils at brownfield sites (Alker et al., 2000). Built cultural heritage (or simply built heritage), another important term in the context of this research paper, refers to buildings, monuments, and structures of architectural and historical value, and is an important resource contributing to the cultural identity of residents (Tan & Ti, 2020). Finally, heritage reuse can be defined as a process undertaken to "to preserve the essential qualities and values of a heritage building while improving it to be used in the present and transferring it to the future" (Arfa et al., 2022).

Over the past two decades, several major research works, including governmental and international projects aimed at identifying success factors of brownfield regeneration processes, were implemented in order to support public policy in this field (e.g. English Partnerships, 2003; CABERNET, 2006; Ferber et al., 2006; Tölle, 2009; Osman et al., 2015; Longo & Campbell, 2017). Considering the spatial scale, the drivers and barriers of brownfield regeneration can be divided into three groups: general, location and site-specific factors (Frantál et al., 2013). The location factors, and among them the centrality of brownfield sites, are shown to be a significant driver of successful regeneration in some studies (Frantál et al., 2013; Osman et al., 2015; Longo & Campbell, 2017; Turečková et al., 2018, 2021; Preston et al., 2023). There is relatively little evidence, however, on how different new uses of regenerated brownfields are related to their proximity to the city centre: Frantál et al. (2015a) is one the few examples. Besides, the role of the cultural values of built heritage located on brownfields as a regeneration factor seems to be underrated and only recently has been analysed in depth (Szabó & Bozsoki, 2022).

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The aim of the paper is to answer the following research questions: First, is there a relationship, and to what extent, between the distance of completed brownfield regeneration projects from the city centre and the new use of the site? In other words: which of identified new uses of regenerated brownfields are likely to be located closer or further from the urban core, and which are independent from this factor? The second question relates to the post-industrial heritage, re-used as a part of a brownfield regeneration project: Is the new use of a regenerated brownfield site related to the presence and cultural value of these resources? The key element of the research procedure is the interpretation of the results in the context of the rent gap theory and the brownfield redevelopment potential model (so-called ABC model).

2. Theoretical background

The literature on brownfield regeneration can be divided into 4 main thematic groups: (1) brownfield redevelopment potential; (2) factors affecting redevelopment for a specific new use; (3) analysis and evaluation of regeneration effects; and (4) proposals of regeneration management tools. Firstly, however, rent gap theory, which was not developed specifically in the context of brownfield regeneration but plays an important role in interpreting the results of this paper, will be discussed here.

2.1 Rent gap theory

Rent gap theory was originally built to explain the redevelopment process of housing stock in city centres as a part of the gentrification phenomenon (Smith, 1979). It can also be helpful in understanding the motivations of developers to re-develop post-industrial brownfields, however, for various residential uses.

The key terminology, on which the theory is based, includes four definitions: house value (or generally property value); property sale price; capitalised ground rent; and potential ground rent. House value is measured by the quantity of socially necessary labour power required to produce it, taking into account its rate of depreciation through use, as well as its rate of appreciation through the addition of more value. The sale price reflects not only the value of the house, but also an additional component for rent since the land is generally sold along with the structures it accommodates. Whereas the ground rent is commonly defined as a claim made by landowners on users of their land, the capitalised ground rent is the actual quantity of ground rent that is appropriated by the landowner, given the present land use. The potential ground rent is, in turn, the amount that could be capitalised under the land's "highest and best use", which means, usually due to location, that such an area may be able to capitalise higher quantities of ground rent under a different land use than the present one. The

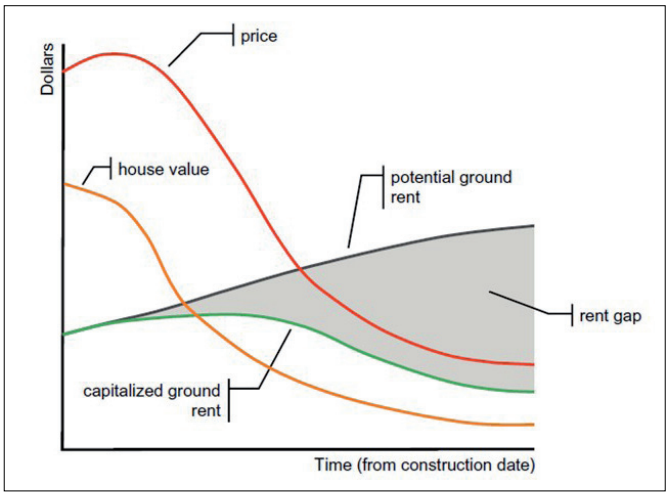

Fig. 1: The rent gap theory
Source: Diappi & Bolchi (2008, 9)

rent gap is the disparity between the potential ground rent level and the actual ground rent capitalised under the present land use (see Fig. 1). It is generated primarily by capital depreciation (which diminishes the proportion of the ground rent able to be capitalised) and by continued urban development and expansion (which has historically raised the potential ground rent level in the inner city). Only when this gap emerges can redevelopment be expected since if the present use succeeded in capitalising all or most of the ground rent, little economic benefit could be derived from redevelopment (Smith, 1979; Clark, 1995; Darling, 2005; Diappi & Bolchi, 2008; Lees et al., 2008; Slater, 2015).

