

The functional transformation and dynamics of industrial buildings in Central Europe on the example of Wrocław agglomeration from 1980s to 2020s

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Abstract. Following the post-1989 political transformation, industrial areas in Central European urban agglomerations experienced significant dynamism and large-scale change. Their distribution and, above all, the functions of buildings have evolved markedly. This study examines the scale and nature of functional transformations in Wrocław's industrial areas. Its novelty lies in the use of quantitative analysis of building function changes based on cartographic data from the 1980s–2020s, applying GIS tools and change detection methods. Previous research mostly provided qualitative descriptions of transformation mechanisms without precisely defining their scale or extent. Findings reveal an ongoing process of deconcentration of industrial areas, alongside growing diversification of building functions in formerly monofunctional, production-oriented zones. Consequently, Wrocław's urban space – as in other Central European cities – is becoming more functionally complex, with notable social, spatial, and planning-related consequences that require ongoing monitoring regarding their impact on urban quality of life.

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1. Introduction

Cities and their immediate surroundings are under constant transformation. The directions of these transformations, their scale, dynamics and aspects depend on many conditions of global, regional, and local nature. Among the most important factors shaping the face and spatial structure of cities were and are the transformations taking place in the political and economic systems of the countries in which the cities are located (World Economic Forum, 2024). The discourse on the transformation of cities most often draws examples from the broadly understood Western World and its global transformations (e.g. Kirkwood, 2005; Kaplan et al., 2009; Dicken, 2015) or the increasingly exposed Asian cities (e.g. Yeung 2011; MIT, 2021). However, an excellent example confirming the above statement is the process of transformation and development of Central European (CE) cities, initiated several decades ago as a result of political, social, and economic changes in this part of the world. The changes began with the collapse of communism and the system of centrally planned economy in 1989. The consequences of the processes that took place at the time were multidimensional socio-economic, demographic and spatial transformations that significantly affected the urban areas of CE (Cudny & Kunc, 2022).

Among the numerous examples of land use transformation of CE cities, it was industrial areas that stood out in terms of the pace and scale of development transformation. Gradually, CE cities began to implement policies of deconcentration and deglomeration of industrial zones (Sikorski & Kryczka, 2023), resulting in the progressive disintegration of these urban areas in the hitherto compact urban fabric. As a consequence, not only the spatial distribution of industrial activity changed (mainly involving a shift away from industrial activity in the city to its development in the suburban zone), but also the use of existing buildings located within these areas.

The purpose of the study is to determine the direction, scale and regularity of functional transformation of buildings within industrial areas in the CE urban agglomeration on the example of Wrocław (SW Poland). Using cartometric methods in a GIS environment, the scale, dynamics, and directions of the described transformations of these uses in the study area were clearly determined. However, it is beyond the scope of this study to diversify the economic structure of the region in the industrial areas in question. The focus of the

present study is solely on the functional and spatial structure of the agglomeration and the building fabric within the previously identified industrial areas.

The existing literature demonstrates a lack of this type of research in CE, namely one based not only on a qualitative (description of mechanisms and noted changes) and geostatistical approach (e.g. Hamilton et al., 2005; Haase & Steinfuhrer, 2005; Grabkowska, 2017), but, above all, one that shows these changes quantitatively on a local scale allowing to realistically measure this process in terms of a specific urban functional area. Such a local approach grounded in a global context will make it possible to identify the main directions of the transformation of industrial areas of CE cities and the implications for the formation of development policies in cities of a similar nature.

2. Tracing CE industrial transitions

The transformation of industrial buildings is intrinsically linked to broader changes occurring within industrial sites. The topic of industrial site transformation – particularly brownfield redevelopment – has been extensively explored in both international and national literature (Zheng & Masrabaye, 2023).

Numerous scholars have sought to understand and explain the processes underlying the transformation of industrial areas, including the redevelopment of associated buildings. These transformations are most commonly examined through their outcomes: economic (particularly in the context of sustainable development and the green transition; e.g., Gu & Pan, 2022), functional-spatial (e.g., Kunc et al., 2023), socio-demographic (e.g., Sikorski & Smętkiewicz, 2024), morphological (e.g., Kotlicka, 2008), and in terms of their influence on spatial valorization (e.g., Szafrńska, 2010). However, it is worth noting that the majority of these studies adopt a retrospective and causal (cause-effect) perspective, focusing on identifying the factors that have led to observed changes (Ravaz et al., 2024).

A review of the literature on the transformation of industrial sites reveals that, once industrial activities have ceased, these areas often lack clearly defined redevelopment pathways. Numerous studies highlight that such transitions frequently result in the emergence of brownfields, which may pose environmental or social risks (e.g., Litt & Burke, 2002). Nevertheless, the cessation of

industrial functions can also create opportunities for regeneration and redevelopment, enabling these sites to once again contribute to local socio-economic development (e.g., Kuzior et al., 2022). In some cases, the emergence of brownfields draws attention to a site's cultural or industrial heritage, providing an impetus for its preservation through legal protection (e.g., Chmielewska, 2015).

In CE, interest in the transformation of industrial sites increased significantly after 1989, following the political and economic shift from centrally planned economies to market-oriented systems. These structural changes profoundly affected the use of industrial land and associated buildings across the region. Initially, the most visible transformations took place in major urban centres, particularly in national capitals. One of the pioneers in this field was the Hungarian researcher Kiss (1999, 2002), who in the 1990s addressed this issue through studies on the transformation of industrial areas in Budapest. Czech researchers also began investigating this phenomenon relatively early, focusing on changes in Prague's industrial zones (e.g., Sýkorová, 2007). In Romania, scholars such as Săgeată et al. (2023) have explored similar processes in Bucharest.

Following the accession of most CE countries to the European Union in 2004 and 2007, academic interest expanded to include smaller urban centres. Notable examples of well-studied cities in this context include Brno in the Czech Republic (e.g., Frantál et al., 2015; Kunc & Tonev, 2022), as well as Łódź (Piech, 2004; Kotlicka, 2008; Kaczmarek, 2010) and Katowice (Krzysztofik, 2022) in Poland. The transformation of brownfield sites in post-socialist cities of CE represents a crucial component of broader urban transformation processes in the region. Following the collapse of communist regimes, numerous industrial sites were abandoned or fell into disrepair, raising pressing questions about their reintegration into the urban fabric (Kunc et al., 2023).

