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Research paper

Revitalization possibilities of post-industrial and warehouse areas on the example of Warsaw's Żerań

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Abstract: Suburbanization and urban sprawl, alongside the concept of creating compact cities, highlight the need to repurpose undeveloped, degraded spaces, such as post-industrial and warehouse areas. Revitalizing these spaces involves addressing the land's physical condition and improving the social and economic well-being of local communities. In many European cities, the late 20th century saw industrial activity dominate. However, after 1989, political changes in Poland led to the relocation of industry from central districts to make room for modern residential and service developments. An example is Warsaw's Żerań, previously centred around industrial hubs. A key challenge in redeveloping such areas is addressing land contamination, reclaiming degraded post-industrial zones, and eventually revitalizing the space to introduce new functions. Contamination often leaves these areas unused for years, but proper remediation can breathe new life into them. Furthermore, public spaces such as parks and squares in Żerań are often underused, but proper design following cleanup can foster social connections and contribute to a well-functioning urban environment. Revitalizing degraded urban areas ensures rational use of available space, aligning it with desired functions. Identifying and addressing these areas can transform neglected industrial zones into thriving residential and service centres, attracting new residents and investors.

Keywords: urbanization, revitalization, post-industrial areas, compact city, warehouse areas, Żerań

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1. Introduction

The progressive phenomenon of suburbanization and urban sprawl and the idea of creating a compact city create the need to find undeveloped, degraded spaces and give them a new function. Up to 21% of urban space is estimated to be degraded [1]. Such areas include, among others, post-industrial areas and warehouse areas often present in cities.

One of the main challenges of rational spatial planning in cities is the reuse of abandoned post-industrial areas, distinguished by their attractive location and existing infrastructure [2, 3]. This is possible thanks to a correctly performed revitalization process, consisting of getting them out of a crisis, both in terms of the space itself and in improving the local population's social and economic conditions [4].

Revitalization (from Latin re+vita, bringing back to life, re-invigoration) is a key element of urban development and rational and sustainable shaping of space, both in cities and rural communes [5]. It is an environmental, social, economic, formal, legal and spatial problem, and therefore an extremely complex problem. Such complex and complicated activities often require significant financial outlays and an interdisciplinary approach. This need has been recognized in international legal acts, including Regulation 1828/2006, laying down detailed rules for implementing Council Regulation (EC) No. 1083/2006. Under it, the revalorization of industrial areas and the reclamation of contaminated land have been recognized as one of the priority areas of intervention for European Union funds. Revitalization is a continuous and long-term process, the success of which is influenced by the involvement of residents, institutions and social organizations of the revitalized area [6]. Local communities' participation occurs through social participation activities such as discussions, excursions or field trips. There is also a close relationship between spatial planning and revitalization, understood as mutually complementary tools for implementing the development policy of the city/commune [7]. Regardless of the adopted revitalization goals, preparing this process requires taking action in many different areas. As mentioned earlier, this means that interdisciplinary, multi-threaded and multi-dimensional action is necessary. These activities can be classified into three basic groups: planning and design, organizational and financial, and promotional and informational. In many European cities, the second half of the 20th century was dominated by the development of industrial activity [8]. Production plants were close to the centre, often by the river, for easier access to water. Entire industrial and workers' estates were built in cities, which in Poland was particularly visible in Upper Silesia, but also in the main administrative centres: Warsaw, Łódź and Poznań [9]. However, the political change in Poland in 1989 gradually led to the displacement of the industry from central districts in favour of introducing modern residential and service development there [10]. Since the 1990s, there has been a prevailing tendency to combine revitalization activities with the cultural heritage of a given area. Instead of demolishing or omitting historic buildings, a renovation places them in the central point of interest [11].

A special type of post-industrial space is warehouse areas [12]. Unlike "typical" industrial areas, no production processes took place in their area, and therefore, they were much less frequently affected by the problem of exceeding permissible pollution standards (unless toxic materials were stored there). A uniform spatial structure and equipment with basic media most often characterize them. The fact that these areas have been used so far for the location

of warehouse development also largely excludes restrictions caused by the occurrence of unfavourable ground. In addition, current trends in city planning also indicate a gradual removal of warehouse areas to logistics centres located on the outskirts of cities near communication nodes [13, 14]. The study aims to analyze the potential of revitalized post-industrial and warehouse areas in Warsaw's Żerań to introduce new functions – residential, service, and public spaces. The following research questions were also formulated:

1. What factors influence the possibilities of revitalizing post-industrial and warehouse areas?
2. Can revitalized post-industrial and warehouse areas quickly adapt to new functions?
3. What are the potential opportunities and barriers related to revitalizing post-industrial and warehouse areas?

2. Historical context of the research area

The origin of the name Żerań is not entirely clear – it may derive from the word "żer" which means a forest pasture [15]. This was probably the original function of the area [16]. The village of Żerań was first recorded in the 13th century. In the 16th century, as royal property, the area was equipped with a ferry crossing over the Vistula, a mill and fields located on sands. During the Polish-Swedish war, the village was completely burned down and rebuilt [17]. In 1659, Żerań received the right to transport goods across the Vistula from John Casimir. From references from the first half of the 19th century, it is known that industry was already developing in the area of Żerań (a brewery and a vinegar factory). At the end of the 19th century, the now non-existent Jabłonowska narrow-gauge railway was built through Żerań [18]. In the interwar period, it was decided to develop heavy industry in Żerań, during which Metalowe Zakłady Hutnicze Żerań S.A. was established, and preparations for the construction of a power plant and a canal began [19]. The latter was planned to connect the Vistula with the Bug in the first half of the 19th century.