2.2 Brownfield redevelopment potential

The key role in the classification of the economic potential for redevelopment of brownfields plays a model created for the UK government by the National Regeneration Agency (English Partnerships, 2003), which became the basis for the so-called ABC model (Franz et al., 2006). The main idea behind this concept is to divide brownfield sites into three categories based on the estimated cost of redevelopment and the potential value of new land use: (A) suitable for redevelopment based on the market rules without public intervention; (B) requiring public intervention or funding through public-private partnerships; and (C) unsuitable for any economically viable redevelopment (CABERNET, 2006; see Fig. 2). It should be noted, however, that this model has a dynamic character, as the actions of public authorities resulting in a reduction of the redevelopment cost or an increase in the expected value may contribute to a change

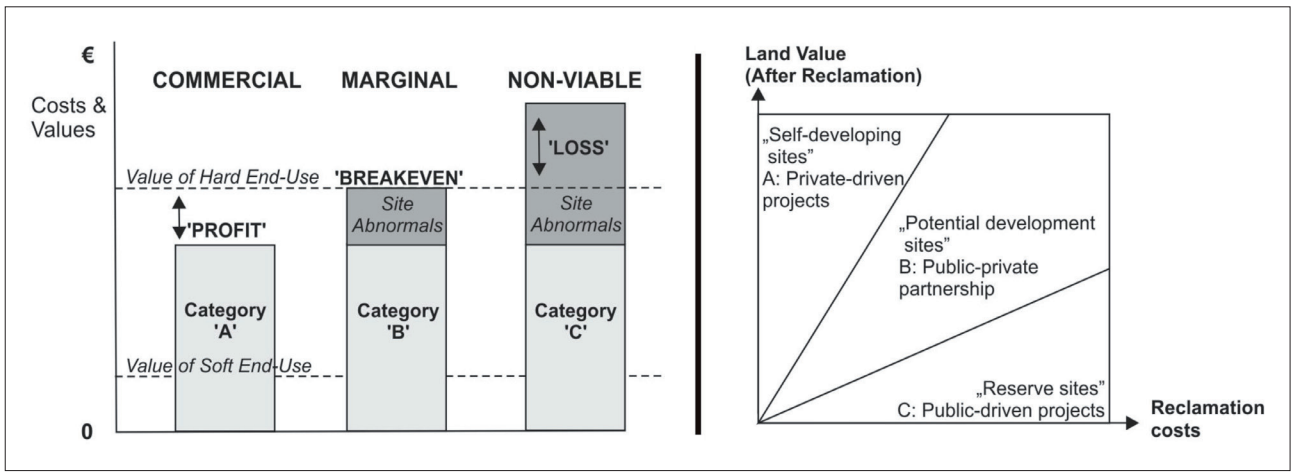

Fig. 2: Left: The Cabernet ABC Model
Source: Franz et al. (2006, 138). Right: The ABC model –brownfield redevelopment financing models (Source: Doleželová et al. (2014, 35)

in the classification of a given area to a more favourable one (English Partnerships, 2003). Considering the weaknesses of this model, Franz et al. (2008) note that in some cases parts of one brownfield site can belong to different categories; furthermore, a redevelopment of one part can involve re-categorisation of the remaining area. These authors also propose a further development of this model by adding a fourth D-category, covering areas that cannot be redeveloped even by the public sector, for which a possible scenario is natural succession. Doleželová et al. (2014) argue, that the practical usability of the ABC model may be limited, as in reality public subsidies are often directed to projects implemented in commercially attractive areas (category A), which limits the redevelopment opportunities for areas with little or no potential to attract private investment (categories B and C). Vojvodíková et al. (2021) note, that even though the ABC(D) classification model is widely accepted by experts, there are no universal criteria for assigning a given brownfield to an appropriate category. Therefore, these authors propose to base the categorisation on an assessment whether there is no obvious obstacle to redevelop a brownfield site (A), there is a barrier that can be removed within a few years (B), there is a significant barrier that precludes the site from redevelopment (C), or the site poses a danger resulting from contamination or degraded buildings (D) (cf. Vojvodíková et al., 2021, 4).

Regarding the location-related factors affecting brownfield redevelopment potential, Franz et al. (2006) only briefly mention 'wrong' location as a barrier to sustainable regeneration. Frantál and colleagues (2013) associate the impact of location with a local development potential or the area competitiveness, being the resultant of environmental conditions, economic potential, and social capital. These authors classify the location issues as meso-level factors, including transport links, the socio-demographic structure of local populations, economic potential, rates of unemployment and business activities, social capital et cetera (see Frantál et al., 2013). Further studies emphasise the importance of proximity to railway lines, support of local government and the removal of contamination before the start of an investment (Osman et al., 2015), the threat of the risk of environmental burden related to former functional use (Novosák et al., 2013), or unemployment and depopulation in the neighbouring area (Tintěra et al., 2014), as well as the demand for real estate of a given type and appropriate planning regulations (Frantál et al., 2015a).

Apart from the location issues, the site-specific factors affecting the redevelopment potential of brownfields should be considered. Frantál et al. (2013) mention both the physical aspects of brownfield sites (size, original use, buildings and structures, contamination, infrastructure) and those of a socio-economical nature (ownership relations and property price). Some of them are believed to be universal in nature, e.g. complex ownership structure and environmental burden leading to higher redevelopment costs (Frantál et al., 2015b). The remediation costs, however, may be difficult to predict before the beginning of the process (Kurtović et al., 2014). The barriers also include excessive duration of the period from the end of the original industrial activity to the decision to redevelop the brownfield, resulting in various forms of temporary land use (Johnson et al., 2009), and the asymmetry of information disadvantageous for potential investors (Trouw et al., 2020). Besides, the negative image of brownfields is mentioned as a constraint to redevelopment, but it can be overcome thanks to a pioneering approach of certain developers (Krzysztofik et al., 2013). Other identified site-specific barriers include uneven topography, irregular plot shape, and water bodies (Preston et al., 2023). The success factors in the completion of already started projects are the involvement of all stakeholders (Rizzo et al., 2015), particularly the local community (Lehigh et al., 2020), the level of income of local residents and the share of green areas in the designed land use (Green, 2018), as well as good management in the public sector, especially in less developed regions with lower investment attractiveness (Klusáček et al., 2018).