Although the body of literature on the transformation of industrial areas is substantial, a significant research gap remains. Specifically, there is a lack of comprehensive, longitudinal studies that adopt a holistic view of industrial area transformation within entire, compact urban agglomerations. Such an approach could help identify prevailing patterns and trajectories of change in CE cities and offer valuable insights for shaping urban development policies in cities with similar post-industrial characteristics.

3. Materials and methods

3.1. Study area

The Wrocław agglomeration is located in Central Europe (CE), in the southwestern part of Poland, in the central-eastern part of the Lower Silesian Voivodship (province) (Fig.1). It consists of the city of Wrocław (the agglomeration's core) and nine municipalities (Czernica, Długołęka, Kobierzyce, Kąty Wrocławski, Miękinia, Oborniki Śląskie, Siechnice, Wisznia Mała and Żórawina) surrounding the city (suburban zone). According to data from the National Census of Population and Housing (Census 2021), the agglomeration has a total population of 876,930, of which as many as 669,564 live in the city of Wrocław. The area of the agglomeration is 1391.8 km², including the city of Wrocław – 292.8 km².

The genesis of the development of the Wrocław agglomeration is typically urban and depended to a large extent on the fate of the city of Wrocław itself, which was characterized by numerous changes in affiliation as well as political, social and economic system throughout its historical evolution (Kulak 2001). This was influenced by the geographic location of this agglomeration (at the junction of Poland, Germany and Czechia), the proximity of the mineral-rich Sudeten Mountains and the historical fate of this part of the world related to, among other things, war damage (e.g., 70% of Wrocław was destroyed during the Second World War) or functioning in a socialist economy (in 1945 – 1989 Poland was a communist country) (Książek & Suszczewicz 2017).

An important factor that historically limited the spatial expansion of Wrocław and continues to pose challenges for its transport system is the hydrographic structure of the urban agglomeration. The city is situated on the River Odra and its four tributaries, encompassing a network of 12 islands and more than 100 bridges and footbridges. This complex water-based morphology – unique among Polish cities – not only shapes the urban form but also significantly influences infrastructural development and accessibility. As highlighted by Książek and Suszczewicz (2017: 54), the presence of such a dense and fragmented hydrographic system requires considerable investment in bridge infrastructure and maintenance, while also creating specific constraints for the integration of transportation networks across the metropolitan area.

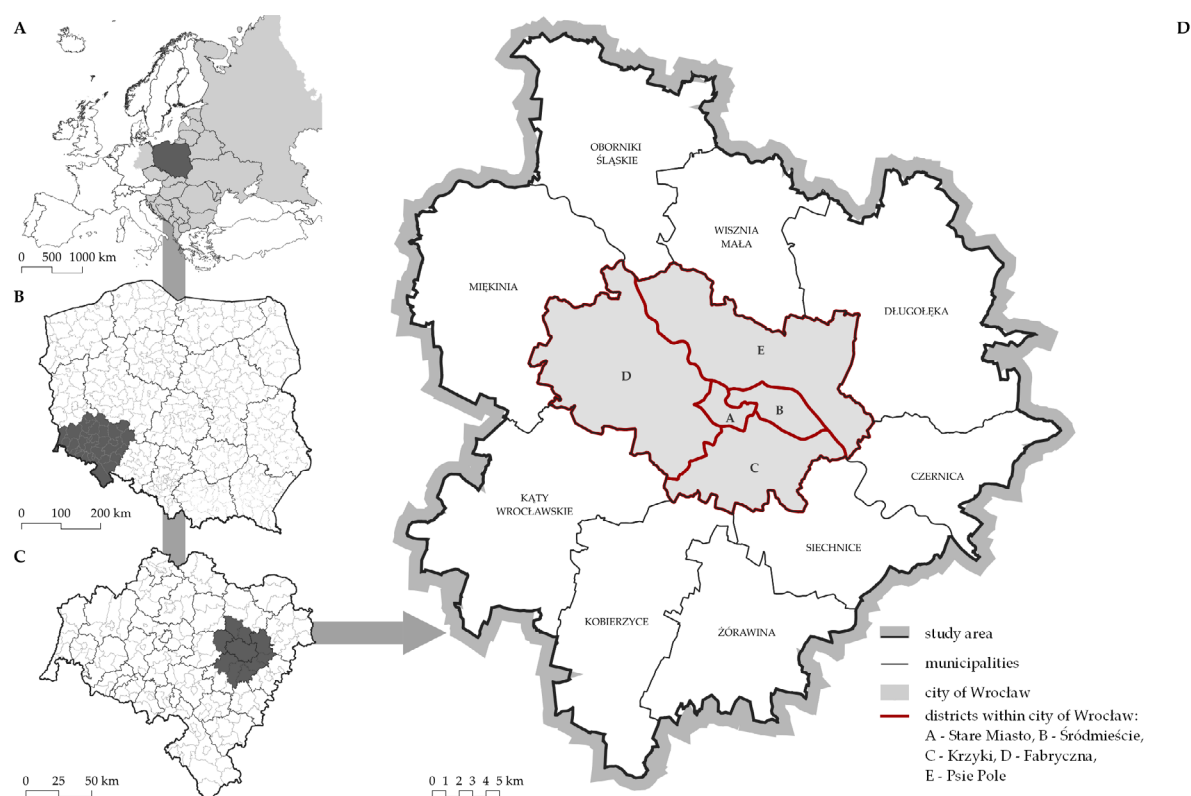


Fig. 1. Study area (D) in Europe (A), Poland (B) and Lower Silesia Voivodship (C).
Source: authors' own research based on (Sikorski & Kryczka 2023).

Moreover, Wrocław's distinctive urban character has been shaped not only by its hydrographic conditions, but also by its complex historical trajectory and multiple shifts in national affiliation. These factors have left a lasting imprint on the city's urban structure and spatial development. In recent decades, Wrocław and its functional area has experienced profound changes related to the emergence of new economic functions, the transformation of its functional and spatial structure, and evolving demographic patterns – further reinforcing its unique development path within the broader context of CE urban transformation (Książek & Suszczewicz, 2017).