The first works on its construction were undertaken after World War I, but the project was suspended due to the war with the Bolsheviks and later financial problems. It was returned in the 1950s when it was finally implemented with the port [20]. Water transport was important for some branches of industry located in Żerań. In each port basin, a reloading quay was built to unload gravel, sand, and other aggregates. Since 1972, this is where these materials were mainly reloaded for industrial plants in Żerań. The last reloading works were carried out there in 1989. Since then, the port has been losing its importance, and currently, it no longer serves an industrial function. The last years of the port's operation are shown in aerial photographs from 1990–1994 [21]. Żerań was mostly incorporated into Warsaw in 1938 and entirely after World War II in 1951. In the post-war period, the pre-war assumption was continued, according to which Żerań was to be an industrial area. At that time, such plants were established as: Żerań CHP Plant with Żerań Port, Passenger Car Factory, Electronic Device Manufacturing Plants "Warel", Warsaw Plastics Factory "Pollena", Warsaw Pump Factory, Building Elements Factory "Faelbet", as well as the Institute of Nuclear Chemistry and Technology and the Institute of Organic Industry. For their needs, railway stations, sidings, and tram lines were built in the

area, but the Jabłonowska railway was liquidated. The "Marywilska" housing estate, built in 1950–1964, should also be mentioned among the more serious projects.

In the 1970s, multi-family housing developed more extensively in Żerań [17]. After the socio-economic changes in the late 1980s, industrial activity in Żerań continued to develop, but warehouses and large-scale commercial facilities also entered the area at that time. The 21st century is a time of intensive development of multi-family housing estates in northern Żerań, especially along Marywilska and Modlińska streets.

3. Methodology and data sources

The Żerań housing estate, located in the capital of Poland, Warsaw, in the Białołęka district, was selected for the study. Fig. 1 shows Poland and Warsaw against the background of Europe, then the location of Żerań against the background of Warsaw and finally, the studied area in Warsaw itself. It covers an area of 14.18 km^2 and is inhabited by approx. 50 thousand residents.

Fig. 1. Location of the study area – Żerań housing estate; Source: own study

Żerań is an example of a housing estate with a rich industrial past, which is currently undergoing transformations leading to the creation of large degraded areas and former industrial and warehouse facilities. The most important of these include Port Żerań and the area of the former Stare Świdry House Factory. Built-in the 1950s, it included the production of wall and ceiling elements as part of the socialist assumptions of the "Large Panel". The former waste storage site of the Żerań CHP plant is directly adjacent to the area. One of the manifestations of the transformation that the estate is currently undergoing is the combination of the industrial past of Żerań with modern urban development. Among other things, new urban developments are planned in the areas of the former Stare Świdry House Factory and Port Żerań. An important element of the changes is the development of communication infrastructure. The planned tram line will connect Żerań with neighbouring housing estates, significantly improving communication accessibility. These initiatives demonstrate the dynamic development of Żerań and make it an attractive place to live, work and relax while maintaining elements of its historical identity.

The research methodology was based on both quantitative and qualitative methods. On the one hand, several indicators were analyzed and calculated using spatial analyses in GIS technology, which referred to both the quality of the natural environment (e.g. terrain, area and quality of plant vegetation) and the nature of the built environment (e.g. availability of public transport and other services, height of buildings). In the case of the latter group of indicators, the guidelines specified in Warsaw urban standards were primarily based because this is a binding document of local law, the provisions of which will have a decisive influence on the possible processes of transformation of this area. In addition, a comparative analysis of the provisions specified in these standards was carried out with the optimal standards proposed in scientific works, and no significant deviations were found, which confirmed that these standards could be the basis for this study.

On the other hand, qualitative research was also taken into account. In this case, the natural environment (e.g. the nature of the ground), the built environment (e.g. the quality of the urban composition) and legal conditions were also taken into account (the provisions of the planning documents were analyzed).

The following spatial data were used for the research: current land development and use (BDOT), historical aerial photographs (resources of the Warsaw City Office), Sentinel satellite images (USGS), digital terrain model with a spatial resolution of 1 m (GUGIK), land ownership map (resources of the Warsaw City Office), planning and strategic documents for the Warsaw City Office (resources of the Warsaw City Office), data and maps regarding geology and threats to the natural environment (GDOŚ and PIG), tree crown map (GDOŚ), flood hazard maps (ISOK), data from the Real Estate Price Register for Warsaw, data from the register of monuments and the register of monuments, statistical data (GUS).

Spatial data were processed and visualized using GIS technology using QGIS software.

Based on the analyses conducted this way, conclusions were formulated, summarising the case study. The discussion indicated to what extent the research was conducted and whether its results could be helpful in a broader context. It also discussed the transformation of relief areas in contemporary cities.

