

Resilience of riverside areas as an element of the green deal strategy – Evaluation of waterfront models in relation to re-urbanization and the city landscape of Warsaw

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ABSTRACT

Riverside management and city water retention provide important issues in accordance with the Green Deal implementation strategy. The research work concerns the issues of shaping riverside areas in the face of climate change and crisis situations to ensure the implementation of social and ecosystem services in the city landscape structure. Moreover, it refers to the development of blue infrastructure in the city landscape in order to create a model of resilience for riverside public spaces and open areas transformed in the process of re-urbanization. An evaluation of the various areas of the Vistula river waterfronts within the administrative boundaries of Warsaw is presented. The left-side areas were intended for re-urbanization based on the hardened regulation of the quay on the tunnel slab and an underground station, interfering with their natural structure (“Warsaw Boulevards”). On the right bank, solutions from the category of waterfront naturalization are used, which provide for ecosystem services and biodiversity (“Praga Path”), to balance the new full of investments in cubature (“Praski Port”). Most of the riverside areas in the city have not yet been developed and require the creation of a comprehensive model that considers resilience in spatial progress. For this purpose, the spatial conditions and solutions for Warsaw were analysed and compared with examples of selected European cities. As a result, a model was developed for implementation of the Green Deal assumptions in the design and transformation of riverside areas in the city, including the urban, landscape, social, and environmental context.

Keywords: Waterfront; Water retention; Blue infrastructure; Resilience; Re-urbanization; City Landscape; Green Deal

1. Introduction

According to the European Green Deal, the European Union’s set of legal regulations on climate, the European continent is to be climate-neutral by 2050 [1]. In connection with this overarching goal, existing laws are to be modified, and new regulations should consider such postulates as a closed-cycle economy, preservation of biodiversity and ecosystems, as well as minimization of pollution. Areas of

life such as transport, industry, and energy supply are also to be reviewed. Also, an important part of the Green Deal concerns demands for sustainable management of water, the entire catchment area, and the expansion of blue-green infrastructure that provides a wide range of aquatic ecosystem services [2].

In the 21st century, problems related to the lack, excess, or poor quality of water in cities are increasing [3]. The genesis of these phenomena can be traced back to the 19th

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century, when industry expanded and water in rivers and urban canals became dirty and polluted, whereas its role in the urban fabric was marginalized. Old canals and waterways lost their importance. The waterworks and urban sewage systems built in the 19th century forced sewage and rainwater into the system of underground pipes (in 1883 the construction of waterworks and sewage systems in Warsaw began [4]). In the last century, expanding cities moved more and more away from water; huge areas of tight, concrete-sealed land were created, which did not absorb rainfall. Land for investments was effectively “cleared” of water. This resulted in a disconnect between the urban structure of the city and water [5]. Progressing urbanization processes, expansion of the urban fabric also in water-supplying catchment areas resulted in lowering of groundwater levels and hindering or preventing runoff and infiltration of water into the ground. This often results in drought phenomena and periodic flooding during periods of heavy rainfall and snowmelt. Urban development puts enormous pressure on the environment. Therefore, proper management of the city and its ecosystem must be part of modern urban planning [6]. Planning the processes of re-urbanization, revitalization, and re-naturalization of urban areas and introducing the integration of green and blue infrastructure are the basis for the sustainable development of the functional and spatial structure and water management.

Although flood is mainly associated with the discharge of river water, this definition of the phenomenon is not a complete one. According to the definition of a flood included in the Water Law, a flood occurs in natural watercourses, water reservoirs, canals, or at sea, when the water, after crossing the coastal state, floods river valleys or depressive areas and causes threats [7]. Due to the cause of its emergence, four types of highs (floods): precipitation, thaw, winter, and storm [8]. As far as the source of the threat is concerned, floods can be divided into river floods, floods from sea waters, floods from groundwater, floods from technical infrastructure, urban floods (from faulty sewage systems, caused by surface runoff) [9]. As stated by prof. Piotr Kowalczak, according to data on natural disasters collected by the International Federation of Red Cross and Red Crescent, in recent decades, 90% of natural disasters were associated with hydrological and meteorological phenomena [10]. Scientists indicate the likelihood of an increase in flood risk in various regions of the globe [11]. Recently, many of these forecasts have come true, as exemplified by heavy rains and floods that affect, for example, Poland and neighboring countries (in 2016, 2013, 2010, 2009, 2002, 1999, 1997).

Over the last 30 years, the approach to flood issues in the context of architecture and spatial planning has changed. Since the introduction of Directive 2007/60/EC (the so-called Floods Directive), integrated flood risk management has been promoted, which is expressed in the desire to retain water where it occurs, using ecological methods to improve water retention rather than removing water from floodplains [12]. The belief that it is necessary to “move water away from people” by technical measures including the construction of dikes and large retention basins, so-called hard engineering solutions [13], has been revised due to the high costs of construction and maintenance of such dikes and hydrotechnical infrastructure (example of the Dutch Plan Delta [5]).

