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CONVERSION AND INTEGRATION INTO GREEN INFRASTRUCTURE OF FORMER INDUSTRIAL URBAN QUARTER: THEORETICAL MODEL AND EXPERIMENTAL DESIGN SOLUTIONS

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Abstract. The regeneration of former industrial sites has become increasingly relevant in the context of urban regeneration and sustainable urban development in general. Industrial structures in urban environments, shaped by the socioeconomic conditions of their time, often fall into disuse, posing significant challenges for urban planners and developers. Such neglected sites not only deteriorate physically but also fragment urban areas, disrupting social and ecological networks. This research raises the hypothesis that by converting abandoned industrial areas into ecologically integrated urban spaces, cities can enhance public access to nature, reduce their environmental footprint, and revitalize fragmented neighborhoods. The paper includes the analysis of relevant literature on the topics of urban regeneration, building conversion, and green infrastructure, existing conversion projects, and proposes a theoretical model that guides the transformation of former industrial sites into viable, sustainable urban spaces. The formulated theoretical model was applied to experimental design of a former industrial site in Kaunas (Lithuania). The findings of the research emphasize the significance of re-establishing human interaction with nature through adaptive reuse and underline the potential social, economic, and ecological benefits of integrating formerly abandoned areas into the urban fabric.
Keywords: industrial site regeneration, conversion of industrial buildings, sustainable urban development

Introduction

The concept of "site and building resurrection" has historical roots extending further than commonly anticipated, tracing back to Roman times (Stratton, 2000). In the present day, many countries face a similar challenge - abandoned buildings and territories that seem to recede into the background, overshadowed by contemporary urban and architectural developments. However, these structures remain significant for various reasons. For example, factories, workshops, warehouses, and similar facilities were shaped by the socioeconomic and political conditions of their respective historical periods, with their design and placement influenced by the economic and governance systems of the time (Jackson et al., 2010) and thus are important formants of local identity and have historical significance. Moreover, in contemporary highly urbanized areas, the disconnection from nature becomes more pronounced as developers prioritize rapid high-rise construction. These new developments often create barriers between individuals and natural environments, limiting access to recreational spaces and diminishing opportunities for engagement with nature. At the same time abandoned industrial sites with limited human activities provide the possibilities for spontaneous emergence of urban nature. The hypothesis can be raised that regeneration of abandoned industrial sites in urban environments taking into account urban nature at the same time, can contribute to social, economic, and ecological revival of the area as well as integration of formerly fragmented areas into urban fabric and ecological networks. Italian architect S. Boeri states that nature and buildings should not be viewed as separate entities as they belong to the same ecosystem and must help each other to live (Harrouk, 2021).

This study aims to explore the concept of "resurrecting" former industrial buildings or areas in the urban environment and analyze how this process can be effectively implemented in order to achieve the integration of these areas both into urban fabric and ecological networks. It investigates the potential for the re-establishment of human interaction with nature through conversion of former industrial sites and the significance of these efforts not only for individuals but also for the city, focusing on the enhancement of its natural framework. The study includes a review and analysis of literature, discussion of relevant concepts, analysis of existing projects and their outcomes, and the development of a theoretical model grounded in the research findings. The theoretical model is applied to the experimental design of conversion proposals of an industrial territory in Kaunas, Lithuania, located between the Karaliaus Mindaugo embankment and Kaunakiemio Street, demonstrating how the territory can be revitalized to provide renewed social, cultural, economic, and ecological value.

Theory: interaction between urban regeneration, building conversion and green infrastructure

Urban regeneration. As defined in the Report of the expert group meeting of UN Habitat "Urban regeneration as a tool for inclusive and sustainable recovery" (Un-Habitat, 2021), urban regeneration represents an integrative and inclusive process and essential city planning instrument that combines physical, environmental, and socio-economic measures. This process (and instrument) aims to transform urban areas into more diverse and vibrant, more inclusive, resilient, safer, and sustainable neighborhoods and extend those positive impacts into the wider city-scale (Un-Habitat, 2021). This connects to the definition of regeneration by Roberts et al. (Rudvalytė, 2011) as a holistic and multi-stranded set of interventions: "a comprehensive and integrated vision and action which leads to the resolution of urban problems and which seeks to bring about a lasting improvement in the economic, physical, social, and environmental condition of an area that has been subject to change."

Central to the process of urban regeneration is the concept of building conversion: converting abandoned or underutilized buildings into functional spaces not only preserves architectural heritage but also contributes to wider revitalization of urban environments and thus becomes a vital mechanism within the larger framework of urban regeneration, creating opportunities to reconnect fragmented urban spaces and ecological networks, and enhance the quality of life in neighborhoods.

Building conversion. Conversion refers to the process of change. In architectural terms, it primarily involves the reconstruction of a building or its spaces by altering their original function (Roberts et al., 2017). Conversion is not limited to individual buildings only, it can also apply to areas or quarters containing building complexes whose original purposes have become obsolete in modern days. In such

cases, it is crucial not only to change the functionality of these spaces but also to enhance the overall quality of the urban environment through the process of conversion (Leitanaitė, 2007). Preserving significant existing buildings within an area contributes to maintaining the authenticity of the place. For both residents and tourists, these sites are valuable as they convey unique stories and possess distinct identities. Their functionality can provide experiences and qualities that no other part of the city, region, or building can offer (Žmėjauskaitė, 2022).