4. Research results

4.1. Functional structure

The area of Żerań is mainly covered by warehouse and industrial development (Fig. 2). On the south-eastern side of the Żerań Canal, there is almost exclusively such development. The exceptions are several large-scale service facilities, a housing estate of a dozen or so single-family houses with adjacent allotment gardens located on the Toruńska route, and a multi-family housing estate between Marywilska Street and the railway tracks. In the northern part of Żerań, east of the railway tracks, industrial and warehouse development also dominates, with large-scale service facilities, but this advantage is minor. There is also single-family development with a dispersed rural character, in places taking the form of street houses. The area with the best transport accessibility is near the tracks near the Warsaw Żerań city and regional railway stop.

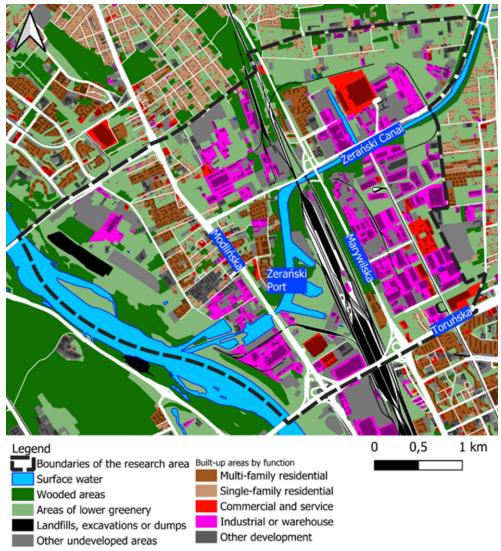


Fig. 2. Functional structure in the area of Żerań; Source: own study based on BDOT data

The area along Modlińska Street north of the Żerański Canal has a different characteristic. Industrial and warehouse developments occur mainly near railway sidings. The remaining part is dominated by residential development, primarily multi-family housing estates built in the 21st century. It should be emphasized, however, that the development in this area is fragmented and does not create a coherent urban space.

4.2. Local law

The Study of Conditions and Directions of Spatial Development is currently in force for the discussed area – a document defining the main directions of land development. According to its provisions, the area of Żerań, except riverside areas and some along the canal, is planned

for development. According to the Study, the area of Żerań should mainly develop production and service development. Only a part of the areas located along Modlińska Street north of the Żerański Canal is planned for housing. However, the Study is not an act of local law, and its provisions may become binding only after adopting a local spatial development plan for a given area. The area of Żerań is only covered by such plans to a small extent (Fig. 3), as a result of which developments inconsistent with the provisions of the Study are also being built in this area. It is worth emphasizing, however, that the Study document was adopted in 2006 when a large part of the currently inactive production areas was still in operation.

Most of the studied area is not covered by the provisions of local spatial development plans, but several such documents are in force in this area. On a small fragment by the Toruńska route, the plan establishes single-family housing and service development. The north-eastern edge of the area is planned for industrial and service development. On the other hand, those areas located along Modlińska Street, which are covered by the plans, are designated for housing development with accompanying services. The areas designated for housing development in the plans are currently mainly invested.

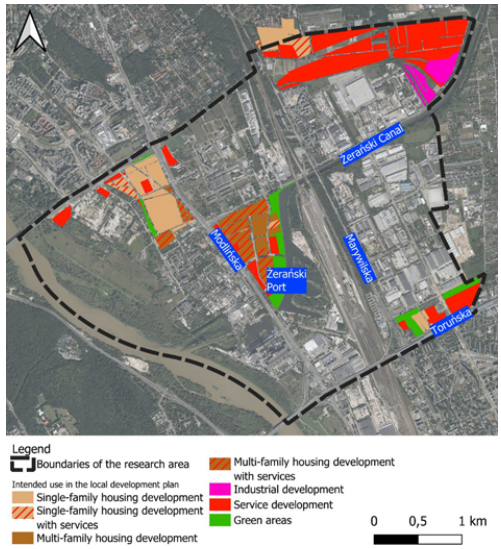


Fig. 3. Provisions of local plans in the area of Żerań; Source: own study based on BDOT data

On the other hand, the areas designated for other functions remain largely undeveloped. According to local regulations, residential development can also be implemented without the appropriate land designation in the local plan, but then it is necessary to meet the local urban standards specified by the city council. In the case of the discussed area, the most important standards from the point of view of the possibility of developing the residential function are those related to communication accessibility (distance from bus, tram, metro and train stops), accessibility of social services (schools, kindergartens) and height of neighbouring buildings – for these aspects, detailed studies were carried out based on the Network Analysis method in GIS technology. Other local urban standards, such as green area per resident, can be

implemented by appropriately shaping individual investments, which is why they were not considered in this study. One of the urban standards states that a residential investment built in the urban zone can be located no further than 400 meters from existing public transport stops. The analysis shows that all areas along main roads have access to public transport stops at no more than 400 meters. The areas adjacent to them are also partially serviced. In areas with insufficient services, it is possible to increase the range of stops by supplementing the network of pedestrian paths, which could be implemented in parallel with the implementation of potential investments. In addition, local urban standards distinguish rail transport stops with a high frequency of connections from all public transport stops (Fig. 4). For residential investments implemented in the urban zone within 800 meters from such stops, reduced parking indicators apply (0.8 spaces per apartment). The Żerań area, due to tram lines and the second line of the Warsaw metro, partially qualifies for such a reduction of this indicator. This refers to the areas located along Annopol Street, in the vicinity of the FSO Żerań tram terminus and the western end of Żerań located within the range of the tram line to Białołęka. In addition, in the Żerań area, there are two urban and regional railway stations (Toruńska and Żerań), which currently do not sufficiently meet the condition of high frequency.