2.3 Factors affecting brownfield redevelopment for a specific new use

The research to date (Frantál et al., 2015a) demonstrates that the central location of a brownfield and its good transport connections are positively correlated with redevelopment into commercial facilities and offices, and negatively with the redevelopment for housing and public services. The preferences of residents are also of great importance, who, according to the research, value functionality more than the aesthetics of completed projects (Martinát et al., 2018), and the further the area is from the city centre, the stronger the preference for recreational functions (Navrátil et al., 2018). Researchers have also identified a pattern according to which transformations into a recreational function prevail in the case of the largest facilities, including such specific ones as mine dumps, disused settling ponds or landfill sites (Pytel et al., 2021). Moreover, the redevelopment of brownfield areas for recreational purposes is favoured by the public ownership of land and location in the vicinity of residential districts (Siikamäki & Wernstedt, 2008), and the main barriers are the weaknesses of spatial policy (Kristiánová et al., 2016). Redevelopment of brownfields for recreational purposes is also considered to be more acceptable by local communities than commercial ones (De Sousa, 2003), but due to the lack of generated income, they require securing funds not only for the investment process, but also for future maintenance (Doick et al., 2009; Krzysztofik et al., 2020). In turn, regarding housing development, it is noted that due to the higher cost of brownfield site preparation, in order to be profitable, developers must increase the intensity of development, which should be included in the local development plans (Karadimitriou, 2013). The potential of using public-private partnership in the development of housing investments is also emphasised, subject to the need for the interests of both sectors to be aligned, as well as public ownership of the land and the participation of an academic institution (Lia et al., 2016).

2.4 Evaluation of brownfield regeneration effects

When analysing the effects of regeneration projects, much attention is paid to the assessment of their compliance with the principles of sustainable development, both in the environmental (Franz et al., 2006; Pediaditi et al., 2010) and social aspect (Dixon, 2007; Glasson & Wood, 2009). What is important is that sustainable development in terms of nature does not force brownfield areas to be transformed only into green space, because also redeveloping them for other functions allows a reduction in the consumption of greenfield areas (Franz et al., 2006). Researchers have identified measurable benefits in this regard using the example of Luxembourg, where the regeneration of 550 ha of brownfields allowed avoiding expansion into uninvested land equivalent to the area previously consumed by the city over a period of three years (Glumac & Decoville, 2020). On the other hand, in terms of economic issues, it is emphasised that although redevelopment from public funds does not generate jobs or an increase in property tax revenues as private investments, it brings benefits for residents in the social, health and environmental aspects (Kotval-K, 2016). Regarding the recreational function, attention is drawn to the risk of an increase in housing prices in the area (Noh, 2019), and the threat to human health in the event of improperly conducted remediation (Pecina et al., 2021), which might also apply to housing investments (Squires and Hutchison, 2021). The application of the threshold analysis method, in turn, allowed one to recognise the regularity that only after exceeding the "critical mass" of the office space in the brownfield area, the prices of apartments in the area began to rise sharply (Tang & Wong, 2021).

2.5 Proposals of regeneration management tools

Justifying the use of brownfield regeneration management tools for managing the brownfield regeneration process, researchers point to the need to improve decision-making processes, which should focus on delivering measurable benefits (Atkinson et al., 2014). The concepts include both tools based on multi-criteria analysis (Schädler et al., 2011; Rizzo et al., 2018), as well as those operating within GIS spatial information systems (Beames et al., 2018). Hammond et al. (2021) made a critical review of the instruments used, pointing to their weaknesses: insufficient use of quantitative socio-economic criteria, a tendency to focus on later stages of regeneration, an underdeveloped user interface and negligible use of forecasting models. Chen & Young (2022) propose a Brownfield Redevelopment Query (BRQ) model aimed at converting environmental, economic, and social impacts into the benefit-cost ratio (BCR) as a unified evaluation benchmark, considered in the scenarios of site redevelopment for residential, industrial, commercial, or public services use. Preston et al. (2023) developed a brownfield hierarchical typology based on the proportion of impervious land cover, landscape metrics (size, slope, shape indicators, etc.) and mean land cover distribution, to assess their potential to contribute to urban ecosystem services and green infrastructure.

Summing up the theoretical aspects, according to rent gap theory discussed above, the redevelopment potential of a brownfield is related to the gap between the current ground rent and the potential rent after the change site use to a possibly most effective one. This concept, however, does not consider factors other than proximity to the city centre, which may affect the potential ground rent, nor does it consider the necessary redevelopment costs. In the light of the ABC classification model, the potential of some brownfield sites resulting from both location and site-specific factors discussed above (e.g. good condition of buildings and structures that can easily be adapted for new use, low pollution, limited conservation restrictions, ownership structure) is so high that their redevelopment is possible without public intervention (category A). Some brownfields, due to various constraints, can be redeveloped only with the substantial support of public funds (category C). As shown by the international experience in the field of post-industrial brownfields regeneration – their return to beneficial use by private companies is possible provided that the investment is supported by public entities (category B). Even though the general concept of this model is quite commonly acknowledged, there are no universal criteria of categorising brownfield sites by their redevelopment potential. The significance of location issues was demonstrated in a number of the research works discussed above; but some studies suggest a greater importance of other site-specific or general factors. Furthermore, there is not enough evidence of the relation between the centrality of a brownfield site and its suitability for redevelopment for a certain use. Besides, the role of the cultural value of built heritage seems to be underrated among other site-specific factors. In this paper, we are trying to contribute to a discussion regarding the above-mentioned gaps.