Publications on the development of the Vistula River describe methods and Flood Resilient Strategies, as well as offer multiple-case studies as examples of buildings and amphibious structures at the Vistula River [14].

Moreover, attentions should be paid also to strategies and solutions for managing rainwater and increasing flood resilience with structural soil as a method [15].

In the UK, Germany, or the Netherlands, programs and slogans considering the need to create space for water and to coexist with it have already been established for several decades. These include “Room for the river” (in the Netherlands), “Room for rivers”, “Making space for water”, “the LIFE project” – Long-term Initiatives for Flood-risk Environment (in the UK). River restoration is also part of these activities. At the level of rainwater management, solutions are used which mimic natural processes that occur in the natural environment: retention, infiltration, purification, evaporation, and evapotranspiration together with phytoremediation – referred to as Sustainable Urban Drainage System (SUDS). Innovative new elements of conscious urban management such as eco-swales, bioretention facilities are also being introduced. Publications point to claims that reclaimed wetlands, aerated bays, flood adaptive landscape are elements of a larger concept, resilient to the destructive effects of the water factor [13]. The negative effects of periodic lack or accumulation and excess of water in urbanized areas are also linked to the effects of climate change and the threat of drought experienced increasingly also in Poland.

This calls for integrated research, planning, and implementation activities with which to set new standards for urban investment in re-urbanization processes. Such approach should be defined as the re-development of previously urbanized areas leading to permanent changes in the functional and spatial structure of the city, also in its natural and social system. These investment activities constitute a transformation or supplementation of the functional and spatial structure and infrastructure of the city with a significant impact on the resilience and landscape of the city.

2. Methodology

The research work concerned the identification of conditions and the existing methods for land development in order to characterize and recommend land transformations between the embankments of Vistula River within the administrative boundaries of the capital city of Warsaw, Poland as well as the areas adjacent to the embankments. An analysis of the catchment area, surface waters (ponds, artificial reservoirs, retention reservoirs, dry flood banks, polders), natural watercourses and canals, systems of tributary rivers, surface and waters in the catchment area of the Vistula River were conducted, along with destruction or damage scenarios for the embankment and damming structures. The theoretical multiple-case method was applied in the research work [16].

2.1. The conducted multi-criteria analyses included

- geological, hydrological, eco-physiographic source materials, tree crowns map, documents are available on the geoportal of the city of Warsaw [17]

- developing water management strategies and plans, as well as canal retention systems to counteract drought
- documentation and source materials provided by the Polish Waters and the National Protection System (ISOK)), including preliminary flood risk assessment maps, flood risk map, Flood Hazard Map, water management plans – map [18], National Program for Municipal Wastewater Treatment [19], Map of SIGW (Polish Information Water Management System) for analysis of the location of damming structures (weirs and dams), water facilities, swimming pools [20]
- maps that present the historical course of the river bed
- Study of the conditions and directions of spatial development for Warsaw
- Local Spatial Development Plans adopted and planned
- Authors' analyzes and evaluation of spatial and landscape, social and ecosystem needs analysis
- Authors' analyzes and evaluation of urban and architectural solutions for buildings and facilities located in the analyzed area
- analysis of publications related to research issues

An analytical model and databases for the evaluation of land development have been developed.

An assessment of implementation and solutions adopted in Poland and elsewhere (source literature research, source materials and authors' own analyzes) was performed on the basis of which a catalog – database of examples of waterfront management and waterfront shaping, which can be implemented in Warsaw, was developed. Using the created databases (multi-criteria analysis of the existing state and a catalog of recommended solutions), a model is formed for analysis for the purpose of determining the functional and spatial structure and parameters for transformations.

The analytical study based on the developed method analyses the areas of the Vistula River waterfront on the territory of the Warsaw – the capital city of Poland. Results of the analysis of the existing state, evaluation, and research related to risk factors selected by the research team and important for shaping the city's resilience are presented. The aim of the research was to develop an evaluation model for the design and transformation of riverine areas in the city, with account to the urban, landscape, social, and environmental context. Another goal was to conduct a case study for Warsaw with the use of a developed analytical method.

Research questions were as follows:

- (1) How to conduct evaluation of waterfronts in criteria of city resilience and implementation of Green Deal strategy?
- (2) What actions should be recommended for coastal development following the analysis of the existing state and evaluation thereof?

The structure of the article includes a presentation of the research background in the introductory part. Secondly, evaluation of waterfront models in relation to re-urbanization and the city landscape of Warsaw is provided as a review of the existing methodology. Subsequently, the results are presented in relation to resilience of riverside areas – evaluation in the criterion of flooding and water retention.

The conclusions are focused on the presentation of a model for restoration and resilience of waterfront areas in comparison to solutions applied in other countries.