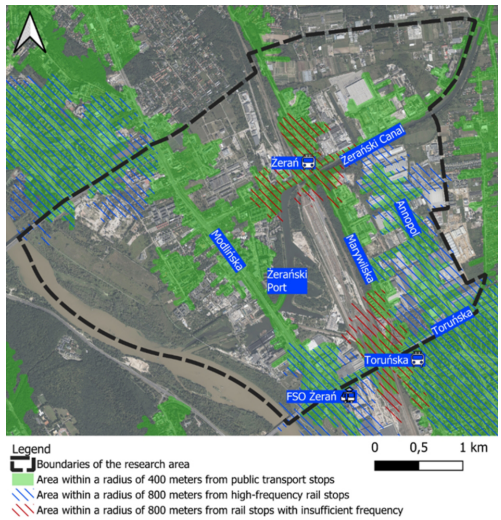


Fig. 4. Accessibility of transport in the area of Żerań; Source: own study

Warsaw urban standards allow for locating new residential buildings in the urban zone if the distance from the nearest primary school and kindergarten is no greater than 800 meters (Fig. 5). There is only one primary school in the studied area, which is located between the Vistula and Modlińska Street, and therefore covers only a tiny part of the entire area. Schools located outside Żerań cover only a small area on the north-western side of the Toruńska route, which is also insufficient for the development of the residential function in Żerań. The situation is similar to the availability of kindergartens in the studied area. Limited access to educational services seems to be a significant barrier to developing the residential function in Żerań.

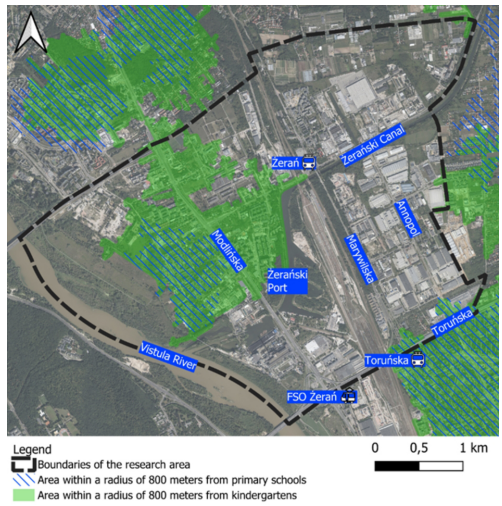


Fig. 5. Accessibility of education services in the area of Żerań; Source: own study

According to urban planning standards, the height of residential buildings cannot exceed seven storeys above ground unless there are buildings with more than seven storeys within a radius of 250 meters from the building being constructed. In Żerań, residential buildings with several storeys in the range of 7–14 are located only on Modlińska Street, in the area covered by the Local Spatial Development Plan, i.e., where urban planning standards have limited application. A small part of Żerań in the vicinity of the Toruńska route is located in the buffer area of 11-storey buildings, but this is the area of a road junction.

4.3. Suitability for development

It is worth emphasizing that in terms of soil and water conditions [22], Żerań is mostly a suitable housing estate for introducing new development. In terms of load-bearing capacity, a significant part of the land (85.7%) is suitable for development without restrictions; the exceptions are areas of alluvial soils (F), suitable with restrictions, and areas of muck soils (M) and waters, unsuitable for development. Areas suitable with restrictions and unsuitable for development are located along the Vistula River, in protected areas near the flood embankment. However, they constitute only 3.4% and 0.2% of the area of Żerań, respectively (Fig. 6).

Regarding humidity, a significant part of the land (83.6%) is suitable for development without restrictions; the exceptions are areas of black earth, suitable with restrictions, and green areas, unsuitable for development. Areas suitable with restrictions and unsuitable for development are located along the Vistula, in protected areas and the north-eastern part of Żerań, in the vicinity of the Żerański Canal. However, they constitute only 4.7% and 1.0% of the area of Żerań, respectively. Żerań does not have significant land elevations, and the terrain is flat (Fig. 7). The most remarkable height differences occur on the quays and in the vicinity of the combustion waste storage site. The maximum recorded height of 98.49 m above sea level

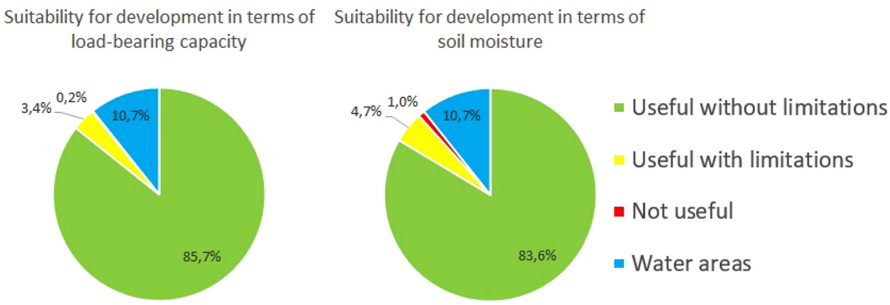


Fig. 6. Suitability for development in terms of load-bearing capacity and soil moisture; Source: own study