3. Data and methods

Silesian Voivodeship is one of 17 Polish regional administrative units (NUTS 2). It is located in southern Poland covering an area of 12,333 km^2. With a population of 4,375,947 (in 2021) and population density of 355 inhabitants per km^2, it is the most densely populated voivodeship in the country, and with 76% of the population living in urban areas – also the most urbanised. The largest cities are Katowice, Częstochowa and Sosnowiec – with 283, 211 and 192 thousand residents respectively in 2021 (Statistics Poland – Local Data Bank, 2022). This region was chosen as the study area because until 1990 it was one of the most industrialised regions in Poland, in the field of coal mining, metallurgy and energy, and to a lesser extent also the automotive and textile industry. Consequently, the restructuring of the national economy after the change in the political system, in particular the extensive deindustrialisation, resulted in the emergence of substantial quantity of post-industrial brownfields. In the first quarter of 2020, an inventory was carried out to identify possibly all brownfield regeneration projects that were completed between 1990 and 2019. The collection of data on the regeneration of post-industrial brownfields, that lost their original functions after 1990 and were redeveloped for new uses, was carried out using and reviewing the following sources:

- Scientific publications on regeneration and history of post-industrial brownfields in Silesian Voivodeship.
- Internet article databases of national (Gazeta Wyborcza, 2020) and local press (Dziennik Zachodni, 2020) based on keywords related to the brownfield regeneration process;
- Database of projects co-financed from EU aid funds in the programming periods 2004–2006, 2007–2013 and 2014–2020, based on keywords related to the brownfield regeneration process (Grants Map EU, 2020);
- Database of sites on the Industrial Monuments Route of the Silesian Voivodeship (2020);
- Database of industrial and technology parks published by the Polish Investment and Trade Agency (2020); and
- Database of urban regeneration projects of the Silesian Association of Municipalities and Counties (2020).

Additionally, a review and an update was carried out regarding the information on the projects of regeneration of post-industrial brownfields identified in the 2010 study on the impact of post-industrial brownfield regeneration on the labour market in Silesian Voivodeship (Jarczewski & Huculak, 2010). The data collected comprise of location of brownfield regeneration projects, the regeneration costs including share of public support, type of new use, size of redeveloped area, number of jobs created, and value of cultural heritage located on brownfields and reused within the projects. For the analysis, it was decided to choose the type of new use as the dependent variable, and the location as well as the value of cultural heritage as independent variables. The quantitative data and coded qualitative data were analysed using descriptive statistics, the normality of the distribution was verified by the Shapiro-Wilks test, and the statistical difference between the variables was verified by the Kruskal–Wallis test.

The new uses of regenerated brownfields were aggregated into four categories, based on the classification of Chen and Yang (2022): public services (cultural, educational, and recreational facilities); commercial services (retail facilities, offices and hotels); manufacturing/investment zones; and housing. The basis for identification of city centre locations was the National Register of Boundaries published by the Head Office of Geodesy and Cartography (2020). In the process of verification, the market square was considered the central point of the city. In the absence of a market or a central square, the functional centre of gravity of city-forming services was considered as the central point, based on the search of internet sources and analyses of the city structure. The distance between each regeneration project and the city centre was measured as a straight-line distance using GIS tools. Regarding the value of cultural heritage included in the brownfield regeneration projects, the projects were coded basing on a rating of 3 to 0 points: 3: sites entered into regional register of historical monuments or belonging to the Industrial Monuments Route; 2: buildings and structures included in the municipal register of historical monuments or erected before 1945; 1: buildings and structures erected after 1945 integrated into an older, historical spatial arrangement; 0: no cultural heritage involved in the project.

4. Results and discussion

4.1 Structure of completed brownfield regeneration projects

As a result of the study, 125 post-industrial brownfield regeneration projects were identified, which are predominantly located in the central, most urbanised part of the region (see Fig. 3). The total value of these projects at the end of the first quarter of 2020 amounted to PLN 7.4 billion (Tab. 1), which was then approximately EUR 1.6 billion.

In terms of quantity, the largest group consisted of brownfield sites with various uses related to public services. Almost all these projects were implemented by public entities (mainly local governments), and the vast majority obtained funding from EU aid funds, mainly from the European Regional Development Fund (ERDF). The second largest group of ventures were commercial projects carried out exclusively by private entities, basically without the support of public funds. It should be noted, however, that the average project value in this category was approximately

New use	Number of projects	% of total number	Estimated value of the projects (million EUR)	% of total value	Average value per project (million EUR)
Public services	40	32.0	209	12.9	5
Commercial services	38	30.4	954	58.9	25
Manufacturing/investment zones	38	30.4	370	22.8	10
Housing	9	7.2	88	5.4	10
Total	125	100.0	1,621	100.0	13

Tab. 1: The number and value of post-industrial brownfield regeneration projects in Silesian Voivodeship by new use
Source: authors' research and calculations (as of March 31, 2020)