Wrocław and its suburban zone were chosen as the study area due to their representation of a typical socio-economic transition from a socialist to a post-socialist urban model. Since 1989, the city's development has not been shaped by capital city functions or extraordinary growth conditions, making it a representative case. This trajectory mirrors the transformation patterns observed in many medium-sized cities across Central Europe. The historical development of this city and its hinterland was strongly linked to the development

of industry, causing it to become the most important industrial centre in the region (Slenczek, 1994, 1996). However, with the onset of political changes in the early 1990s in Poland and Central Europe, industry, which until then had played a key role, began to rapidly lose its importance and faced the need to redefine its place and role in the economy and urban space of such cities (Sikorski, 2013, 2019). The processes and socio-economic transformations that took place in Wrocław and its hinterland were of a similar or even identical nature to those in other CE cities (e.g. Korec & Ondoş, 2022; Kunc & Tonev, 2022; Szczyrba et al., 2022).

3.2. Urban dynamics of Wrocław's agglomeration

The genesis of industrial development in the Wrocław agglomeration reflects a pattern characteristic of urbanized regions in CE (Sikorski & Brezdeń, 2021). Since the medieval period, Wrocław and its surroundings have functioned as a significant centre of production, with development historically linked to the availability of raw materials from the

Sudetenland (Slenczek, 1996). Over time, industrial activity in the agglomeration became spatially concentrated in distinct zones, the location of which has been largely shaped by both internal and external transport infrastructure. These industrial zones are predominantly situated along major transit corridors, road, rail, and the Odra River – facilitating access to water resources and enabling efficient logistics. This spatial configuration supported the rapid and cost-effective transportation of raw materials and semi-finished goods, fostered inter-industry cooperation, and contributed to the emergence of technical and technological synergies among industrial facilities (Sikorski & Brezdeń, 2021: 7).

In the 1970s and 1980s, following a period of industrial concentration, the processes of industrial deglomeration began to take hold. This shift was manifested by the establishment of branch plants primarily in the satellite cities surrounding Wrocław. These cities, located along the main transit routes leading from Wrocław and adjacent to established industrial concentration zones, were further reinforced by the emergence of numerous economic subzones during the post-socialist transformation period (Sikorski & Brezdeń, 2021: 7).

Following 1989, as a result of significant systemic changes in the Polish economy, new economic phenomena emerged within Wrocław's industrial sector. These included changes in the forms of ownership, as well as the division of large enterprises into smaller units with substantial autonomy in production, finance, and management. This process was accompanied by a considerable spatial relocation of industrial activities within the urban system, leading to functional, morphological, and social transformations in the previously industrialized areas. Consequently, new post-industrial zones began to emerge within the city, gradually being redeveloped by new businesses, primarily in the services and trade sectors (Sikorski, 2013). This transformation continues to unfold in 2020s (Sikorski & Brezdeń, 2021: 7–8).

Jurkowski et al. (2024) demonstrated the urban landscape of the Wrocław agglomeration which has undergone significant transformations in recent decades. These changes, however, reflect broader shifts in the functions of the city and its surrounding areas. Initially, the agricultural land uses of the region diminished, making way for the development of new post-socialist housing estates, including both private and developer-driven investments, as well as transportation infrastructure. Subsequently, the industrial function was gradually restricted within the city centre and relocated to the periphery, particularly in areas with enhanced

transport accessibility. In light of these overarching landscape changes, it can be argued that the primary factors driving the transformation of the urban landscape are related to two key functions of the city and its surroundings: residential development and economic activities, primarily service-based (Jurkowski et al., 2024: 11). The spatial development of Wrocław is illustrated in a series of maps presented in Figure 2, which depict the evolving patterns of industrial area distribution from the pre-World War II period through the 2020s.

Nevertheless, Wrocław and its suburban area is still an important industrial centre with a dominant manufacturing industry. It is a modern urban agglomeration, characterized by one of the highest dynamics and rate of development in the country (Kunc et al., 2023). Among the processes modeling the current development of this agglomeration, one should undoubtedly distinguish the process of suburbanization determining human and economic migration (Sikorski & Szmytkie, 2021; Szmytkie, 2021). Another remarkable process is the gradual servitization of the economy combined with development based on the gradual deconcentration and deglomeration of industry from the city to the suburban zone (Sikorski & Kryczka, 2023).

3.3. Research design

The conducted research is based on the cartographic method of detecting changes in source materials within industrial areas of the Wrocław agglomeration from 1980 to 2020. This method consists in the juxtaposition and comparison of maps from the same area at different time periods, which makes it possible to detect the changes that have occurred and determine their scale and dynamics (Lu et al., 2004).

The study used cartographic sources in the form of topographic maps at a scale of 1:10,000 obtained from national open-source geoportals: (<https://www.geoportal.gov.pl/>) and MAPSTER (<http://igrek.amzp.pl/>) in the period from the 1980s to the 2020s. In order to streamline the analysis and effectively manage the available maps, the time scope was divided into five distinct periods: 1980s (containing topographic map sheets published between 1981 and 1988 – 1), 1990s (map sheets published between 1994 and 1998 – 2), 2000s (map sheets published between 2008 and 2009 – 3), late 2010s (map sheets published between 2016 and 2018 – 4), and 2020s (map sheets published in 2023 – 5). Each decade after 1980 was represented by one representative topographic map. After the data collection stage,