occurs on the top of the former combustion waste storage site "Myśliborska", closed in 2016, currently undergoing reclamation and being prepared for redevelopment. The minimum height of 74.77 m above sea level occurs in the area occupied by the Vistula River. In the remaining landward part of Żerań, the heights are similar and average from 85 to 90 m above sea level. Regarding terrain, a significant part of the land is suitable for development without restrictions; only here and there are areas suitable with restrictions (3–5 degrees) and unsuitable (above 5 degrees). These are the embankments of the previously mentioned waste disposal site and the railway tracks running through the central part of the estate, as well as the banks of the Żerań canal in the area of the Żerań Port.

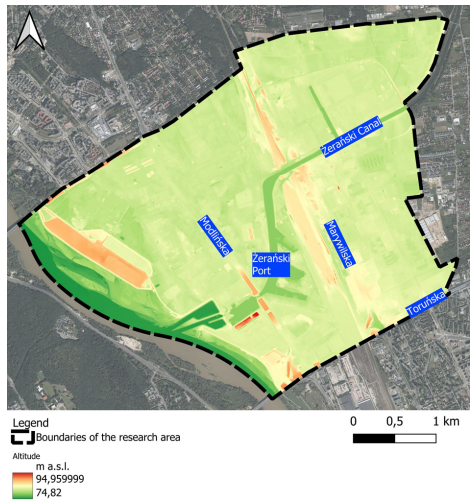


Fig. 7. Terrain hazard in the Żerań area; Source: own study

There is no high flood risk in Żerań (Fig. 8). It mainly concerns the immediate vicinity of the Vistula River, on the section in front of the flood embankment. In this place, the probability of flooding is high and amounts to 10% (once every 10 years). On the south-eastern side of the Żerań Canal, there is a small area with a low probability of river flooding. It amounts to 0.2% (once every 500 years).

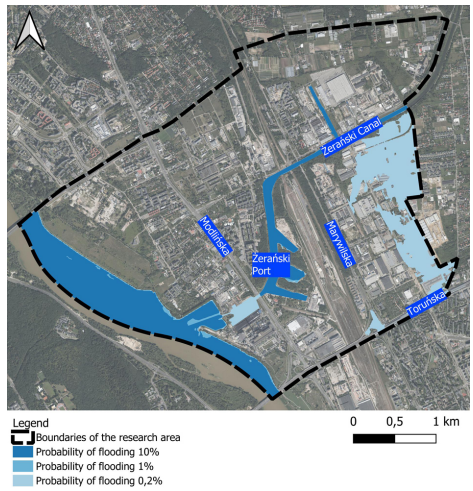


Fig. 8. Flood hazard in the Żerań area; Source: own study

Because development restrictions occur only in areas of particular flood risk, apart from the immediate vicinity of the Vistula, the area of Żerań is entirely suitable for introducing development there. This increases the potential and attractiveness of the estate in this direction.

Additionally, the depth of the first aquifer in the study area is, on average, 2–5 m below ground level, which also does not limit the possibility of developing the area for residential purposes.

The only problem is that in the study area, the groundwater of the primary usable aquifer has been classified as poor-quality water requiring treatment. At the same time, there is a very low level of susceptibility to contamination of the first aquifer because the approximate time for pollutants to reach the PPW is over 100 years.

In the area of Żerań, the dominant formations in the subsoil are sands, silty clays and sandy dust. This does not constitute a limitation or threat to the possibility of developing the area to implement investments related to the introduction of buildings.

4.4. The state of the environment and the quality of biologically active space

The aerosanitary comfort in Żerań is good. Based on the "Annual assessment of air quality in the Mazowieckie Voivodeship. Voivodeship report for 2023", it can be stated that in the Żerań area, only the permissible O3 (ozone) content standards were exceeded in the long term. The average annual concentration of PM2.5 dust in the studied area is 17.5–20.5 μm/m^3, while for PM10 dust it is 20–30 μm/m^3. On the other hand, the average annual concentration of nitrogen dioxide is 20–30 μm/m^3. These values correspond to statutory standards.

Żerań is strongly affected by noise from busy traffic arteries. The average long-term immission level exceeds 50 dB in most areas (Fig. 9).

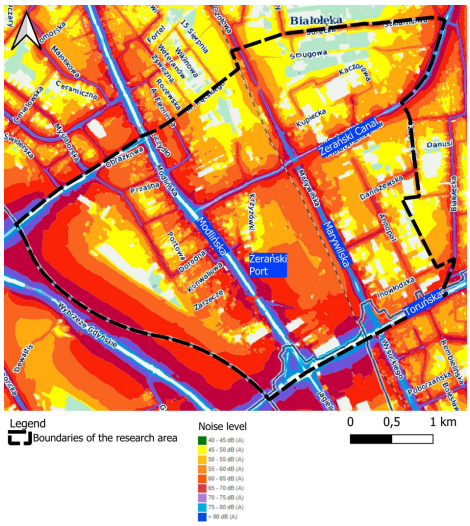


Fig. 9. Road noise level sites in the Żerań area; Source: own study based on Warsaw City Office and GDOŚ data

In the Żerań area, the primary sources of road noise are the following streets: Marywilska, Modlińska, Toruńska and Kuklińskiego. Near these roads, noise reaches 80 dB but drops below the permissible standards to 65 dB at 50 m from the road axis.