Successful conversion of industrial areas can be approached through various methodologies, all aimed at a common objective. There are several author's works that have been analyzed, in one of them it is mentioned that the primary focus must be on designing projects sustainably to mitigate the current environmental impact (Sibilla et al., 2023), while facilitating economic growth. Additionally, these initiatives should enhance the landscape's character by honoring the site's inherent qualities - genius loci - and incorporating elements of its pre-industrial and industrial heritage into the new design, thereby fostering sustainable development (Loures, 2008). Others mention more specific ways to start the conversion process.

V. W. Tam and J. J. Hao (2019) discuss a comprehensive understanding of conversion, outlining the four methods:

- New exterior - old interior: this method involves preserving a well-maintained internal structure while improving the facade, suitable for modern architecture but not applicable to heritage buildings due to strict preservation requirements.
- New interior - old exterior: this approach focuses on reconstructing internal spaces to meet contemporary needs while maintaining historical facades.
- Supplement: this method adapts the building's exterior to blend harmoniously with the urban fabric, balancing old and new elements.
- Filling: recognized as one of the safest methods, this approach preserves the original structure while making minimal changes to the interior.

The analysis of literature has revealed that there is no consensus on the best approach to revitalize buildings. Focusing solely on the structure, whether interior or exterior, fails to consider the local context. Each situation is distinct, and sometimes a straightforward solution, like restoring the facade, may suffice. In sensitive urban areas, such as historic districts, proposed design solutions must align with community values to gain acceptance from citizens.

Green infrastructure. Urban green infrastructure is one of the possible answers to this challenge and can become an integral part of successful conversion of abandoned or underutilized industrial areas. Urban green infrastructure refers to a strategically planned network of natural and semi-natural areas, designed to deliver a range of ecosystem services within urban environments. According to E. Hanna and F. A. Comin (2021), the essential components of urban green infrastructure are natural elements (plants, animals, water, soil and microorganisms etc.) structured in a variety of forms including but not limited to urban squares, street tree lines, parks and horticultural gardens. These are the same components structuring natural ecosystems and making them perform ecological functions, and thus provide ecosystem services: improving air and water quality, reducing the urban heat island effect, and providing recreational spaces, contributing to overall urban resilience and sustainability. Green infrastructure multifunctionality supports both ecological and social well-being, making it a vital component of sustainable city planning. However, recently green infrastructure has increasingly started to be viewed and promoted as part of the wider concept of nature-based solutions (Jones et al., 2022). In 2015 nature-based solutions were officially defined by the European Commission as actions and means that address "environmental, social and economic challenges simultaneously by maximizing the benefits provided by nature (...) inspired by, supported by, or copied from nature". The European Commission states that the "concept of nature-based solutions embodies new ways to approach socio-ecological adaptation and resilience, with equal reliance upon social, environmental and economic domains" (Sowinska-Swierkosz and Garcia, 2022). As it was mentioned above, nature-based solutions are a comprehensive concept for other green concepts. The relationship between these green concepts can be explained by the role of nature in different processes: for example, nature-based solutions promote the use of nature as a way of providing solutions; green infrastructure is a strategically planned network for a multifunctional landscape that delivers ecosystem services; and in turn, ecosystem services refers to the simultaneous provision of benefits and services of nature for various beneficiaries, including non-human (Ramirez-Agudelo, 2022). Literature identifies nature based solutions concept as an "umbrella" term encompassing the following green concepts: ecosystem based adaptation, ecosystem-based disaster risk reduction, green infrastructure, blue infrastructure, green-blue infrastructure, urban forestry, sustainable urban drainage systems, ecological engineering, best management practices, low-impact design, water-sensitive urban design, ecosystem services (Dumitru and Wendling, 2021).

Examples of conversion of former industrial territories and buildings. The analysis of implemented relevant projects is an important part of formulation of theoretical principles for industrial areas and building conversion. Thus a comparative analysis of three significant projects implemented in Europe - Parc des Chantiers (Nantes, France), Frenkel Factory (Šiauliai, Lithuania), and King's Cross (London, England) - each selected for its transformative approach to industrial building conversion, urban regeneration, and integration of green infrastructure was performed (Fig. 1.). These cases illustrate the diversity in strategies for revitalizing abandoned or underutilized industrial sites, while addressing economic, cultural, and environmental challenges. The selection of these cases is based on their shared focus on reusing industrial heritage while contributing to sustainable urban development, yet each example operates within different national, social, and environmental contexts.

Parc des Chantiers project revitalized a former shipyard on the Île de Nantes, transforming it from an industrial site into a vibrant cultural and public space. Initiated in 2005 and completed in 2009, the project preserved key structures from the shipbuilding era and integrated green infrastructure, including walkways, gardens, and sustainable water management systems. The area became a major cultural and tourist destination, home to the renowned "Machines of the Isle," while also promoting urban ecological balance (Parc des Chantiers, 2024). Frenkel Factory, once a significant industrial hub for leather production in Šiauliai, fell into decline during the 20th century, eventually closing in 1998. In the early 2000s, the site was transformed into a cultural heritage center, preserving the architectural integrity of the industrial buildings. The renovated site now includes a museum and cultural venues, drawing tourism and revitalizing the local economy while maintaining a link to the city's industrial past (Meškys, 2017). King's Cross, once an essential industrial and transport hub, experienced a period of decline by the late

Fig. 1. Examples of conversion projects: A. Parc des Chantiers project, Nantes, France. Photographs by V. Joncheray (Parc des Chantiers, 2024); B. Frenkel factory project, Šiauliai, Lithuania: top - the Frenkel factory was built on the bank of lake Talkša, photograph provided by Aušra museum archive, bottom - developed park in the factory's territory, photograph by V. Ščiavinskas (Meškys, 2017); C. King's Cross" project, London, England: top - Granary Square before conversion, image from Science & Society Picture Library (King's Cross, 2018), bottom - current view of Granary Square now, photograph by A. Parsons (King's Cross, 2018)

1800s. A regeneration plan initiated in the late 1990s focused on transforming the area through mixed-use development, combining residential, commercial, and cultural spaces. The revitalization of King's Cross has turned it into a dynamic urban district with public squares, parks, and restored historic buildings, contributing to improved urban connectivity and economic growth (King's Cross, 2024). Selected projects were analyzed and compared from urban regeneration, building conversion, and green infrastructure development points of view.