City landscape studies are based, among other things, on a multi-component analysis of specific sites and their surroundings, which allows for a thorough understanding of the urban structure [21,22]. They include elements concerning both inventory and interpretation issues in the environmental, compositional, functional, and infrastructural spheres [23–26]. In the initial part, the analyses concern the recognition of the most important elements of space occurring in the studied area, such as the functions of land and buildings, the transport system, technical infrastructure system, and the species distribution. As part of the recognition of functions of land and buildings, a division is applied into elements related to residential, commercial and service, industrial, public buildings (including a distinction between buildings with sacral functions, performing various administrative functions to serve the public, etc.) [4,23,27]. The functions of the land include a distinction between green areas, with attention to their different types (the division includes a separate recognition of forests, urban parks squares, urban agriculture areas, etc.) and a division between managed areas with human intervention and natural areas [28]. Separately, a transport analysis is conducted, which includes the recognition of the typology of roads divided into main roads, such as motorways, national and provincial roads, district and estate access roads, and local roads, where woonerfs or connections of very local importance are included [29]. In addition, the layout of parking spaces, public transport stops, and nodal points related to the functioning of roads, the public transport system, and pedestrian transport are recognized. In this group of analyses, elements of technical infrastructure related to urban network systems and energy systems are also distinguished. The results of the analyses conducted for the research purpose allow the data obtained to be checked from a historical and legislative point of view, and then from the point of view of the composition and color scheme of the area under study. Another category under study is that of compositional elements, which includes an assessment of the proportions and height of buildings. The identification of urban and landscape interiors in the urban structure together with wide and gap openings provides a component of this analysis. It also includes the identification and systematization of the layout where dominants, landmarks and compositional axes are presented [23,25]. Simultaneously to the compositional analysis, a color analysis of the space is performed, with consideration to environmental and urban elements. In addition to the informational value related to the recognition of individual elements of the site, this type of analysis can also display a social value, as it allows the recognition of local city values [30]. The research method for the cityscape structure is shown in the analytical diagram (Fig. 1).

In the subsequent research work, an analytical model and action paths were created for establishing resilience in the process of transforming the functional and spatial structure of the city. The action scheme was defined as a set of analytical results organized in relation to possible actions with regards to conditions and opportunities. The model base and action procedures should offer the possibility

to derive a result path for the selected research question. The research team builds a base of knowledge as data in order to enable the application of functions in the schema described according to the model. The analysis is then conducted for the flood risk issue, while environmentally and landscape acceptable solutions are invented.

In the first step, the preconditions, that is the input data for the analytical procedure, are recognized. For the analysis of the determinants, datasets organized according to the following scopes were identified:

- Identification of the causes of the changes;
- Identification of crisis situation;
- Identification of development areas;
- Identification nodal points for the critical path.

On the basis of the initial input data, an analysis follows which leads to a recognition in the following range of datasets:

- Recognition of the City Landscape Structure;
- SWOT analysis (strengths, weaknesses, opportunities, threats);
- Recognition of nodal points for Re-urbanization or revitalization;
- Identifying areas for adaptation or transformation.

Graphically, the scheme is illustrated in Fig. 2.

The next stage in the described procedure of the decision-making process comprises the reference of data obtained in the first stage (conditions) with consideration to the path in sets defined as possibilities (Figs. 2 and 3).

Working in this data area, a further subdivision was introduced with which to order the selection by indicating

the categories identification, reaction. In each of the basic categories, subcategories were defined as sets of data and tasks that condition the further course of the analysis. For the identification category, possible actions were distinguished (non-reaction, destruction, development, and transformations), as well as systematized sets (greeneries, air, soil, water parameters, and quality). Furthermore, the procedure lists possible models of strategic actions described in the reaction category: strategy for re-urbanisation, sustainable development, revitalization, and adaptation. The indicated sets may share common elements. The set of required actions was also divided into subcategories: synergy (of social and eco-system services, green and blue infrastructure) and solutions (smart innovative, regenerative). The scheme of actions is illustrated below (Fig. 3):

The described method may be seen as a model of conduct for supporting planning processes in the implementation of the Green Deal strategy. It was developed on the basis of the team's research experience and analysis of published materials related to the issues of shaping urban resilience, critical infrastructure, and integrated and regenerative design.

The subsequent part of the article describes the results of the research work performed on the basis of the described methodology developed by the authors, for the indicated criterion namely climate change and flooding.

2.2. Resilience of riverside areas - evaluation in the criterion of flooding and water retention

The issues related to the implementation of the Green Deal strategy in the city landscape in the process of re-urbanization and re-naturalization relate directly to the activities in the scope of the urban development strategy based on the ideas of Eco and Smart City [31–35].