The primary source of railway noise is railway line no. 9, serviced by suburban and long-distance trains. In its immediate vicinity, noise reaches a level above 70 dB, falling below the permissible 65 dB at 50 m from the track axis.

The primary source of tram noise is the tram line running along Annopol Street, near which noise reaches approx. 60 dB, and the primary industrial noise source is the Żerań CHP Plant, the Auchan Modlińska Shopping Centre and, until recently, the Marywilska 44 Shopping Complex. However, the noise generated by these facilities does not exceed permissible standards.

In the study area, the forested area is dominated by coniferous trees (such as spruce, pine, and fir), black locusts and white-black locusts. Nearby, along the communication routes, there are also more extensive plantings of lime trees, maples and poplars. It should be noted that black locusts and ash-leafed maple are invasive, alien species. Due to their more excellent adaptive capabilities, in the long term, they pose a threat to native flora, displacing native species and, at the same time, reducing the biodiversity of the urban ecosystem. In Żerań, there are two faunal refuges of significant importance for preserving the biodiversity of fauna – the Żerań Canal (a habitat of protected aquatic mammals – beavers and otters) and the Vistula River (a habitat of waterfowl, fish, bats, a migration route for birds and mammals). This means that these spaces' character must be preserved to enable the continued existence of the aforementioned species.

In the area of Żerań, there are 12 places of historical contamination of the earth's surface (Fig. 10). These are areas of soil contamination associated with industrial and warehouse activities in the area of ul. Modlińska, the Żerań Port and the Żerań CHP Plant. There are

substances such as lead, ethylbenzene, mercury, xylenes, benzofluoranthene, styrene, and benzopyrene. In order to introduce residential and service development, sports and recreation areas or landscaped greenery in these areas, it is necessary to carry out remediation, leading to a reduction in the level of contamination to an acceptable level according to legal standards. Storage areas common in Żerań are not affected by pollution.

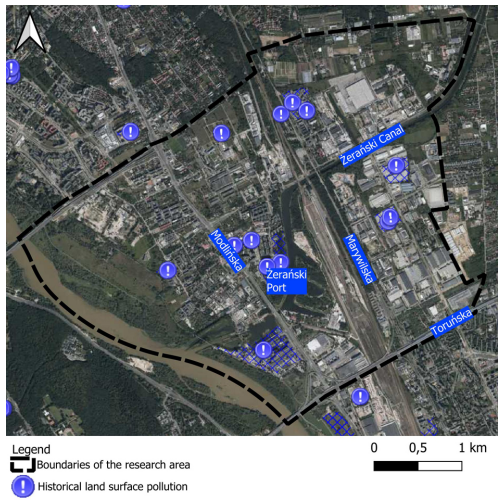


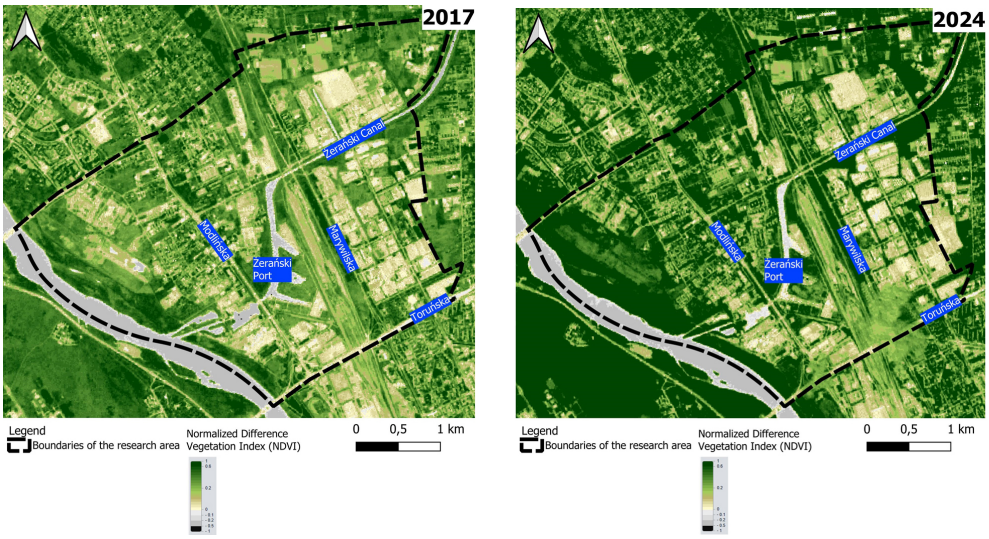
Fig. 10. Pollution sites in the Żerań area; Source: own study based on Warsaw City Office and GDOŚ data

The greenery condition is good and has improved over the last seven years (Fig. 11). This was shown by the analysis of the NDVI (Normalized Difference Vegetation Index). It shows the amount of chlorophyll and biomass in plants. A higher index value indicates a more significant amount of chlorophyll and biomass and, consequently, a better greenery condition. The NDVI value for green areas in Żerań increased from approx. 0.3 to approx. 0.6. The biologically active area did not decrease significantly. However, when planning new functions, it is necessary to remember the highest possible share of green areas arranged in the newly designed urban layout.