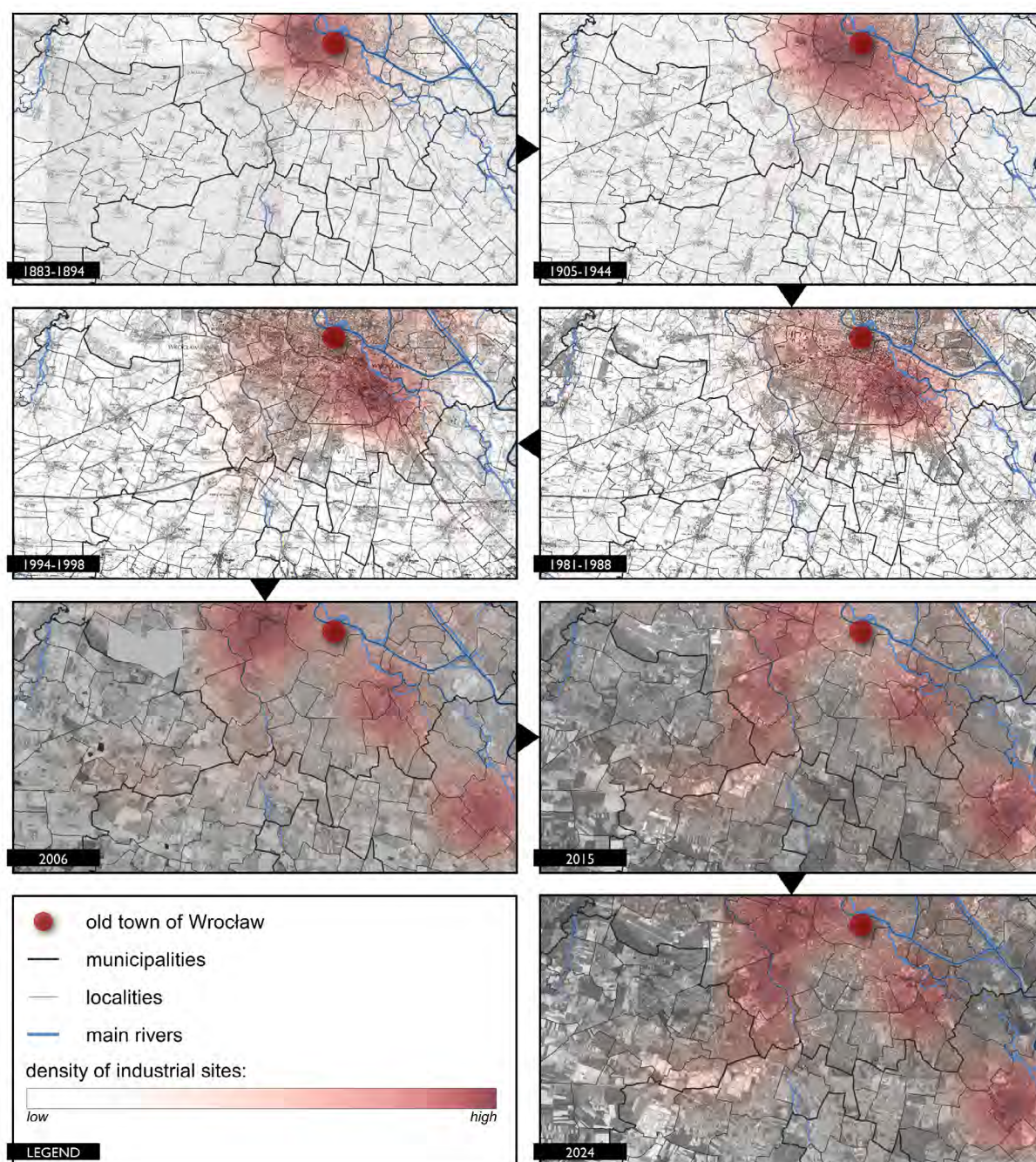


Fig. 2. Spatial development of Wrocław's agglomeration since 1880s and trends in industrial sites location

Source: authors' own research

all maps were calibrated in a GIS environment. Then, using change detection analysis, the exact locations of each industrial area and the buildings on them were identified by analytical period. Their area (measured in hectares) was also determined in distance from the centre of Wrocław (specifically, from the Market Square; measured in meters). The spatial extent of the industrial areas was determined

in each period and then all identified locations were merged into a single layer, within which the buildings were analyzed in consecutive time periods in the next step.

A database of topographic objects (BDOT10k), supplemented by the results of previous surveys, was used to determine the functional aspects of buildings located in the studied industrial areas (Sikorski

2013, 2019), and a complementary urban inventory was carried out. With reference to the indicated database, five functional categories of buildings occurring in the industrial areas were inventoried during the analyzed periods, i.e. residential, public, industrial, business and other (Table 1).

To determine trends in the ongoing changes in the use of buildings in industrial areas, an index of the degree of reclamation of buildings (WRB) was used, showing the extent to which buildings with an industrial function are replaced by buildings with other functions. This index is the ratio of the change in the area of buildings with a (PBi) function to the area of buildings with an industrial function (PBp) expressed as a percentage:

$$W_{RB} = \frac{P_{Bi}}{P_{Bp}} \times 100\% \quad (\text{Note 1})$$

4. Results

4.1. The area of buildings

The area of buildings in the industrial areas of the Wrocław agglomeration increased from 259.47 hectares to 705.12 hectares (an increase of 445.65 hectares; +171.8%) between the 1980s and 2020s. In the 2020s, the building area of industrial zones of Wrocław was 404.90 hectares (57.4%), while in its suburban zone they occupied 300.22 hectares (42.6%) of total area. In the 2020s, in terms of structure, the largest area was occupied by buildings classified as industrial (323.62 hectares; 45.9% of the

Table 1. Functions of buildings identified in the studied industrial areas with assigned BDOT10k mapping codes

Type of buildings	BDOT10k		
	10k cartographic code	Type of the building	Definition
residential	0010_317_1	multi-family residential building	A permanent building in which at least 50% of the total usable floor area is designated for residential purposes. It is primarily intended for permanent human habitation and may include single-family, multi-family, and collective housing units
	0010_318_1	single-family residential building	
	0010_319	high-rise residential building	
public	0010_320_1	public building	A building accessible to the general public, serving collective social functions such as education, healthcare, culture, administration, or religious practice
	0010_321	high-rise public building	
industrial	0010_323_1	industrial building	A building designed and constructed for the purposes of industrial production, processing, or storage, characterized by specific architectural and functional features related to industrial infrastructure
	0010_324	high-rise industrial building	
outbuilding	0010_325_1	outbuilding	A small, separate building located on the same plot as the main building, used for supporting functions such as storage, workshops, small-scale production, services, or agriculture, including greenhouses. It typically supports household needs, small businesses, or farming activities
	0010_337	greenhouse	
other	0010_326_1	run-down building or historic ruin	A permanent building that has lost its original functional utility due to physical degradation or abandonment. This category also includes historical ruins and buildings partially preserved for conservation or documentation purposes
	0010_423	transformer in the building	

Source: own research based on the Decree of the Minister of Development, Labor and Technology dated July 27, 2021, on the database of topographic objects and the database of general geographic objects, as well as standard cartographic studies.

total area of buildings), business (251.59 hectares; 35.7%), public utility (88.11 hectares; 12.5%), residential (38.90 hectares; 5.5%) and other (2.90 hectares; 0.4%).

During the studied period, the area of all building types increased. However, the dynamics of these rose in varied manner. In absolute terms, the area of the following buildings increased the most: industrial (by 178.39 hectares; +122.8%), business (by 171.33 hectares; +213.5%), public (by 55.99 hectares; +174.3%) and residential (by 37.03 hectares; +1985.7%).