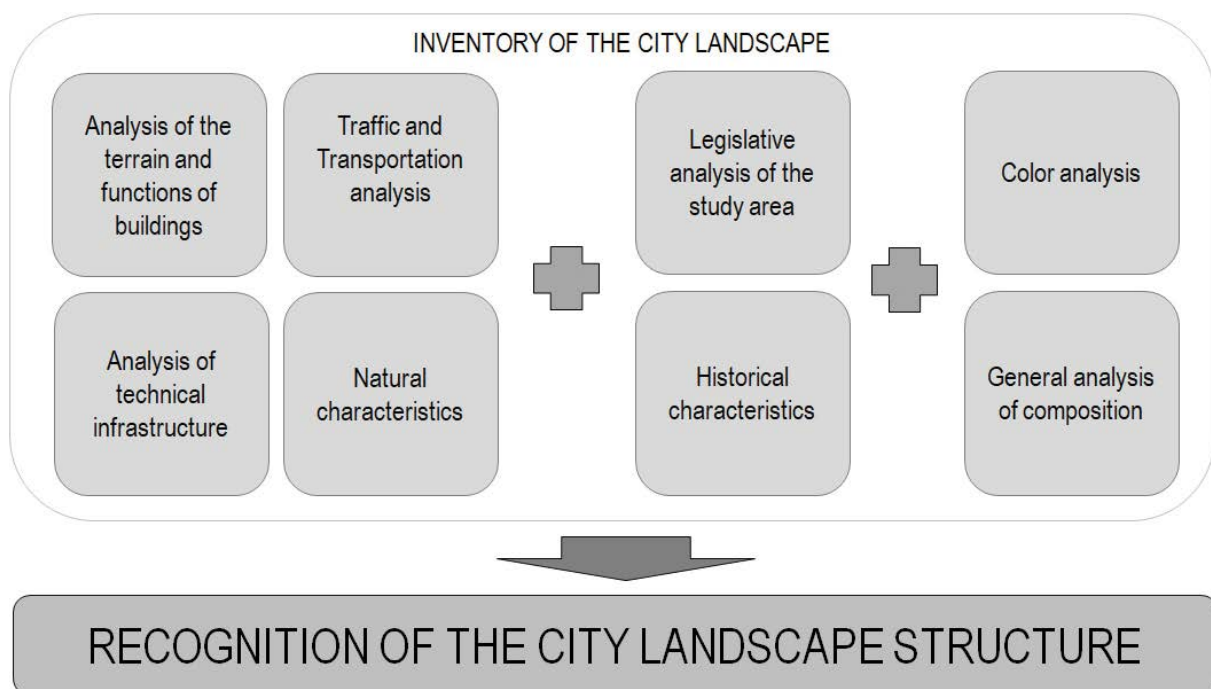


Fig. 1. Recognition of city landscape structure.

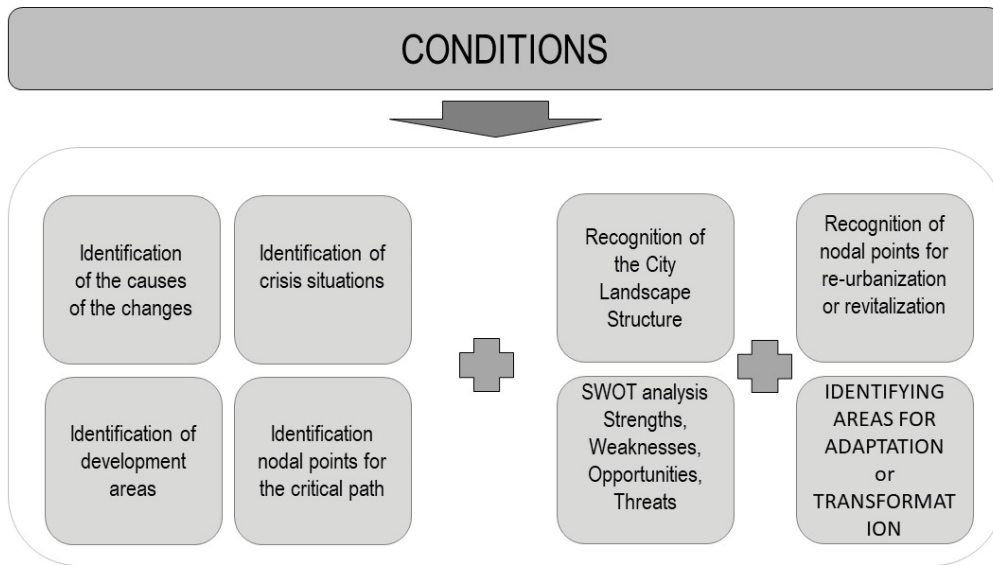


Fig. 2. The first phase in the research method – input data sets for the analytical path choice procedure.