Żerań has attractive investment land, which (based on average transaction prices from 2022) is much lower than in the central districts of Warsaw (from PLN 50 to PLN 1,000 per m^2).

There is a clear need for the location of new housing estates, which is confirmed by the analysis of average transaction prices on the secondary market, which reach prices slightly lower than in the central districts of the city, excluding Śródmieście (from PLN 9,000 to PLN 15,000 per m^2).

However, it should be remembered that the condition for the sustainable spatial development of the city is the introduction of infrastructure and accompanying services along with new housing development. Only comprehensive, functionally diversified development of such areas contributes to creating a city that is friendly to residents.



(a) (b)

Fig. 11. NDVI index in 2017 and 2024 in the Żerań area; Source: own study based on Sentinel data

5. Discussion

Żerań in Warsaw, a housing estate rich in post-industrial and warehouse areas, is an example of a space with great potential for use after revitalization. However, the transformation of this area requires a multi-faceted approach that considers urban, environmental, social, and economic factors.

One of the key challenges is the need to remediate soils contaminated by industrial activity. Areas such as the waste disposal site or the Żerań Port require thorough cleaning to be reused. The development of service infrastructure is also an important aspect to consider. The lack of a sufficient number of primary schools and kindergartens in Żerań is a barrier to introducing new housing development. The construction of such facilities could catalyze positive urban changes, contributing to the integration of new and current residents and creating attractive public spaces.

The soil and water conditions in Żerań are conducive to further urbanization, provided that technologies are used to improve groundwater quality. Additionally, additional stabilization works may be necessary for the waste disposal site and the banks of the Żerań Canal. Thanks to them, creating a functional, ecological and well-designed urban space will be possible.

The advantage of Żerań is its relatively attractive location and good transport accessibility, including rail transport. The development of residential development in this part of the city can increase the use of existing transport infrastructure, which aligns with sustainable development and a compact city. In addition, land prices in Żerań are still relatively low, and prices per square meter of apartments in this area do not differ from the average, so implementing new residential development is economically justified.

One of the important elements of revitalization is also the adaptation of existing development. Warehouse areas that do not require expensive remediation can be developed for new functions, e.g. recreational, without significant financial outlays. This will allow for the effective use of currently available space. The revitalization of Żerań is a complex process that requires an interdisciplinary approach and appropriate coordination of planning activities. It is crucial to develop coherent planning documents that will enable the effective transformation of this area, considering both the needs of residents and environmental aspects.

6. Conclusions

Considering the prevailing land and housing prices in Warsaw, Żerań, a well-connected area, is under excellent investment pressure to transform warehouse areas towards residential use. At the same time, for these transformations, which are not only inevitable but also beneficial in many respects, to create a housing estate of high urban quality, it is necessary to coordinate the ongoing changes. To make this possible, it is necessary to develop coherent planning documents that will reflect the current state of development and prospectively consider its development. In particular, it is necessary to include the existing residential development, created in conflict with the provisions of the currently applicable Study, in the new General Plan of Warsaw.

In order to ensure the availability of the most important services and a good neighbourhood for the residential development created in this way, it will be necessary to allocate at least part of the warehouse areas for residential development with accompanying services. At the same time, the increase in the population density of Żerań, especially in its best-connected areas, may have broader positive consequences. Since Żerań is well served by rail passenger transport (Fast Urban Rail, trams), the development of the residential function in this area can increase the use of sustainable transport methods in the Warsaw agglomeration without the need to create new infrastructure, which limits the financial outlays necessary for the commune. Moreover, greater use of existing infrastructure can result in savings and enable an increase in the frequency of connections, which in turn will have a positive impact on the accessibility of all areas on the given lines. Consequently, the transformation of Żerań into a residential function, if it becomes part of a broader, well-planned process, can contribute to the development of Warsaw by the principles of sustainable development and improve its transport accessibility.

The introduction of new residential development in the analyzed area could be considered sustainable only if the necessary services were provided together with it. Particular attention should be paid to the availability of a primary school: without its construction, the location of new residential development in eastern Żerań is impossible. At the same time, its launch would enable the development of the residential function and positively impact the existing housing estates. In addition, the school, as the most important institution significantly influencing the social integration of the estate, could become the natural centre of the new estate around which further services would be located. In addition, the school could perform other than educational service functions (e.g. related to sports), especially in the first stage, when the school would not be fully used yet, and other service facilities would only be developing.

It is worth emphasizing that Żerań is a beautiful area because, in terms of most possible criteria, it fully meets the suitability conditions for introducing development or another function, such as public space. Due to the lack of existing soil contamination and remediation needs, warehouse areas can be excellent land reserves. Often, in the case of this type of implementation, there is no need to introduce new development; it is only necessary to adapt existing warehouse space – e.g., a former hall – for a recreational function.

In order to efficiently carry out the revitalization process, by the idea of sustainable development, it is possible to apply specific engineering and technical solutions. Due to the poor condition of groundwater, it is justified to use reactive barriers (PRB) to stop the migration of pollutants together with groundwater and remove harmful substances, both inorganic and organic [23]. In particular, zero-valent iron, activated carbon and zeolites are helpful for use in PRB, as they improve the pH of groundwater (Fig. 12) [24].