In terms of building conversion, all three projects prioritize the preservation of historical structures, although the scope and scale of intervention vary. Parc des Chantiers adopted a minimal demolition approach, preserving key structures of the former shipyard while converting the area into a multifunctional cultural and public space. By retaining its industrial character, the project managed to blend historical preservation with contemporary urban needs. Frenkel Factory, while smaller in scale, focused on converting its historical tannery into a cultural heritage site. The main buildings were restored and repurposed for museum use, revitalizing the space for cultural and economic purposes. In contrast, King's Cross combined preservation with extensive new development, resulting in a mixed-use community that balances historical character with modern functionality. This project involved repurposing warehouses and factories while integrating new residential, commercial, and cultural spaces.

From the perspective of urban regeneration, all three projects successfully revitalized neglected areas, but their impacts varied in scale. Parc des Chantiers transformed the Île de Nantes into a viable cultural and tourist hub, contributing significantly to the local economy and social fabric. The project's success lies in its ability to blend adaptive reuse with green infrastructure, making the area more accessible and attractive to both locals and visitors. Frenkel Factory contributed to the local economy by boosting cultural tourism, although its regeneration was more localized, with cultural events and small business activity revitalizing the surrounding community. King's Cross, however, represents one of the most comprehensive urban regeneration efforts, turning a decayed industrial area into a thriving urban district. Its integration of commercial, residential, and public spaces created a dynamic environment that attracted businesses, artists, and residents, enhancing overall urban connectivity and quality of life.

Green infrastructure played an important role in two of the analyzed projects. Parc des Chantiers not only revitalized the former shipyard but also incorporated ecological design elements, such as green spaces, biodiversity-promoting gardens, and water management systems. King's Cross also introduced green infrastructure by creating parks and public squares that offer residents and visitors recreational spaces while contributing to environmental sustainability. In contrast, the Frenkel Factory project did not place as much emphasis on green infrastructure development. Its focus was more on cultural regeneration, with less integration of ecological design in comparison to the other two projects.

It is possible to conclude that while Parc des Chantiers and King's Cross emphasize a balanced approach that integrates historical preservation with green infrastructure and mixed-use development, the Frenkel Factory project focuses more on cultural and economic regeneration.

Theoretical model of former industrial site conversion and integration. Theoretical model of former industrial site and buildings conversion and integration into urban fabric and ecological networks were formulated by extracting relevant principles from the analyzed themes - urban regeneration, building conversion, and green infrastructure - and from analyzed examples.

The component of ***urban regeneration*** includes holistic and inclusive transformation, sustainable reuse of resources and enhancing urban connectivity. Holistic and inclusive transformation means that conversion of the site should be comprehensive, addressing not only physical redevelopment but also socioeconomic aspects, such as improving local economies, creating resilient and vibrant communities, and preserving cultural heritage (UN-Habitat, 2021). Sustainable reuse of resources means that the conversion of the site should focus on adaptive reuse of existing buildings and materials, helping to reduce environmental impacts and enhance sustainability by transforming abandoned or underused areas into functional urban spaces. Enhancing urban connectivity means that conversion projects should reintegrate fragmented areas, both physically and socially,

fostering connections between neighborhoods and improving access to services, public spaces, and transportation.

The component of ***building conversion*** includes adaptive reuse with preservation of cultural heritage, context-sensitive design, and functional and flexible spaces. Adaptive reuse with preservation of cultural heritage means that conversion should prioritize maintaining the historical and cultural significance of industrial buildings, allowing their reuse for modern purposes while retaining their architectural integrity. This enhances the value of the building and preserves the identity of the urban area. Context-sensitive design means that each conversion project should be adapted to its local context, respecting the historical, social, and environmental characteristics of the site and surrounding urban fabric. Solutions must align with community values to gain local acceptance. Functional and flexible spaces mean that converted buildings should be designed to accommodate a variety of uses, including residential, cultural, and commercial functions; flexibility ensures that spaces remain adaptable to future urban needs.

The component of ***green infrastructure*** includes integration of nature-based solutions, enhancing ecological connectivity, and public accessibility and well-being. Integration of nature-based solutions means that green infrastructure should be integrated into building conversion projects, focusing on the creation of parks, green roofs, urban gardens etc. These elements enhance biodiversity, manage stormwater, and mitigate the urban heat island effect. Enhancing ecological connectivity means that green infrastructure within converted industrial sites should promote ecological corridors that connect to existing natural areas, helping to enhance the city's overall green network. Public accessibility and well-being means that green spaces within these projects should be designed to provide recreational and health benefits to the community, offering accessible green areas that improve the quality of life for urban residents.

The analyzed examples also provided valuable insights. For example, Parc des Chantiers demonstrates the importances of minimal demolition and adaptive reuse of industrial structures, while integrating green infrastructure (e.g., walkways, gardens) to balance historical preservation with ecological sustainability. Frenkel Factory exemplifies the focus on cultural and economic regeneration through the preservation of architectural heritage and the transformation of industrial spaces into cultural venues. King's Cross exemplifies combining historical preservation with comprehensive redevelopment, creating a mixed-use urban district where green infrastructure plays a crucial role in public spaces, enhancing both environmental sustainability and urban connectivity.