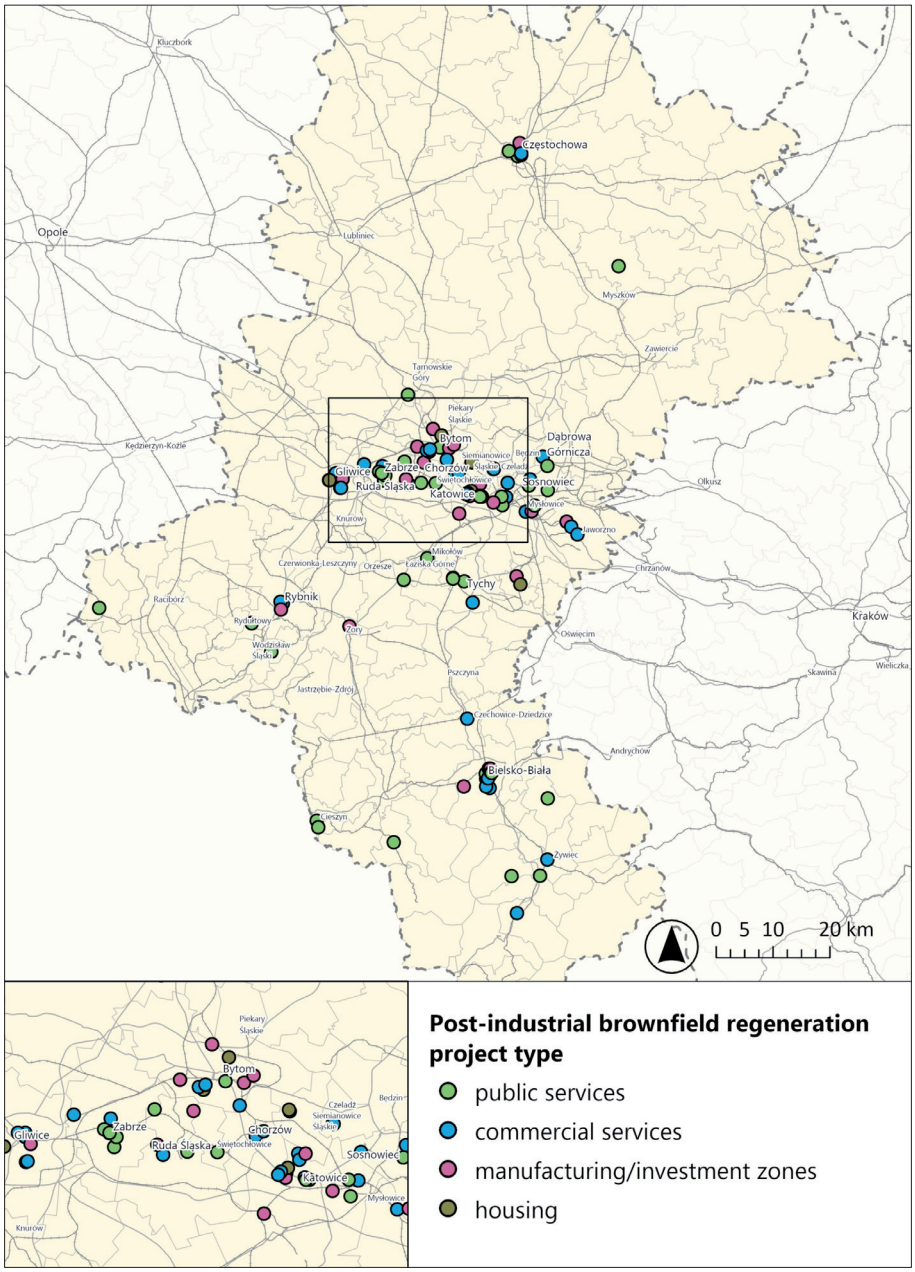

Fig. 3: Distribution of post-industrial brownfield regeneration projects by type of new use
Source: authors' elaboration using their research project findings

five times higher than in case of public services, thus the value of these commercial regeneration projects amounted to almost 59% of all projects' total value. Post-industrial brownfields were also often used to create various types of investment zones aimed at supporting local economic development, and in some cases redeveloped for new industrial activities. These projects, covering ca. 23% of the total value, are a field of interaction between public entities, active at the stage of remediation and infrastructure improvement, and private investors, redeveloping the site for economically viable use. It is worth paying attention to the relatively small number of housing projects – only nine development projects were identified (see Fig. 4), which is related to a relatively weak housing property market in the region resulting from depopulation. More specific characteristics of analysed projects are listed in Table 2.

It is worth emphasising that more than 60% of the projects take advantage of the cultural heritage resources, which is related to the importance of these sites for building local identity of the inhabitants. A very similar share of the projects belonged to an implemented regeneration programme, what means they contributed to the complex regeneration of a larger urban area. Non-public entities, including private capital and NGOs, are altogether responsible for less than one half of the implemented projects. This phenomenon will be discussed further based on the rent gap theory and models of brownfield redevelopment potential. Nevertheless, the fact that more than one third of the projects were supported by the EU aid funds strongly indicates the substantial role of external financing in initiating the regeneration process of brownfield sites.

Characteristic of brownfield regeneration projects	Share of the total number of projects (%)
Preserving and exhibiting elements of material cultural heritage	61
Comprehensive redevelopment of the entire post-industrial area (completed regeneration)	60
Implementation by private capital	40
Co-financing by the ERDF	37
Implementation by non-governmental sector	5

Tab. 2: Selected characteristics of brownfield regeneration projects (overlapping categories – not summing up to 100%) Source: authors' elaboration – as of March 31, 2020

Fig. 4: Housing development located on regenerated brownfield – former spoil tip in Chorzów. Photo: J. Koj

4.2 The role of legal system in the post-industrial brownfield regeneration process

The regeneration of post-industrial brownfield sites basically meets the objectives set for urban regeneration in Poland (leading a certain area out of the crisis), and at the same time has been legally marginalised. The Polish Regeneration Act[1] clearly indicates that, in principle, the subject of regeneration should be residential areas, and "uninhabited" areas, including post-industrial brownfields may be included in the process only if they serve the inhabitants of neighbouring degraded areas.