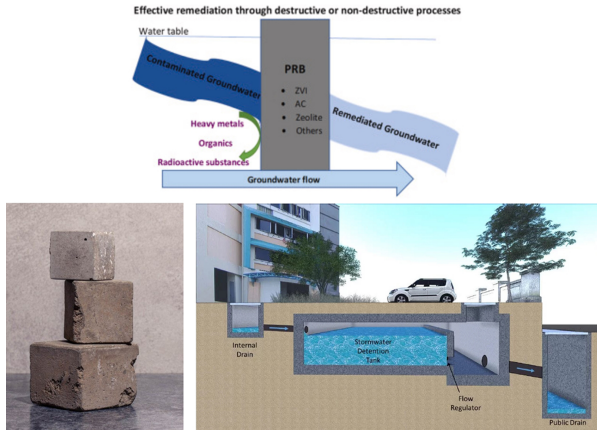


Fig. 12. Examples of engineering solutions; Sources: [23], housing.com, stormwatersydney.com

On land designated for greenery and not planned for development in the coming years, it is worth considering the use of plant species that are hyperaccumulators in order to extract soil contamination in the phytoremediation process [25]. Although this method is more time-consuming, it is much cheaper and natural. The species that would work best in Żerań would be, for example, energy willows, which already naturally occur in this area. Their introduction is justified in contaminated areas that will function as public greenery in the future, just like the former combustion waste dump. The third solution is to use geopolymers in new construction in Żerań, produced from ash and slag, which are the main by-products of the nearby CHP Plant (Fig. 12). The ash and slag themselves (of traditional origin or biomass combustion) can also be used in conventional construction, e.g. construction of roads and bridges, soil stabilization, or the construction of embankments [26, 27].

In large cities, water management is the key element of their proper functioning. It is, therefore, possible to use numerous systems that increase water retention and reduce surface runoff and flood risk. The most interesting solutions include water storage tanks in the Stormwater Tanks technology, which allow the collection of excess rainwater in special tanks

located under the ground surface and its use in crises (Fig. 12) [28]. Thanks to interception systems, water can be collected [29]. Introducing surfaces (e.g. parking lots) in the form of Water Retentive Pavement is also reasonable. Thanks to them, water soaks into the ground or evaporates from the slab's surface, helping reduce the urban heat island effect [30]. The so-called upcycling is justified among typical urban solutions, giving new life to old infrastructure elements. A typical example of this process is, among others, the transformation of railway tracks into walking paths [31].

When revitalizing industrial and warehouse areas, it is worth using the potential offered by the historical heritage they create. It is worth emphasizing that Żerań is one of many examples of such estates that can be identified in most medium and large European cities. Revitalization is never just renovation but a comprehensive process intended to serve the local community. Moreover, this is what decision-makers should strive for when planning cities worldwide.

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Możliwości rewitalizacji obszarów poprzemysłowych i magazynowych na przykładzie warszawskiego Żerania

Słowa kluczowe: miasto zwarte, obszary magazynowe, obszary poprzemysłowe, rewitalizacja, urbanizacja, Żerań

Streszczenie:

Suburbanizacja i rozrost miast, obok koncepcji tworzenia zwartych miast, podkreślają potrzebę ponownego wykorzystania niezagospodarowanych, zdegradowanych przestrzeni, takich jak obszary poprzemysłowe i magazynowe. Rewitalizacja tych przestrzeni wiąże się z zajęciem się stanem fizycznym gruntów i poprawą dobrobytu społecznego i ekonomicznego lokalnych społeczności. W wielu miastach europejskich pod koniec XX wieku dominowała działalność przemysłowa. Jednak po 1989 roku zmiany polityczne w Polsce doprowadziły do przeniesienia przemysłu z dzielnic centralnych, aby zrobić miejsce dla nowoczesnych inwestycji mieszkaniowych i usługowych. Przykładem jest warszawski Żerań, wcześniej skupiony wokół centrów przemysłowych. Kluczowym wyzwaniem w ponownym zagospodarowaniu takich obszarów jest zajęcie się zanieczyszczeniem gruntów, odzyskanie zdegradowanych stref poprzemysłowych i ostatecznie rewitalizacja przestrzeni w celu wprowadzenia nowych funkcji. Zanieczyszczenie często pozostawia te obszary nieużywane przez lata, ale odpowiednia remediacja może tchnąć w nie nowe życie. Ponadto przestrzenie publiczne, takie jak parki i place na Żeraniu, są często niedostatecznie wykorzystywane, ale właściwy projekt po oczyszczeniu może sprzyjać więziom społecznym i przyczyniać się do dobrze funkcjonującego środowiska miejskiego. Rewitalizacja zdegradowanych obszarów miejskich zapewnia racjonalne wykorzystanie dostępnej przestrzeni, dostosowując ją do pożądanych funkcji. Identyfikacja i zajęcie się tymi obszarami może przekształcić zaniedbane strefy przemysłowe w prężnie rozwijające się ośrodki mieszkalne i usługowe, przyciągając nowych mieszkańców i inwestorów.

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