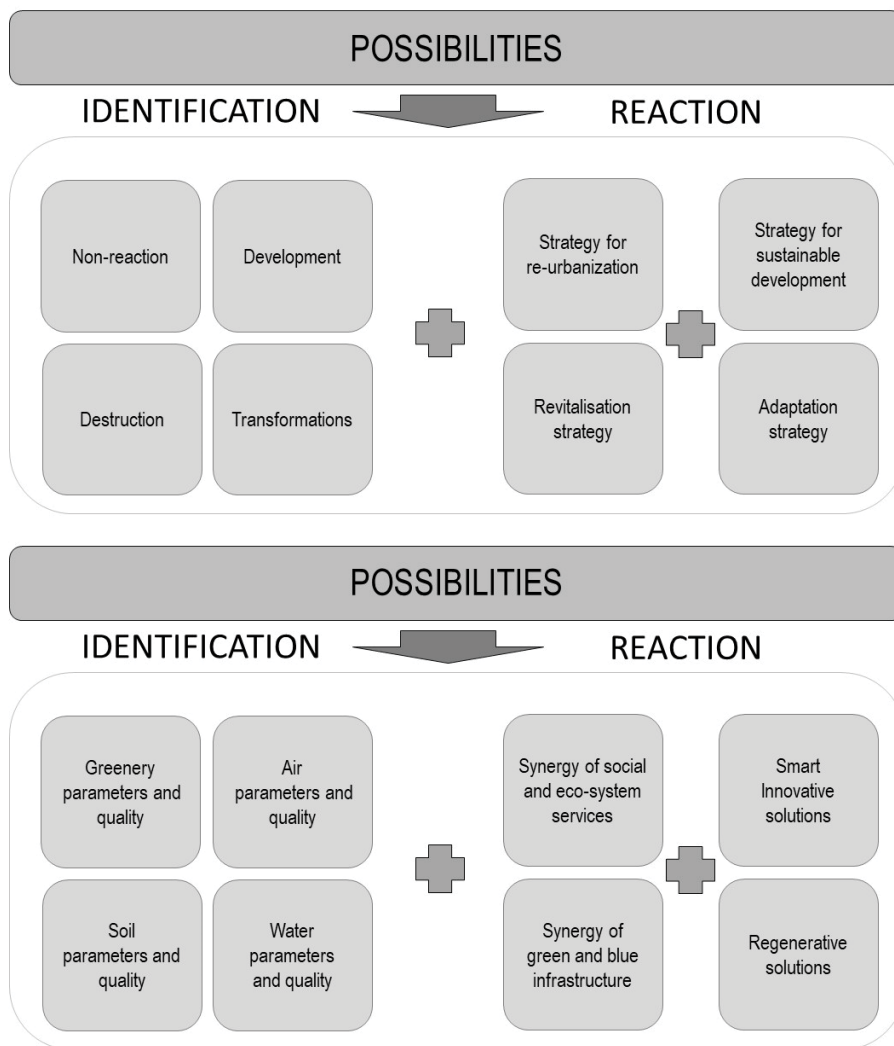


Fig. 3. The second phase in the research method – input data sets for the analytical path selection procedure.

The indicated ideas determine the development of the city taking into account the regeneration action within the existing and planned areas in need of remedial actions undertaken with ecosystem services design [36]. The research team developed an analytical model for landscape and urban resilience in the process of re-urbanization and re-naturalization. Urban and landscape analyses performed in a specific spatial context provide an essential part of planning city development in accordance with the assumptions of sustainable development, with the account to concepts related to the Green Deal and Smart City.

The paper presents research focused on selected risk factors to be included in a model for shaping urban resilience. The team of authors considered priority actions related to periodical floods and water retention in areas in the proximity of the river. Existing methods of flood prevention in the Warsaw area are described, as well as the management of areas along the Vistula River (the right and left bank of the Vistula River) in Warsaw where flood risk exists (Fig. 4). The approach to planning issues in this area offers a challenge for architects, urban planners, engineers, and authorities in the face of current problems that result from climate change. Regulations in this area are provided by the Act of July 20th, 2017 – Water Law, according to which development is prohibited in areas with high flood risk, which remains to be verified by checking ISOK maps [37]. In Warsaw, where residents have repeatedly experienced the effects of flooding, an emerging need for further research into adaptation to extreme weather events is observed. This is an important and topical issue. In Warsaw, measures are being taken to protect the city against dangerous and extreme natural phenomena. These actions include mitigation of the urban heat island phenomenon, protection against storms, floods, and prevention of low water levels in the Vistula River (ADAPTCITY) [38]. Impermeable surfaces constitute an increasing share in the urban space. William Lindley, the creator of the city sewage system, designed it in a combined sewerage model, which means that wastewater and rainwater are conveyed through one outlet. To separate the two systems are unrealistic nowadays. The construction of special reservoirs along e.g., Wisłostrada Street is intended to periodically retain excess water. This measure has been contained in the LIFE+ program, that is an adaptation to climate change.

As part of this undertaking, projects concerning small retention, increasing the permeability of surfaces, as well as supplying urban greenery with water from retention or green roofs, realized, for example, in the Copernicus Centre have been implemented [38].

The most significant anti-flood measures in the area of the capital include the construction and modernization of flood barriers on the Vistula River and care for the proper technical condition of hydrotechnical facilities. The Vistula River flows through Warsaw along a stretch of 28 km. It is characterized by a large difference in water levels – up to 7 m. Since the beginning of the 20th century, the riverbed has lowered by about 220 cm and it continues to lower after each flood wave. According to current forecasts, the water level in the Vistula River is described as “20-year water” [39]. This means the probability of a flood occurring for a given place once in 20 years. The Vistula River embankments are about 5 m high, in Warsaw, those are higher – about 6 m.