Conversion and application of green infrastructure in the former industrial area between the Karaliaus Mindaugas embankment and Kaunakiemis Street in Kaunas

The former industrial quarter with the unique location in Kaunas city between Karalius Mindaugas embankment and Kaunakiemis Street, limited with Nemunas river and bussy city center quarters (Fig. 3. A., Fig. 5. A.), a part of historically known Karmelitai district (Saltonaitė, 2023), was selected for experimental design. This currently underused and derelict territory has strong social, cultural, symbolic, and economic potential as well as provides possibilities for green infrastructure integration. This territory together with surrounding areas in 2012 was annexed to the protected area of the historical part of Kaunas called Naujamiestis (Saltonaitė, 2023), this raises new questions of rehabilitation and actualization of this site. This territory previously was analyzed by V. Petrušonis (1993), A. Miškinis (2009), and more recently by R. Saltonaitė (2019, 2023). Industrial buildings located in the area were analyzed by N. Lukšionytė-Tolvaišienė (2001) and M. Drėmaitė (2016).

Brief history. Geographically the territory under analysis was favorable for development of industrial facilities (Saltonaitė, 2023). The existing complex of buildings, constructed in the 19th century, was established by the Tilmans family of German origin. The pioneering member of the family, Ričardas Tilmans, initiated the enterprise, subsequently bringing other family members to Kaunas. The Tilmans factory specialized in the production of screws, bolts, wire, and other metal products (Vaškevičius, 2019). However, the industrial block was designed with purposes beyond mere manufacturing. The site also included a workers' club, a canteen, a theater, and a school aimed at educating workers and their children (Drėmaitė, 2016). These facilities were important in facilitating the integration of the working class into the broader societal fabric of Kaunas. According to R. Saltonaitė (2019, 2023), the construction activities of the second half of the twentieth century together with the closing of industrial facilities, further negatively affected the territory. The building complex still exists today, though not all of its structures have been preserved due to the frequent changes in ownership. As a result, the original appearance of the complex, dating back to the 19th century, has significantly altered. However, over the past thirty years, the territory has remained largely unchanged. R. Saltonaitė (2019, 2023) had identified buildings of four historical periods and styles in the broader area of Karmelitai district: 19th century historicism, inter-war modernism, socialist realism, post-war modernism. Buildings of 19th century historicism, socialist realism, and some structures of post-war modernism are the most clearly visible in the industrial territory under analysis. Some structures, most often of low aesthetic value, were constructed after 1990. Given its location in the city center, the industrial quarter has become a source of concern, not only as an aesthetic problem but also as an economic burden and a contributing factor to the deterioration of urban environment quality. Once a well-known factory that represented Kaunas through its production and associated activities, the site has been ravaged by time and neglect. The absence of efforts to preserve the territory has meant that the memories and historical significance of this once valuable location have faded. Its failure to adapt to contemporary needs has led to its inevitable decline (Fig. 2 B., Fig. 3. A.).

Territory's context. According to the general plan of the Kaunas city municipality, the analyzed area falls within a mixed-use zone, encompassing both the Old Town and New Town. This location is subject to specific requirements for the protection of cultural heritage, public spaces, buildings, and architectural quality. The area may be utilized for a variety of purposes, including residential, public, administrative, and commercial activities. Among the structures within this zone, only two buildings are recognized as having significant value due to their historical importance: the manufacturing building and the theater's wall (Kauno..., 2024) (Fig. 3).

Main focus of the area is to ensure comfortable car movement, the area is not safe for visitors due to many dangerous constructions which are not fenced off. The narrow streets between the building's are blocked by various structures. There are few places where nature spreads freely without any human intervention in the area under analysis.

Challenges. Prior to any intervention in the sensitive area of the city center, it is essential to thoroughly assess the potential

Fig. 2. Decline of heritage building in the territory under analysis: A. - Tilmans theater building in 1985 (Kaunas..., 2019);
B. - Current remains of Tilmans theater wall. Photograph by D. Žmėjauskaitė

Fig. 3. Territory under analysis: A. - General view from top of Karalius Mindaugas street, on the tight side Nemunas river is visible, on the left side extends the analyzed territory; B. - "Pergalė" factory administrative building. Photographs by D. Žmėjauskaitė

TABLE 1

Criteria for building evaluation. Table by D. Žmėjauskaitė (created by the authors)

Criteria	Description
Heritage	A structure or building included in the Lithuanian Cultural Heritage Register as valuable and protected.
Historical value	A structure or building mentioned in historical sources as a unique architectural, urban object and/or historically containing innovative technological solutions.
Existing physical condition	The current state of the building or structure, determining whether it can be used immediately.
Possibilities of use	The potential to retain the structure or building because it contributes to the identity of the place.
Aesthetic condition	A subjective evaluation based on the presence of rarely seen architectural elements or the structure's connection with the environment.
Relevance in urban structure	The role of the building or structure in shaping the urban layout and its connection with the surrounding infrastructure.

outcomes. The identity of the site, as well as its historical significance to the city, must be considered. A comprehensive evaluation of the existing buildings is necessary, focusing on their historical and architectural importance, while also exploring possibilities to enhance their functionality, ecosystem services, and infrastructural capacity to benefit local residents. Demolition should only be considered once all alternatives have been evaluated to ensure sustainability. In this analysis, six criteria were established to guide decision-making regarding the preservation or demolition of existing structures (Table 1).