Table 3 presents a list of projects for the regeneration of post-industrial brownfields which in the Silesian Voivodeship received the largest funding from the European Regional Development Fund. The impact of each of these projects on the inhabited area directly adjacent to the brownfield site may be considered insignificant, and in some cases, it would be very difficult to find any connections at all.

Such a legal requirement, although it does not exclude completely, may radically limit the possibilities of post-industrial brownfields regeneration supported by public funds. Only in very

[1] Art. 11. Paragraph 3 of the Regeneration Act of October 9, 2015: Uninhabited post-industrial brownfields, including former port and mining areas, military or railway brownfields, where negative phenomena exist, (...) may be included in the regeneration area only in the event when the activities that can be carried out in these areas will contribute to counteracting the negative social phenomena referred to in art. 9, sec. 1.

No.	Project name	New use	Name of the former industrial plant	Municipality	Project value (M€)	ERDF support (M€)
1.	Silesian Museum	museum	Katowice Coal Mine (previously Ferdynand)	Katowice	57	39
2.	National Symphony Orchestra of Polish Radio	concert/event hall	Gottwald Coal Mine (previously Eminencja)	Katowice	67	32
3.	Euro-Centrum Industrial Park	entrepreneurship support	Chemical Equipment Plant Wimach	Katowice	29	19
4.	Galena Shopping Mall	shopping mall	Jaworzno Coal Mine	Jaworzno	42	16*
5.	Nowe Gliwice	entrepreneurship support	Gliwice Coal Mine	Gliwice	22	8
6.	Stara Kablownia Shopping Mall	shopping mall	Silesian Cable Factory	Czechowice-Dziedzice	20	7*
7.	Silesia Industrial-Technology Park	entrepreneurship support	Wawel Coal Mine/ Polska Coal Mine	Ruda Śląska/ Świętochłowice	12	6
8.	Redevelopment of Water Tower in Zabrze at Zamoyskiego st. 2 for social, educational, scientific and cultural uses	museum	Water Tower	Zabrze	7	5
9.	Sosnowiec Science and Technology Park	entrepreneurship support	Niwka-Modrzejów Coal Mine	Sosnowiec	9	5
10.	GPP Business Park	entrepreneurship support	Spoil tip of the Silesia Zinc Works	Katowice	7	5
11.	Częstochowa Industrial-Technology Park	entrepreneurship support	Częstochowa Steelworks	Częstochowa	6	4
12.	Postindustrial Coal Mining Heritage Centre in Zagłębie	museum	Saturn Coal Mine	Czeladź	5	4
13.	Bytom Industrial Park	entrepreneurship support	Orzeł Biały Mine and Metallurgical Plant	Bytom	6	4

Tab. 3: Regeneration projects for post-industrial brownfields in Silesian Voivodeship with the highest value of support from the ERDF
*Notes: * Repayable support through JESSICA initiative*
Source: authors' elaboration based on Grants Map EU

specific situations, regeneration of post-industrial brownfields "counteracts negative social phenomena" in the neighbouring area. Usually, projects undertaken in such areas (shopping centres, business parks, museums, concert halls, new industrial plants) are targeted at much wider communities – residents of the city, region, and even international partners.

4.3 Relationship between the distance from city centre and the new use

Based on the analysed data, it is possible to indicate a statistically significant relationship between the distance from the city centre of post-industrial brownfield regeneration projects and certain new uses of the sites. The distances of the analysed projects from the city centre varied from 0.1 km to 11.1 km, with a mean value of 2.2 km and standard deviation of 1.9 km. The first, second (median), and third quartiles were 0.9, 1.6 and 2.7 km respectively. The results of the Shapiro-Wilk test performed ($W = 0.81$, $p < 0.001$) demonstrate a significant deviation of the distribution of the distances variable from the normal distribution. The statistical distribution of distances from the city centre of brownfield regeneration projects by new use are shown in Table 4.

The significant result of Kruskal-Wallis test together with post-hoc test, $\chi^2_{\text{Kruskal-Wallis}}(3) = 13.61$, $p = 0.004$, $\varepsilon^2_{\text{ordinal}} = 0.10$, $N = 125$, testified that distance from the centre was significantly lower for commercial services use than for the manufacturing and investment zones, $p_{adj} = 0.003$. Furthermore, no significant differences in the distance between other pairs of groups were found. A graphical representation of the distributions of distances from the centre for each group along with the test results can be found in Figure 5.

New use	Number of projects	Distances from the centre [km] (Median Q1–Q3)
Commercial services	38	1.57 (0.64–2.12)
Public services	40	1.41 (0.70–4.09)
Housing	9	1.57 (0.85–1.78)
Manufacturing/investment zones	38	2.21 (1.58–3.62)

Tab. 4: Distribution of distances of brownfield regeneration projects from the city centre by new use of the site. Source: authors' calculations

New use	Number of projects	Value of the cultural heritage (Median Q1–Q3)
Commercial services	38	0.0 (0.0–2.0)
Public services	40	3.0 (1.0–3.0)
Housing	9	0.0 (0.0–1.5)
Manufacturing/investment zones	38	0.0 (0.0–1.0)

Tab. 5: Distribution of the of the cultural value of industrial heritage by new use of the site. Source: authors' calculations