For water from the Vistula River to overflow the embankments in Warsaw, a flood wave would have to reach about 8.5–9 m high. [37]. According to hydrologists, the most sensitive points in Warsaw are the zoo area, where the embankment is very low, and the floodgate at the Praski Port. The project for the restoration of meadows along the Vistula River, conducted between 2014 and 2016 by the Property Management of the City of Warsaw in cooperation with the Faculty of Biology, the University of Warsaw, is also an activity that affects flood safety. Thanks to this program, in the area of 67 hectares of the Vistula section, proper, diversified species composition of floodplain meadows has been restored in the districts of Białołęka, Praga Północ, Praga Południe, Śródmieście, Mokotów, Wilanów. This has contributed to the increased attractiveness of recreational areas along the Vistula River.

In order to minimize the risk of flooding, interdisciplinary measures should be taken. The development and construction of hydrotechnical facilities should go hand in hand with appropriate legislation, spatial planning, education of the public, alarm systems, and the restoration of natural retention in drainage basins. Flooding is an extreme phenomenon for which no complete flood protection is possible to be provided. The situation in riverine areas is dynamically shifting along with the current climate change in a variety of contexts, such as spatial and functional, aesthetic, and cultural ones. The development of riverine areas and flood-prone areas becomes an important planning challenge.

3. Results

The analyzed areas were divided into sixteen sections related to successive segments of embankments with variable characteristics. For the purposes of the article, a detailed description of the selected research section No. 10 is provided. The analyzed area is determined by the length of the embankment section between the Średnicowy Bridge and the Śląsko-Dąbrowski Bridge, i.e. the diagonal embankment with a length of 1,612 m (Fig. 4). In the area between the embankment diametric (for the right bank of the Vistula River) and the bank of the Vistula between the embankment of the Czerniakowska Gate and the Młociński Embankment for the left bank of the Vistula River.

Basic results from the geotechnical opinions made in the area of passive flood protection of Warsaw from the side of the Vistula River and its tributaries are as follows:

The subsoil of the research area is characterized by complex soil and water conditions, with the domination of the share of non-load-bearing soils of considerable thickness, uncontrolled anthropogenic banks, and the presence of organic soils in the form of mud. The occurrence of groundwater with a free water table and under the hydrostatic pressure was found. The water table under hydrostatic pressure was drilled in 5.8–9.5 m below the water level, and it was stabilized at 3.7–8.6 m below ground level. The groundwater table can change its position depending on the water level in the Vistula River.

In periods of intense rainfall and spring thaw may occur seepage may occur on the cohesive soil layer, and the existing ones may intensify. There are cohesive soil