The analysis of existing buildings in the territory under analysis is presented below and in Fig. 4. The locations of the buildings are identified in Fig. 5. A.

A. Tilmans theater. The site retains historical significance due to its unique architectural openings and the remaining protected wall. Located between important roads, it once served multiple community functions, including a school and theater. Despite its poor condition, its historical value and contribution to the area's identity justify preserving the remaining wall.
B. Buildings and structures. Structures such as garages, residential houses, and shops hold no significant architectural or cultural value for the area or city. These buildings can be demolished.
C. Building complex. Though not part of the cultural heritage, this complex is historically significant, notably for housing the first innovative furnace in Kaunas. Positioned between Kaunakiemis St. and K. Mindaugas St., it is in fair condition. Insignificant buildings within the complex will be removed.
D. Buildings and structures 1. This group, which includes a gas station and warehouses, lacks historical or architectural value and will be demolished.
E. Reinforced concrete cranes. As the first reinforced concrete structures in Kaunas, they connect Kaunakiemio St. and King Mindaugas Ave., offering views of Kaunas' natural landscape and the Nemunas River. Their retention is under consideration due to their potential interest as industrial heritage.
F. Building complex 2. The complex showcases historical architecture on its northeastern facade, while its western facade highlights connectivity with Karalius Mindaugas Ave. Insignificant sections of the complex will be

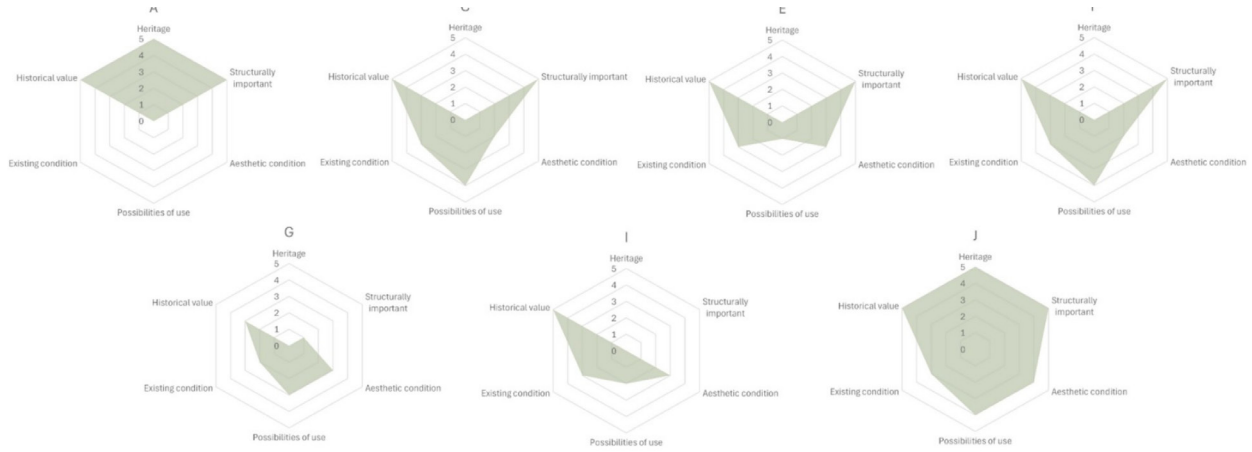

Fig. 4. The example of evaluation of selected buildings according to the set of predefined criteria. Schemes by D. Žmėjauskaitė

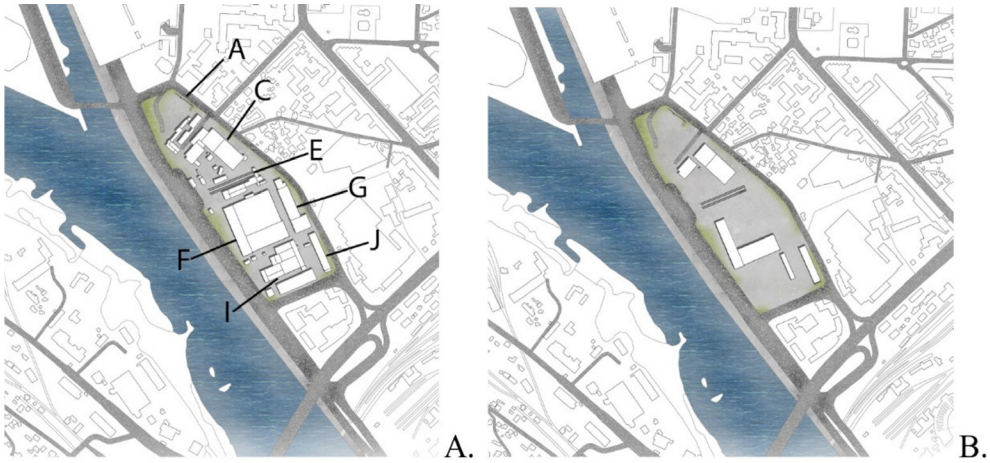

Fig. 5. Territory under analysis:
A. - current situation with identified main buildings
(A - remains of Tilmans theater,
C - building complex,
E - reinforced concrete cranes,
F - building complex 2,
G - detached buildings,
I - service and storage block,
J - "Pergalė" factory administrative building);
B. - proposed demolition of buildings.
Schemes by D. Žmėjauskaitė

demolished to emphasize its key features.

G. Detached buildings. The administrative building and storage facilities, despite their distinct orientation towards Kaunakiemis St., lack significant identity-forming characteristics. These buildings will be demolished.

H. Temporary structures and sports arena. These buildings do not align with the historical architectural intent for the area and will be demolished.