Since the 1980s industrial buildings have had the largest share among all building categories in the industrial areas. However, especially since the 2000s, there has been a significant regression in the share of this building category (down from 56.0% to 45.0%; -11.0%) mainly at the expense of an increase in the share of outbuildings (up from 30.9% to 35.7%; +5.8%), and residential buildings (up from 0.7% to 5.5%; +4.8%).

As already mentioned, the area of buildings has been on the increase throughout the agglomeration

between the 1980s and 2020s. This growth was generated mainly by an increase in the area of buildings in the suburban zone of the agglomeration. During this period, the area of buildings there increased from 31.06 ha to 300.22 ha (by 269.16 ha; +866.6%). In the same period, the building area in the city of Wrocław increased from 228.41 ha to 404.90 ha (by 176.49 ha; +77.3%).

The suburban zone owed the dynamic growth of the area of buildings in industrial zones mainly to the growth of industrial buildings from 16.84 ha to 155.30 ha (an increase of 138.46 ha; +822.2%) and outbuildings from 12.50 ha to 131.99 ha (an increase of 119.49 ha; +955.9%). The growth dynamics of the area of the studied buildings in the city of Wrocław was lower. In particular, the area of outbuildings (by 51.84 ha; +76.5%), public buildings (by 45.72 ha; by 149.3%), industrial buildings (by 39.94 ha; +31.1%) and residential buildings (by 36.67 ha; +2236.0%) developed during this period (Table 2).

Between the 1980s and 2020s, the share of individual building functions in the total building

Table 2. Area, functions and dynamics of change of buildings in the industrial areas of the Wrocław agglomeration from the 1980s to the 2020s

Type of buildings	(1-3)	1980s	1990s	2000s	2010s	2020s	1980s-2020s	
		ha					ha	%
residential	(1)	1.64	1.86	7.64	10.88	38.31	36.67	2236.0
	(2)	0.23	0.31	0.70	0.80	0.59	0.36	156.5
	(3)	1.87	2.17	8.34	11.68	38.90	37.03	1980.2
public	(1)	30.63	39.07	71.02	74.53	76.35	45.72	149.3
	(2)	1.49	2.63	5.29	10.36	11.76	10.27	689.3
	(3)	32.12	41.70	76.31	84.89	88.11	55.99	174.3
outbuilding	(1)	67.76	91.76	118.56	124.50	119.60	51.84	76.5
	(2)	12.50	18.33	59.78	82.93	131.99	119.49	955.9
	(3)	80.26	110.09	178.34	207.43	251.59	171.33	213.5
other	(1)	0.00	0.00	2.86	2.86	2.32	2.32	-
	(2)	0.00	0.00	0.50	0.55	0.58	0.58	-
	(3)	0.00	0.00	3.26	3.41	2.90	2.90	-
total	(1)	100.03	132.70	200.08	212.76	236.58	136.55	136.5
without	(2)	14.22	21.26	66.27	94.65	144.92	130.70	919.1
industry	(3)	114.25	153.96	266.35	307.41	381.50	267.25	233.9
industrial	(1)	128.38	164.96	143.75	147.35	168.32	39.94	31.1
	(2)	16.84	23.00	34.70	78.46	155.30	138.46	822.2
	(3)	145.22	187.96	178.45	225.81	323.62	178.39	122.8
total of all	(1)	228.41	297.66	343.83	360.12	404.90	176.49	77.3
	(2)	31.06	44.25	100.96	173.10	300.22	269.16	866.6
	(3)	259.47	341.91	444.79	533.22	705.12	445.65	171.8

(1) – city of Wrocław, (2) – suburban zone, (3) – agglomeration

Source: authors' own study.

Table 3. Degree of saturation with buildings of industrial areas in the Wrocław agglomeration in 1980-2020

Area	1980s	1990s	2000s	2010s	2020s	1980s-2020s
	%					percentage points
city of Wrocław	16.7	20.6	41.4	40.3	46.1	+29.4
suburban zone	21.6	20.6	16.6	23.4	35.4	+13.8

authors' own study

area across the entire agglomeration changed. Most notably, the share of industrial buildings declined (from 56.0% in 1980s to 45.9% in the 2020s; -10.1 percentage points, primarily in favor of an increase in residential buildings (from 0.7% to 5.5%; +4.8 percentage points) and outbuildings (from 30.9% to 35.7%; +4.7 percentage points). A characteristic feature of this process was its faster pace in the agglomeration core — the city of Wrocław (e.g., the share of industrial buildings fell from 56.2% to 41.6%; -14.6 percentage points) — than in its suburban zone (where the decline was from 54.2% to 51.7%; -2.5 percentage points).

The degree of saturation of industrial areas in the Wrocław agglomeration with buildings in the period 1980 – 2020 increased steadily (Table 3), which effectively means that these areas were gradually densified with new buildings. It also means that the new development zones were ultimately designed with a high proportion of the built-up area. This growth was higher in the agglomeration's core than in its suburban zone. At present, over 40% of the area of industrial zones is covered with buildings, with this indicator in Wrocław oscillating around the value of 46.1%, and in the suburban zone – 35.4% in 2020.

4.2. Regularity of the location

As the area of buildings in the industrial areas of the Wrocław agglomeration changed, so did their distribution. Initially, most of the buildings in the industrial areas were located in or near the centre of the agglomeration. In the 1980s, as many as 69.5% (180.34 hectares) of the buildings were located within 6 km from the Wrocław market. As much as 88.0% of the area of all buildings was then located within the city boundaries. This situation has changed over the years. In the 2020s, only 39.7% (279.63 hectares; -29.8%) of the building area was located within 6 km from the Wrocław market, and 57.4% (404.90 hectares) of the total building area was within the city itself.

In recent decades, the development of building areas in the industrial zones of the Wrocław agglomeration has been particularly dynamic in the suburban zone. The largest increase in building area was recorded in the suburban zone in the 12-16 km belt from the centre of Wrocław. Between the 1980s and 2020s, the area of buildings in this area increased from 8.16 hectares to 180.00 hectares (over 21-fold increase) (Fig. 3).

The aforementioned changes in the distribution of buildings in the Wrocław agglomeration demonstrated certain regularities (Fig. 4A-D). Firstly, as years passed, the concentration of development increased in the industrial areas of the suburban zone. However, it is still the core of the agglomeration (the city) that concentrates the most buildings in such areas (Fig. 4A). Secondly, among the building categories studied, only residential buildings showed an increase in concentration within the city boundaries of Wrocław (Fig. 4B). The other categories of buildings, especially industrial (Fig. 4C) and outbuildings (Fig. 4D), showed a definite trend of deconcentration of buildings in the agglomeration core and concentration in the suburban zone. Finally, since the 2000s, there has been a definite process of deconcentration of development in the agglomeration core and its concentration in the suburban zone. Intense development in the Wrocław agglomeration has particularly occurred in the belt from 12 to 16 km from the centre of Wrocław.