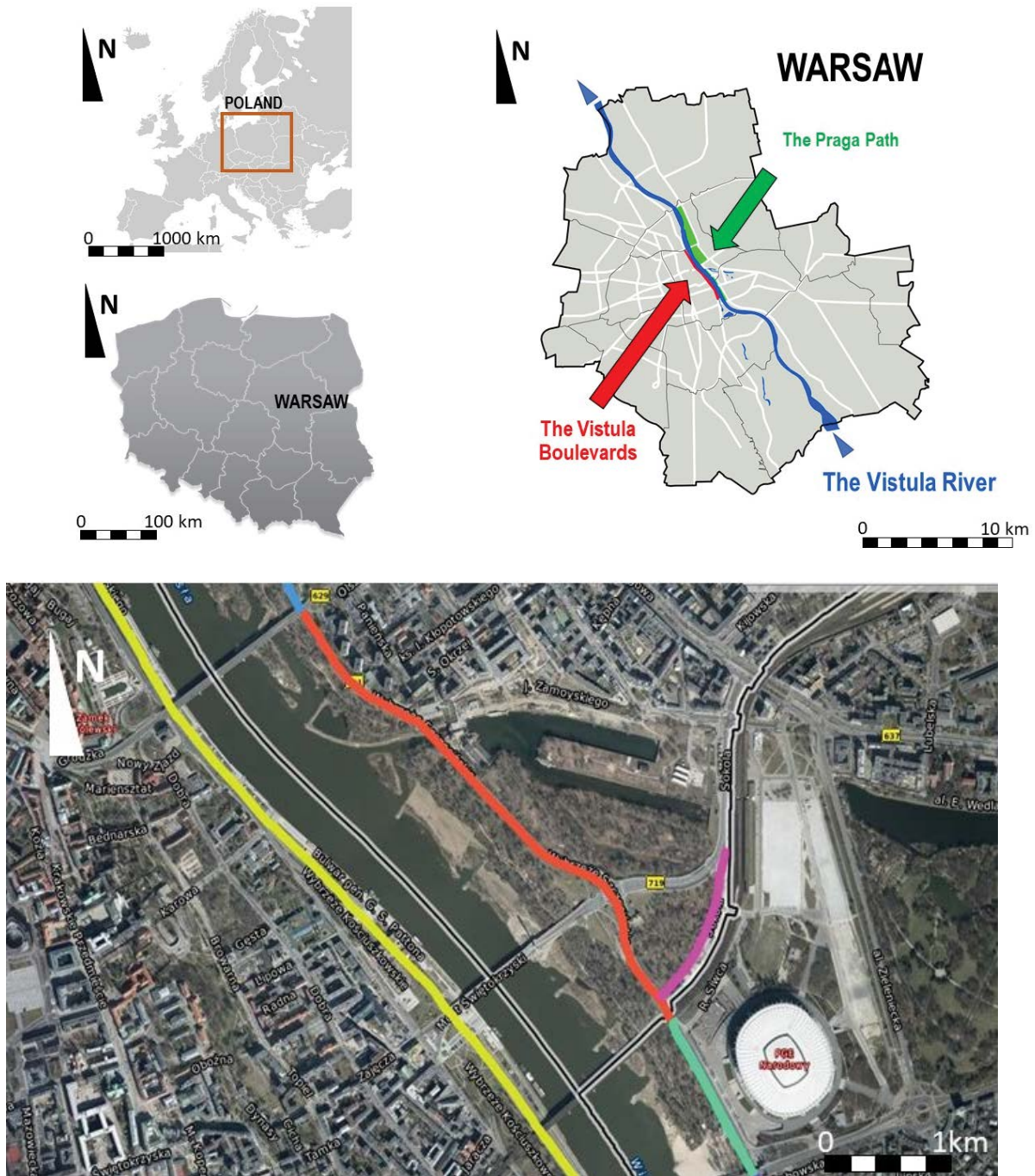


Fig. 4. Localization of research area with The Warsaw Boulevard, The Praga Path and flood banks [17] – the line colors indicate the elements of the embankments that determine the division into section with Recreation Path on the right bank of the Vistula River and Boulevards on the left bank of the Vistula River.

Legend:

- red line – the right bank of the Vistula River – the section of the Średniczy embankment from km 0 + 000 to km 1 + 612, km of the Vistula River
- green line – the Vistula right embankment line – the section between the Srednicowy and Miedzeszyński embankment, Vistula river km according to ISOK from 422 + 865 to 423 + 338
- yellow line – the line of the left bank of the Vistula River – the section between the Czerniakowska Gate embankment and the Młociński embankment, Vistula River km according to ISOK from 411 + 982 to 423 + 308

layers represented by clays, tills, and stagnant soils occur. The increase in humidity of these soils will lead to their plasticization, which reduces the strength of the soil and increases the deformability of the soil. Changing the properties of these soils may lead to exceeding the limit load capacity of the subsoil [40,41,17].

3.1. Results from the analysis of the Vistula River bed course in the years 1825–2020

In the analyzed time periods, the Vistula River had a similar course of the left bank. Currently, the shore is regulated, reinforced, and concreted. However, for the right bank in the analyzed section, significant transformation of the riverbed boundaries was discovered, as compared to the data from 1,825, 1,841, and 1,934, respectively. In the plans from 1939 and 1960, the routes of the canals are marked in accordance with the current regulated coastlines in the area of the present Praga Port. In the area of the analyzed section 10, there is the Kamionkowskie Lake partially fed by the Goławski Canal with an outlet through the Wawerski Canal and the Praga Port with the Kamionkowski Canal presented in Fig. 4.

3.2. Results from the vegetation analysis

The area along the right bank of the Vistula River: single trees, greenery mainly introduced in pots and on the slab above the road communication tunnel and partly on the native soil. Single specimens: hazel, apple tree, linden, silver maple, hornbeam, ash maple, white willow, black pine, sorbus, birch, plane tree on the native soil, single trees: pedunculate oak, chestnut, sycamore maple, small-leaved linden, elm, Norway maple, poplar, ash, birch, red oak, ash. A large amount of hardened, impervious or partially permeable

surfaces. Areas with grass and perennials, spontaneous green areas (Figs. 4 and 5).

The area along the left bank of the Vistula River: linear tree plantings parallel to the river, willow and poplar clusters and single ash-leaved maple, mulberry, robinia, elderberry, yew, fruit trees, silver maple, and spontaneous green areas (Figs. 4 and 6).

The quays and the analyzed areas are planted with a small number of shrubs. There is no rush vegetation and no water vegetation of phytoremediation importance. No rush vegetation and no floating plants with bioremediation, purification from heavy metals, phosphorus, and nitrogen compounds. However, some tree species on the right bank of the Vistula, such as willows, can fulfill this function. Moreover, no water gardens and floating stands with plants for remediation occur.

The analysis of the restoration conducted with elements of sustainable development, being the implementation of the investment called “Praga Path” seems to be particularly important for further planning of the development of Warsaw’s Vistula waterfronts.