I. Service and storage block. The administrative building, constructed in 1867, and other connected red-brick structures have historical ties to the area. However, these blocked buildings will be demolished due to the decision that the historical parts of this block have been changed multiple times thus making it impossible to implement them into the new site design.

J. "Pergalė" factory administrative building (Fig. 3. B.). This exceptional structure, with distinct architectural elements and in good condition, an example of socialist realism architecture, is historically significant and protected as heritage and will be preserved.

Fig. 5. B shows the territory with preserved buildings after demolition of structures of low value.

Following a comprehensive assessment of the existing buildings and their significance, a detailed analysis of the site revealed the presence of an underground Nemunas tributary known as Girstupis. The Girstupis stream flowing through this valley of the Nemunas was one of the reasons why first residents, and later industrial facilities, were established here. As the number of cars and train traffic through Girstupis increased, bridges were built. Thus, gradually, the whole part of the stream that flowed through the valley was sewered during the Soviet era (part of the stream is still visible in the Kaunas city plan of 1967, while Girstupis is no longer marked in the 1986 map) (Saltonaitė, 2019). Given that this area has experienced ecological degradation as a result of industrial development, daylighting of Girstupis holds the potential of ecological and aesthetic regeneration of the area and connecting it to a wider ecological framework. The city of Kaunas is characterized by a diverse natural framework, featuring variable topographies that enhance the aesthetic quality of the environment, along with two intersecting rivers that give rise to natural islands and public spaces for recreational use, seasonal events, and community engagement. Despite ongoing discussions regarding sustainable urban development and the importance of accessible natural spaces, many of these areas remain isolated and underutilized.

Solutions. The area under consideration is planned to accommodate mixed-use functions, with the goal of achieving territorial autonomy - specifically, the ability to sustain itself and meet the needs of its various functions. The current distribution of functions in the territory is chaotic and difficult to comprehend. The division of the territory into five distinct zones is envisioned (Fig. 6., Fig. 7.). The zoning concept for the territory involves each zone incorporating an existing building or structure, with interventions implemented to ensure seamless functionality and mutual enhancement between the existing and new constructions. The description of functional zones is presented below.

- Elevate zone is a mix of commercial and residential purposes. The goal is to restore the existing structures and integrate them with new architecture in a way that highlights cultural heritage while respecting the surrounding scale. The project achieves a total of

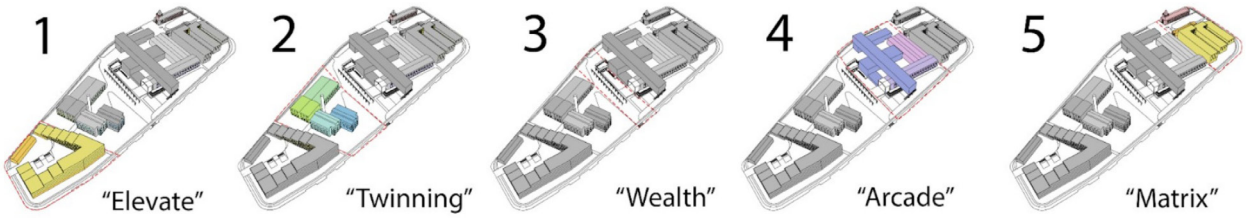

Fig. 6. Proposed zoning of the territory. Schemes by D. Žmėjauskaitė

Fig. 7. Visualizations of the proposed zones. Schemes by D. Žmėjauskaitė

164 residential units and commercial spaces, with a concealed parking area beneath a green roof. The design also incorporates public green spaces between the buildings, accessible via steps that serve both functional and recreational purposes.

- Twinning zone combines cultural and hospitality uses, including a museum, gallery, restaurant, and hostel. The goal is to create a harmonious architectural blend by duplicating an existing building while altering its texture to respect the original design. The project achieves an integrated space where different functions support one another, promoting interaction between visitors. The zone is densely landscaped to enhance privacy and preserve the area's natural identity, with technical facilities covering all infrastructure needs.
- Wealth and Arcade zones have distinct ideas but function together in a complementary manner. The first zone, focused on water accessibility and called Wealth, aims to create a direct connection between key streets while making a water source easily reachable through a system of steps. The second zone, named Arcade, features interlocking building volumes that form different spaces, but operate as a cohesive complex, designed to create visual contrast and attract attention.
- Matrix zone focuses on residential buildings with varying heights to optimize natural lighting. The tallest structure has four floors, with the height decreasing by one floor to allow better sunlight access. The design conceals ground-floor parking for residents and visitors, with a total of 125 apartments and 400 parking spaces. Inner courtyards are formed through recessed volumes, accessible from shared corridors. Additionally, a nearby building will be repurposed as the headquarters for Kaunas StartUp center, supporting new businesses, while commercial spaces will be integrated within the complex.

The proposed experimental project involves not only the analyzed area, but also its surroundings. The proposed general plan incorporates the analyzed area, the Nemunas riverbank, Karaliaus Mindaugo Avenue, and newly established connections to Vytauto Avenue (Fig. 8). Currently, the area is closed off, inaccessible to the public, and visually unappealing, detracting from the charm of Kaunas' city center. The conversion of this area transforms it from a bleak industrial complex into a key connection between the city and the Nemunas River.