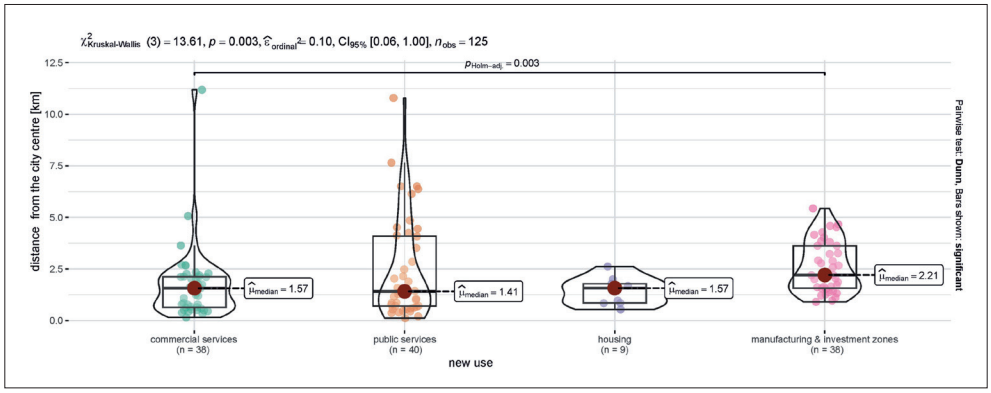

Fig. 5: Distribution of distances of brownfield regeneration projects from the city centre by new use of the site
Source: authors' elaboration

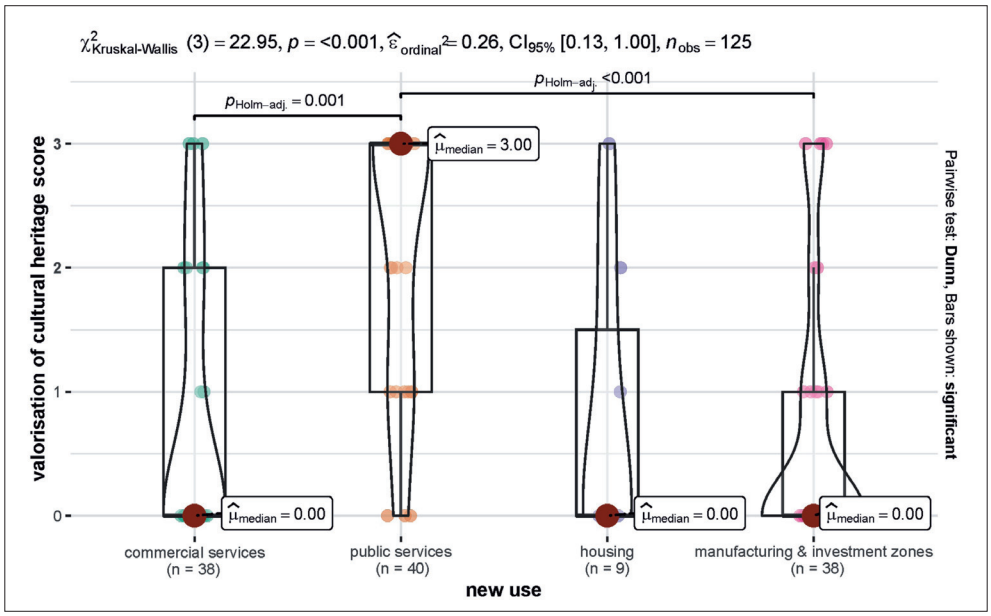

Fig. 6: Distributions of cultural heritage values by new uses, within test scores for between-group differences
Source: authors' elaboration

4.4 Relationship between cultural values and the new use

Apart from the impact of the project's location on the new use of the site, a relationship between the cultural value of built heritage involved in the regeneration process and the new use was also found. The mean value of cultural heritage according to the applied rating scale was 1.13 with a standard deviation of 1.26. The significant results of the Shapiro-Wilk test proved that the value of cultural heritage was characterised by a significant difference from the normal distribution. The distributions of the measures of central tendency together with the measures of the position of the cultural heritage value by new use of the site are presented in Table 5.

The significant result of Kruskal-Wallis, $\chi^2_{Kruskal-Wallis}$ (3) = 22.95, $p < 0.001$, $\varepsilon^2_{ordinal} = 0.26$, $N = 90$, together with Dunn's post-hoc test, showed that value of cultural heritage was significantly higher for public services use than for commercial services, as well as for manufacturing and investment zones. For a graphical representation of cultural heritage value by the new use of brownfield site, see Figure 6.

The trends presented in Table 3 and Figure 4 can be partially interpreted in the context of the rent gap theory (see Fig. 1). As discussed above, rent gap is the difference between the current land rent obtained with the current use of the land and the potential rent expected with new, more profitable use. According to this theory the attractiveness of vacant land suitable for redevelopment is determined by the size of the gap, which reflects the expected profits from the investment. In the immediate vicinity of city centres, the greatest profits would come from investing in commercial services, i.e. office buildings, retail facilities and hotels, and the areas which are most distant from city centres would be profitable to use for new industrial plants and investment zones.

The urban land rent model is not able to explain all projects related to regeneration of post-industrial brownfields, however, because some of the actors actively involved in spatial development are public bodies, in Polish conditions most often state or local government. These bodies, when implementing brownfield regeneration projects, most often follow goals other than maximising profit while minimising costs. These are, among others, the need to preserve and exhibit the cultural heritage (museums, galleries), creating public utility buildings important for local communities (schools, sports and recreation facilities, cultural institutions, and conference rooms), creating space necessary to support local entrepreneurship etc. An example of the regeneration preserving the historical-cultural heritage is the project of the contemporary art gallery in the complex of former coal mine and power plant in Czeladź city (see Fig. 7).