4.3. Degree of reclamation

The ratio of the area of industrial buildings to the area of other buildings tells us about the degree of reclamation of the studied areas, clearly indicating which functions of buildings are displacing industrial development (Fig. 5A-D). Different trends in the reclamation of industrial areas are noticeable between the 1980s and 2020s. Initially, industrial buildings were dominant in the Wrocław agglomeration. However, since the 1990s, this trend began to change rapidly, especially in the suburban

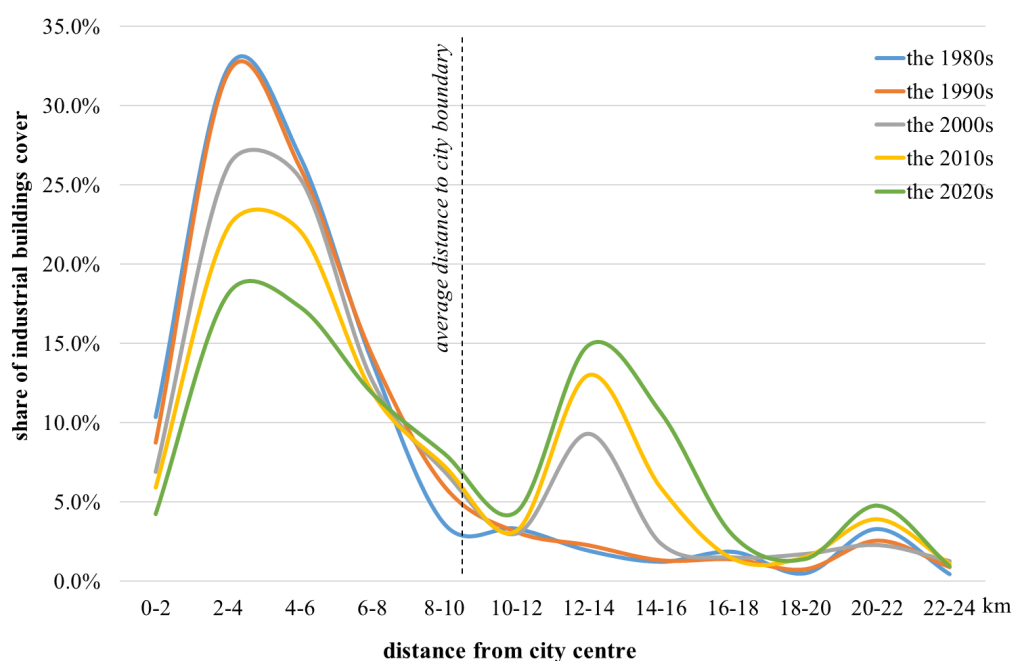
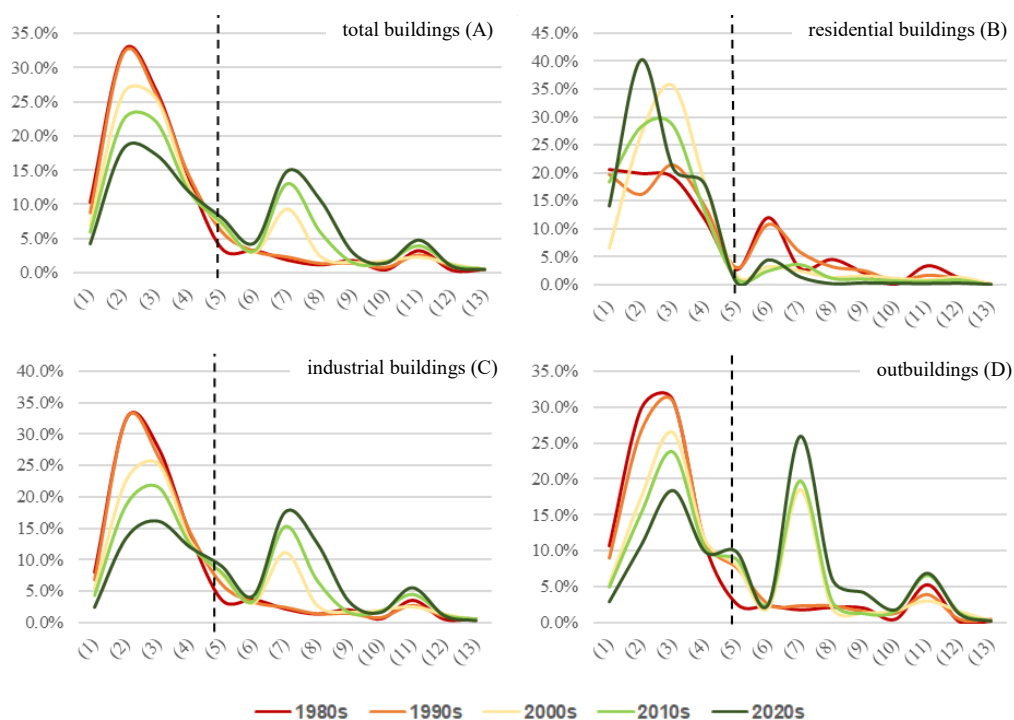


Fig. 3. The area of buildings as a function of distance from the city centre in the industrial areas of the Wrocław agglomeration in the 1980s-2020s

Source: authors' own study



OX-axis [distance]: (1) 0–2 km, (2) 2–4 km... (13) 24–26 km.

--- - average distance from the city's administrative boundary

Fig. 4. All buildings of industrial zones (A) by function and distance from the city center in the Wrocław agglomeration from the 1980s to 2020s: residential buildings (B), industrial buildings (C), outbuildings (D)

Source: authors' own study

zone, where in the 2000s the ratio of the area of remaining industrial buildings was 191.0%. In the following decades, these trends reversed and stabilized again. In the city of Wrocław, the degree of reclamation oscillates around the value of 140%, and in the suburban zone around 93% (Fig. 5A).

The replacement of industrial buildings in the city of Wrocław largely took place through the appearance of buildings with a residential function (Fig. 5B) and the public buildings (Fig. 5D) on industrial areas. In turn, in the suburban zone, alongside industrial buildings, buildings with basic functions, i.e., outbuildings, began to play an important role, especially in the 2000s (Fig. 5C).