Residential buildings and a StartUp center are strategically placed at the intersection of Kaunakiemio Street for visibility

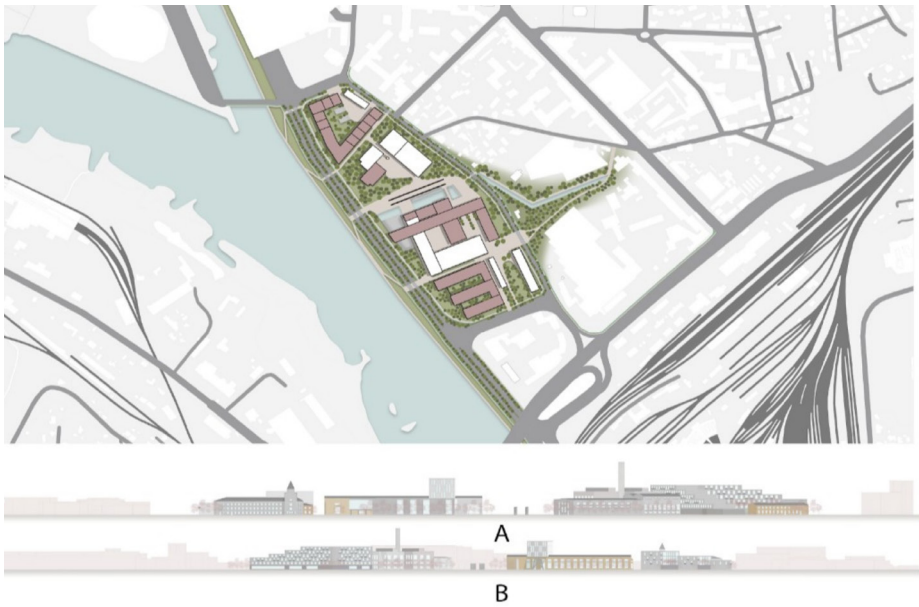

Fig 8. Proposed general plan of the territory and street views.
A. - street view from Kaunakiemis street;
B. - street view from K. Mindaugas street.
Schemes by D. Žmėjauskaitė

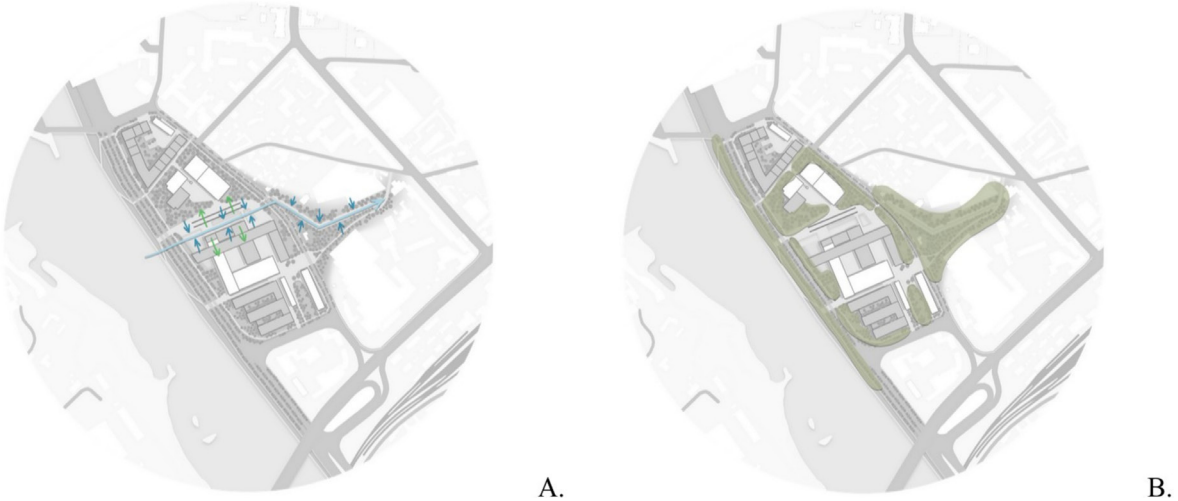

Fig 9. Schemes of natural water collecting system (A) and green infrastructure (B). Schemes by D. Žmėjauskaitė

TABLE 2

Correspondence of experimental design solutions to the theoretical model of former industrial site and buildings conversion and integration into urban fabric and ecological networks (created by the authors)

Theoretical model component	Principles	Project evaluation
Urban regeneration	Holistic and inclusive Transformation	The project reconnects the industrial site to the city, supporting a variety of uses (residential, cultural, commercial) and fostering community engagement near the Nemunas River.
	Sustainable reuse of resources	Adaptive reuse of heritage buildings reduces environmental impacts and revitalizes existing structures for new functions.
	Enhancing urban connectivity	The project improves pedestrian flow and access to the city center and Nemunas River, aligning with goals to reduce automobile dependency and improve public access.
Building conversion	Adaptive reuse with cultural heritage preservation	The preserved heritage buildings, including the "Pergalė" administrative building, enhance the area's historical character while repurposing them for modern uses.
	Context-sensitive design	Design solutions respect the local historical and cultural context, ensuring alignment with Kaunas' architectural heritage.
	Functional and flexible spaces	New spaces accommodate various functions (residential, commercial, cultural), allowing adaptability to future urban needs.
Green infrastructure	Integration of nature-based solutions	The daylighting of the Girstupis stream, green roofs, and the addition of tree-lined streets contribute to biodiversity and improve ecological resilience.
	Enhancing ecological connectivity	Reopening the Girstupis stream restores hydrological connections, linking the area to Kaunas' wider green network and enhancing ecological corridors.
	Public accessibility and well-being	Public green spaces are integrated, improving recreational and aesthetic value for residents and visitors, and developing pedestrian-friendly environments around the river and city center.

and easy access. To avoid cluttering the area with parking spaces, parking is located in the ground floors of residential buildings, as underground parking is risky due to proximity to the Nemunas River and the newly opened stream.