Therefore, apart from the rent gap theory, the research results must also be interpreted in the context of the so-called ABC model (Fig. 2), according to which the redevelopment of a given brownfield site also depends on the costs necessary to start a given activity The potential of some sites (e.g. location, good condition of buildings, low contamination, limited conservation restrictions, ownership structure) is so high that their redevelopment is possible without public intervention (category A). Some brownfield sites, due to various constraints, can be redeveloped only with the substantial participation of public funds (category C). As shown by the international experience in the regeneration of post-industrial brownfields, in many cases their redevelopment by business partners is possible provided that the investment is supported by public entities (category B).

The commercial (market) use of post-industrial brownfields requires that expenditures on regeneration, included in the total costs of an economic venture, should not be a barrier to achieving a satisfactory profit for the investor. This situation is basically possible in two cases:

a. the economic activity planned in the regenerated area will bring income that will allow the investor to generate an appropriate profit in the planned period; and
b. a part or all the costs related to regeneration will be financed from public funds, reducing the total costs of the project to the level acceptable to the investor.

5. Conclusions

As a result of this research, it was found that there is a relationship between the location of a post-industrial brownfield regeneration project and the new use of the site. Statistically significant differences were observed only between certain uses, however, e.g. commercial services were located considerably closer to the city centre in comparison to manufacturing plants and investment zones. For other identified uses of regenerated brownfields, e.g. public services and housing, no significant

Fig. 7: Contemporary art gallery called "Power Plant" in the former coal mine complex in Czeladź. Photo: J. Koj

relationship was observed. As discussed above, the applicability of the rent gap theory to explain this phenomenon is limited due to two constraints: first, it focuses on redevelopment processes initiated by private investors; second, it considers only potential profits of new use without considering the redevelopment costs. Therefore, we propose a modification of this model, in which the rent gap would be reduced by the required investment expenditure capitalised over the project's lifetime at a given interest rate. It would then reflect the real potential profitability of the redevelopment for a new use by a private investor, or in case the projected costs exceeded the potential benefits – the amount of necessary public support.

The results have also showed a connection between the cultural value of built heritage located on a regenerated post-industrial brownfields and new use of the site. Public services were developed on brownfields with significantly more valuable built heritage than commercial services or manufacturing plants and investment zones. Only for projects related to housing development was no significant relation observed. Therefore, it can be concluded that valuable heritage resources can be either an important driver or a barrier to brownfield regeneration, depending on the intended new use. In this context, we propose a modification of the ABC model, which should include, in addition to the economic value already considered, also the cultural value of brownfields related to their built heritage. We believe that for certain new uses (e.g. museums, galleries, hotels, restaurants) the cultural value should be considered as a factor increasing the redevelopment potential of brownfield sites, in some cases compensating for higher costs necessary to be incurred by the investor.

Based on the example of this study area, it is impossible to ignore the role of industrial heritage preservation and reuse for the local communities. The importance of this issue is evidenced by the creation and development of the Industrial Monuments Route of the Silesian Voivodeship, the first of its kind in Poland, with 40 sites in nearly 30 municipalities as of April 1, 2021. Before the pandemic, the last edition of the festival of this route named Industriada attracted over 100,000 participants (Industrial Monuments Route of the Silesian Voivodeship, 2022). Other examples of how important the fate of post-industrial heritage is for the inhabitants, are the Zabrze authorities' efforts to recognise the most valuable historical colliery complex in the city as a National Historical Monument, as well as the application of a local NGO taking care of the historic silver and lead mine in Tarnowskie Góry to the World Heritage Committee – in both cases successful.

The regeneration of post-industrial brownfields in this study area was carried out mostly at a distance not exceeding 2.7 km from the city centre (75% of the projects). It is then one of the ways of strengthening the regeneration processes outside the strict city centre, but still within the inner-city area. Thereby, it might contribute, albeit to a limited extent, to mitigating the effects of the crisis of city centres resulting from depopulation and changes in the way that residents spend free time. The process of regeneration of post-industrial brownfields involves significant private funds (ca. 40% of the projects, amounting to ca. 60% of total regeneration costs of all analysed projects), but, nevertheless, often also requires public support. This applies in particular to those projects that are preserving and reusing tangible post-industrial heritage. Unfortunately, the provisions of the Polish Regeneration Act significantly limit the possibility of including such projects in publicly supported urban regeneration programmes. As a result, they not only can possibly have worse access to EU aid funds, but also in the minds of local authorities and inhabitants it may be difficult to build the awareness of importance and urgency to redevelop such sites. Therefore, we would recommend a public policy to consider the issues of disadvantageous location of brownfield sites and the high cultural value of their built heritage as factors favouring public financing. We believe that this approach would be more effective than the requirement to counteract negative social phenomena, currently included in the Polish Regeneration Act, which in many cases may be difficult to prove and evaluate.

Acknowledgements

The paper is based on research carried out as part of the "The new model of urbanisation in Poland – practical implementation of principles of responsible urbanisation and a compact city (Gospostrateg 1/384689/20/NCBR/2019)" project, co-financed by the National Centre for Research and Development under the Strategic Programme for Scientific Research and Development Works "Social and economic development of Poland in the conditions of globalising markets" – GOSPOSTRATEG.

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Please cite this article as:

Jarczewski, W., & Koj, J. (2023). Spatial factors affecting the functional diversity of regenerated brownfields: The case of Silesian Voivodeship (Poland). Moravian Geographical Reports, 31(2), 84–94. https://doi.org/10.2478/mgr-2023-0008