5. Discussion

The study clearly showed that the area of buildings in the industrial areas increased significantly during the period under review from the 1980s to 2020s (an increase from 259.47 to 705.12 hectares; +271.8%). This was primarily related to the process of densification of buildings in already existing industrial areas (the share of building area in the total area of industrial areas increased from 17.2%

to 40.9%; +23.7 percentage points) than to the overall increase in the area of industrial zones and the construction of new buildings (the area of industrial zones increased from 1510.0 hectares to 1725.8 hectares during this period; +14.3%) (Sikorski & Kryczka 2023). Particularly, the process of densification of industrial areas with buildings was evident in the studied agglomeration in its core, i.e. the city of Wrocław (the share of built-up area increased from 16.7% to 46.1%; +29.4 percentage points). The key date for the described processes is the turn of the century, when the share of building area in industrial zones in Wrocław increased from 20.6% in the 1990s to 41.4% in the 2000s (+20.8 p.p) (Table 3). This increase was largely associated with Poland's accession to the European Union in 2004 and the related acceleration of economic transformations in the country, including changes in land use and building functions in urban agglomerations (Michałek & Hagemeyer, 2024).

The observed regularity is part of a general trend noted in other such cities in CE, where one of the consequences of the socio-economic transformation of post-socialist cities was an increase in the intensity of space use (Stanilov, 2007a). This was influenced by a number of factors and conditions, the most important of which were: the changing

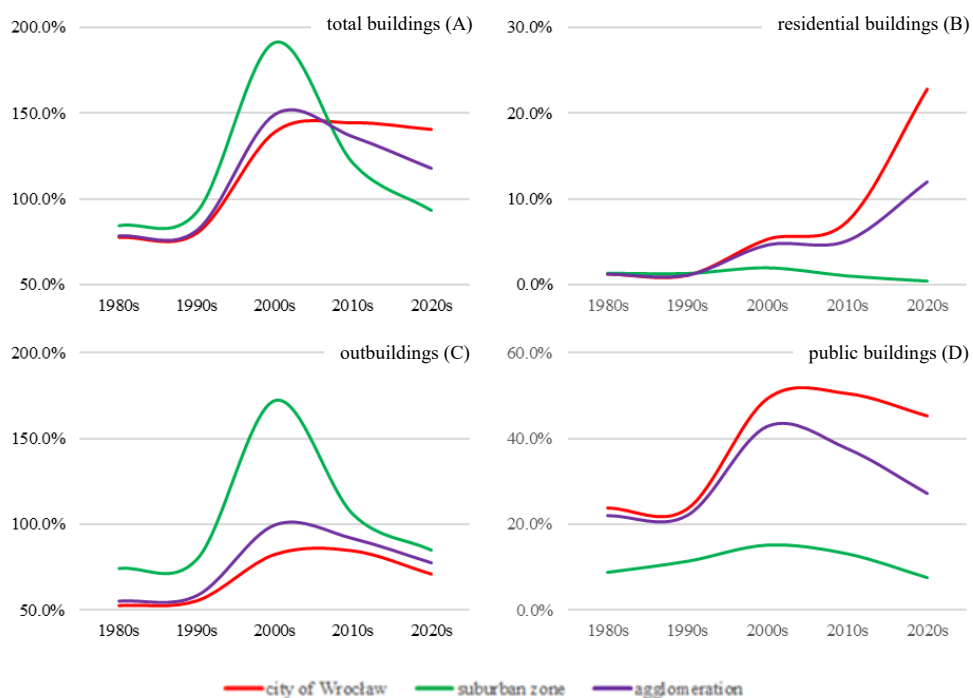


Fig. 5. Rehabilitation of industrial buildings in per cent of all buildings (A) located in industrial areas in the Wrocław agglomeration from the 1980s to 2020s: residential buildings (B), outbuildings (C) and public utility buildings (D)

Source: authors' own study

needs of industry for necessary facilities and installations, land rent, the policy of deglomeration or deconcentration of industry from the largest urban agglomerations, as well as the desire to raise the quality of residents' life and to eliminate the nuisances associated with industrial activity (Słodczyk, 2001).

When looking at the increase in the share of industrial land development, it is also worth noting what type of buildings are appearing in terms of function in such areas. An analysis of the data shows that until the 2000s, mainly buildings with an industrial function predominated and grew in number in industrial areas. After the 2000s, there is a clear reversal of the trend and an increase and dominance of buildings with functions other than manufacturing in industrial areas (Table 2). In addition, the rate of growth of buildings with a function other than industrial was significantly higher in the suburban zone of the agglomeration under study than in its core (in the core of the agglomeration the area of buildings increased almost 2-fold, and in the suburban zone as much as almost 10 times) (Table 2). Only buildings with a single residential function were characterized by a higher rate of area growth in the city than in its surroundings.

The observed trends in changes in the function and distribution of development of the industrial areas of the studied city are in line with general trends seen in other CE cities. As numerous studies have shown, the turn of the millennium (around the year 2000) is the period when the process of suburbanization, consisting of the gradual migration of the population of large cities from the core to their suburban zones, begins to develop intensively in most post-socialist countries in Central Europe (Ouředníček, 2007; Stanilov, 2007b; Kovács et al., 2013; Szmytkie, 2021). Thus, it can be argued that suburbanization in post-socialist CE cities was not merely a demographic phenomenon, but also exhibited a distinct economic dimension, influenced by factors such as lower land prices, favorable tax conditions, local investment incentives, better transport and traffic connections, and the availability of labor, among others (Sikorski & Szmytkie, 2022). Thus, this suburbanization was accompanied by the gradual deconcentration and deglomeration of industry (Sikorski & Kryczka, 2023). Consequently, the increase in the area of buildings with a function other than industrial (in addition to buildings with a residential function) in the suburban zone of the agglomeration was largely associated with the transfer of economic activity from the urban core to its surroundings (economic suburbanization), which

provided more space and opportunities for the development of economic activity than the densely built-up areas of a large city. This activity, as the study shows, was no longer of a sole manufacturing nature, but was much more diversified. The significant increase in outbuildings suggests that there was a significant increase in the demand for facilities related to various types of storage rather than to the manufacturing and production process itself. Such conclusions are almost identical to other studies of this kind on the examples of Chemnitz, Leipzig, Łódź, Kielce, Katowice, Bratislava, Nitra, Olomouc and Brno (Kunc & Cudny, 2022). As a result of the processes that have taken place in the suburban zone of the urban agglomerations of Central European countries, logistics and logistics-warehousing centres have been created to a large extent on industrial areas as a natural base for serving the entire agglomeration market (mainly the agglomeration core). In turn, the vacant post-industrial space in the city was used, largely for the development of shopping centres, but also for the emergence of new development estates (Kunc et al., 2023; Sikorski, 2022).