The project proposes to uncover and extend Girstupis stream within the adjacent vicinity of the site. This intervention aims to mitigate the image of densely built-up urban areas, while facilitating the restoration of natural hydrological connections. Opening the Girstupis stream creates new urban connections, restores the surrounding ecosystem, and lays the foundation for the expansion of green infrastructure, allowing the city's ecosystem to regenerate naturally. Additionally, the redevelopment of Kaunakiemis Street will reestablish vital linkages within the urban fabric, fostering the development of an independent ecosystem in the city center. The newly opened water sources function as a natural collection system for runoff water from adjacent buildings and surfaces, with potential use for local residents' domestic needs.

The diversity of volumetric forms enriches the architectural landscape, as observed in the street elevations (Fig. 8 A. and B.). This variety, along with new architectural forms, functions, and public spaces, is intended to attract people to the area. By integrating existing buildings into the complexes, a new identity is established, while maintaining and highlighting their significance to the overall site.

High concrete fences in the city center obstruct passage, so a key goal is to make the area more accessible and permeable by analyzing pedestrian flow and extending connections to improve infrastructure between the city center and the river. Automobile traffic is deprioritized in the city center to improve access to the water. Instead of eight traffic lanes in Karaliaus Mindaugo Avenue, four are preserved, with green

zones dividing them. Planting of trees is envisioned on both sides of this street to reduce pollution and provide shade for pedestrians in summer (Fig. 9). This approach also extends to green roofs on buildings, preventing overheating in large complexes exposed to intensive southern sunlight.

The project aims to create a shift in Kaunas' urban infrastructure towards greening and nature-based solutions. The evaluation of experimental design solutions correspondence to the theoretical model developed in the previous section is presented below (Table 2). The analyzed area would serve as a starting point, encouraging industrial buildings to either relocate from the city center or be repurposed with new functions. These regeneration and conversion methods could radically change the city's landscape, transforming the area from a bleak, abandoned district into a welcoming part of the city where residents and visitors would want to stay.

Conclusions

Urban regeneration is a multifaceted process that incorporates physical, environmental, and socioeconomic measures to create sustainable, resilient, and inclusive neighborhoods. Building conversion plays a crucial role in this process by preserving historical structures while adapting them to modern needs, contributing to the revitalization of urban environments. Integrating green infrastructure and nature-based solutions further enhances this transformation by improving ecological connectivity, enhancing public well-being, and promoting sustainable urban development. The comparative analysis of Parc des Chantiers, Frenkel Factory, and King's Cross highlights diverse strategies for industrial building conversion within the context of urban regeneration. Parc des Chantiers and King's Cross effectively integrated historical preservation with green infrastructure and mixed-use development, promoting both cultural and environmental sustainability. In contrast, Frenkel Factory focused primarily on cultural and economic regeneration, with less emphasis on green infrastructure, demonstrating that different approaches can address unique urban challenges. The theoretical model for converting former industrial sites integrates principles from urban regeneration, building conversion, and green infrastructure to create a comprehensive and sustainable framework. It emphasizes holistic transformation, adaptive reuse, and the integration of nature-based solutions to address both physical and socioeconomic aspects, while enhancing ecological and urban connectivity.

The experimental project of the former industrial site in Kaunas aligns well with the proposed theoretical model by incorporating principles from urban regeneration, building conversion, and green infrastructure. The urban regeneration component is fulfilled through a comprehensive transformation, aiming to reconnect the site to the city and enhance public access to the Nemunas River, fostering urban connectivity. Building conversion is sensitively approached, with adaptive reuse of culturally significant structures and context-sensitive design, providing both residential and commercial functions within restored heritage buildings. The green infrastructure component is achieved through the daylighting of the Girstupis stream and creation of green zones, including green roofs and public green spaces, to support biodiversity and enhance ecological connectivity.

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Kopsavilkums
Bijušo industriālo vietu atjaunošana ir kļuvusi arvien aktuālāka ilgtspējīgas pilsētvides attīstības kontekstā kopumā. Rūpnieciskās struktūras pilsētvidē, ko veido sava laika sociāli ekonomiskie apstākļi, bieži vien vairs netiek izmantotas, radot ievērojamas problēmas pilsētplānotājiem un attīstītājiem. Šādas novārtā atstātas vietas ne tikai fiziski nolietojas, bet arī sadrumstalo pilsētu teritorijas, izjaucot sociālos un ekoloģiskos tīklus. Šis pētījums izvirza hipotēzi, ka, pārvēršot pamestas industriālās teritorijas ekoloģiski integrētās pilsēttelpās, pilsētas var uzlabot sabiedrības piekļuvi dabai, samazināt to ietekmi uz vidi un atdzīvināt sadrumstalotās apkaimes. Darbā iekļauta atbilstošas literatūras analīze par pilsētvides reģenerācijas, ēku pārveidošanas un zaļās infrastruktūras tēmām, esošajiem pārbūves projektiem, kā arī piedāvāts teorētiskais modelis, kas virza bijušo industriālo objektu pārveidi dzīvotspējīgās, ilgtspējīgās pilsēttelpās. Formulētais teorētiskais modelis tika izmantots Kauņā, Lietuvā. Pētījuma atklājumi uzsver cilvēka mijiedarbības ar dabu atjaunošanas nozīmi, izmantojot adaptīvu atkārtotu izmantošanu, un uzsver iespējamos sociālos, ekonomiskos un ekoloģiskos ieguvumus no agrāk pamestu teritoriju integrēšanas pilsētas struktūrā.