In addition to the political transformation and the growing influence of suburbanization after 1989, the observed changes in industrial areas were also shaped by legal and regulatory reforms in Poland and other CE countries. The expansion of built-up areas, combined with the progressive liberalization of construction law, undermined the conditions established by earlier development models. The gradual prioritization of property rights in social perception over spatial planning procedures and spatial order, along with the resulting dynamics of the real estate market, has further intensified the negative impact on the functionality of industrial zones. This issue is particularly significant in the context of recent spatial planning reforms (2023) in Poland, which risk blurring the lines of responsibility for municipal spatial policy. As a result, strategic planning decisions may be made by individuals lacking appropriate professional qualifications or expertise (Kryczka & Lisowska-Kierepka, 2025; Kryczka, 2025). These processes have contributed to increasing functional disorder in post-socialist cities, particularly within former industrial areas. The conditions and consequences of this transformation in the Wrocław metropolitan area have been examined, among others, by Jurkowski et al. (2024). Kryczka (2024) even demonstrated that overly permissive spatial planning at the local level can lead to an increasing degree of monofunctionality within urban districts, resulting

in dysfunctional patterns of functional and spatial development.

The transformation process of industrial areas in the city area is of critical importance in shaping local development policy. The transformation of brownfields such as industrial land covers in the city core into urban residential areas may have positive effects in terms of reducing congestion and using existing urban infrastructure (Gyurkovich & Gyurkovich, 2021). Nevertheless, these may have been areas used for intensive production, which very often significantly affects the environment (*Note 2*). The conversion of these areas must involve a comprehensive assessment of the state of the environment, remediation of the land, and an assessment of the investment's influence on the environment and human health, providing that the environmental quality standards will be met (Lorber, 2011; Potseshkovskaya & Soroka, 2021). It is also crucial for local spatial planning, as from 2023 most of the Polish municipalities are obliged to prepare general zoning plans. The awareness of the scale and patterns of industrial transformation processes can strengthen the integrity of spatial development and counteract potential spatial conflicts at an early planning stage.

The degree of reclamation of industrial buildings in the industrial areas of the studied agglomeration clearly indicates a gradual transition from monofunctional to multifunctional land use over the study period. A noticeable pattern reveals that within the economic landscape - including industrial areas - it is increasingly uncommon to encounter plots characterized by purely monofunctional use (i.e., a single type of economic activity). The growing spatial diversity of cities has been widely documented in the literature (e.g., Kunc & Tonev, 2022), and strongly suggests that the urban fabric of CE cities is increasingly resembling that of Western European cities, where spatial multifunctionality is a common feature (Ghafouri & Weber, 2020).

6. Conclusions

Our research clearly shows that industrial areas often visualized on the map as homogeneous and monofunctional areas in reality have always been and still are diverse and multifunctional. The degree of diversity of these areas depended on several factors, one of the key ones being the rent of location in relation to the centre of the agglomeration core and, consequently, the determinants of spatial accessibility. The analyses unequivocally showed

that development in industrial areas is becoming increasingly diversified and depends on the function of time (the closer to the 2020s, the greater the diversification) and the function of distance from the centre of the agglomeration core (the closer to the centre, the greater the diversification). Such determinants of changes in industrial land use are largely the result of the transformation of Central European cities from typical socialist cities into the so-called post-socialist cities (Ouředníček, 2007; Kiss, 2007; Kunc & Tonev, 2022).

The transformation of industrial areas and their development shows a gradual process of deglomeration and deconcentration of industrial activity and its gradual relocation to the suburban zone of the agglomeration. The released space is being replaced mainly by services (in the agglomeration core it is commercial services in the form of shopping centers, business support entities, etc.; in the suburban zone it is services in the form of logistics and warehousing centres), and in recent years there has been a significant increase in residential development in the city itself (the agglomeration core). These changes in the land use of CE cities have had important implications for the structure and functional aspects of the city, which have already been repeatedly described in the literature (for example, socio-demographic changes were written about by Haase and Steinfuhrer (2005), Steinfuhrer and Haase (2007), Ott (2001), Stenning and Dawley (2009) or Szafrńska (2014, 2015, 2017), while functional-economic changes were studied by Cudny (2012), Chapain and Stryjakiewicz (2017) or Chaloupková et al. (2018), among others).

The functional transformation of industrial buildings also have practical implications (e.g., social, economic, planning-related), particularly for the city of Wrocław. For example, in the socio-economic sphere, the number of people employed in industry in Wrocław decreased from 214 593 in 1995 to 38 741 in 2023 - a drop of over 80% (Sikorski, 2013; BDL, 2024). At the same time, the number of industrial entities in the city has remained relatively stable (8 573 in 1999 vs. 8 493 in 2024), although their structure has changed significantly. In the late 1990s, Wrocław was home to nine industrial enterprises employing more than 1,000 people each, while today that number has declined to just four or five (Sikorski, 2013; BDL, 2024). A positive outcome of the transformation of industrial areas in Wrocław has been their commercialization and the opening up of these spaces to a variety of uses. However, this has at times led to spatial and transport-related chaos, due to the overdevelopment of a single

function (e.g., commercial or residential) (Sikorski & Smętkiewicz, 2024).

The research carried out, due to the quantitative analysis of the phenomenon, demonstrates a morphometric approach to the issue of studying the transformation and displacement of industrial land and its development, since so far studies of this type have mainly focused on describing the mechanism of this process without giving a specific scale and value of it. However, it does not fill all the gaps of the described research issue. Literature still lacks studies that prove by means of geostatistical methods what factors influence the transformation and displacement of industrial areas of Central European cities.

Notes

1. Interpretation: 0-100% - in the industrial area buildings with industrial function dominate, > 100% - in the industrial area buildings with other functions begin to displace the ones with industrial function.
2. Among such sites in the Wrocław metropolitan area, one can point to a former construction machinery company located next to a copper and copper alloy processing company – both located in the downtown area. Currently, the sites of the former have been converted to multi-family residential buildings.

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