The Praga Path constitutes a natural and freely shaped pedestrian route along the right bank of the Vistula River (Fig. 5). The initiative to create the path emerged in 2008 and is connected to the initiative of Marek Piwowarski a landscape architect, then the Plenipotentiary for the Development of Vistula River Embankments of the Capital City of Warsaw. Initially, the design was based on the concept of restoring two beaches: Praga beach – on the side of the Warsaw Zoo and Saska beach – at the level of Kryniczna Street. Prior to the restoration, the specified area consisted mainly of rubble, rubbish dumps, and municipal waste. Such state of affairs resulted as a remnant of the city policy, under which the whole area was one big rubble embankment until 1950s. It was only following the regulation of the



Fig. 5. Recreational path on the Vistula River (model made by Maja Ratyńska, Konrad Zientara/Mark Design) [42] and authors photo.

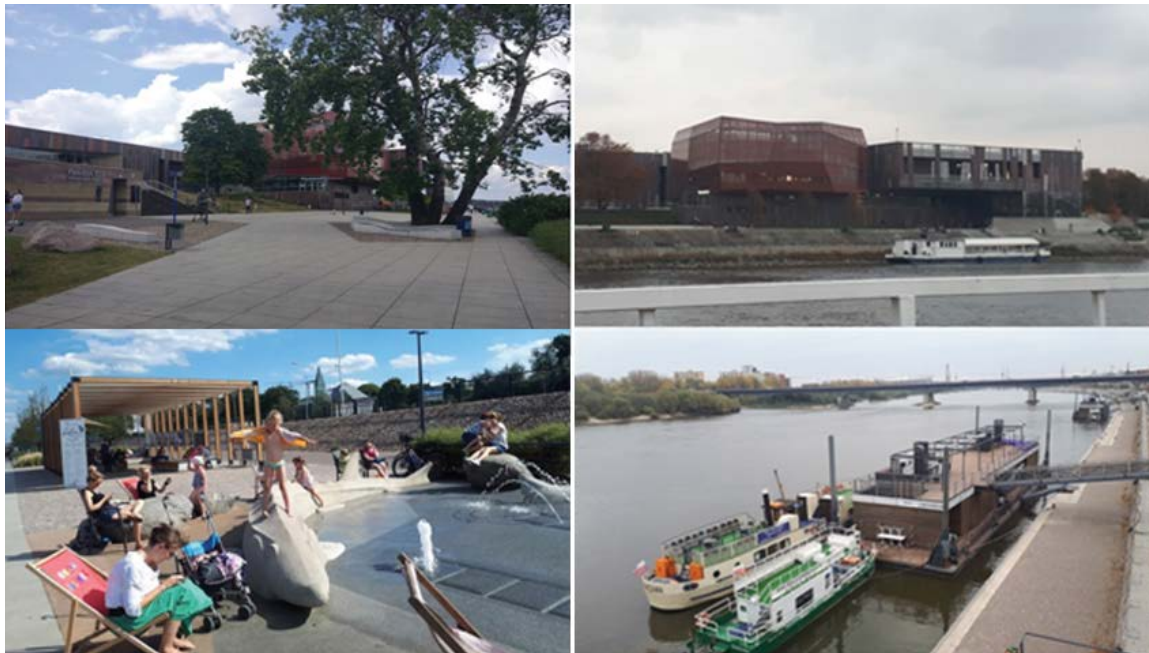


Fig. 6. The Vistula Boulevards, author's photo.

Vistula river in the 1960s that a habitat for the encroachment of riparian forest was established there. During the inventory of the area in 2008, it was decided to renaturalise the riparian forests by selective cutting of self-seeded ash-leaved maple (*Acer negundo* L.). The guidelines for carrying out this process were designed by phytosociological Czesław Wysocki and Piotr Sikorski and covered the cutting of 1,500 maple trees on the section from the Łazienkowski Bridge to the Gdański Bridge to be performed over the period of three years. The concept prepared by them indicated the way in which the path would be built, including how it would be drained and how it would be edged with branches pegged to the ground. Fascine fences were to be braided along the river banks. The course of the path was designed along anglers' forebodings in cooperation with ornithologists Jarosław Matusiak and Renata Kuryłowicz [42]. The path is now 10 km long and connects two Warsaw bridges – the Poniatowski Bridge and the Grot-Rowecki Bridge. The cost of its construction was relatively low and only amounted to around 40,000 E. At the beaches along the walking trail, stops are located for the ferry that connects the right bank of the Vistula River with its left bank. The path connects three beaches to the south: (1) the beach at the zoo with a recreational playground and accompanying wooden pavilion that contains sanitary facilities and a small restaurant. (2) so called "Poniatówka" which is one of the oldest "wild" beaches in Warsaw (its origins date back to the 1920s) and (3) the northernmost Saska beach (Fig. 5). The route of the path passes through three coastal zones. On the side of the riverbed, there are natural sandy and grassy areas adjacent to which there is a belt of shrubs with willows inhabited, by species such as beavers (*Castor fiber*) and a large number of bird species. Another belt is formed by a riparian forest. The shrub layer is pruned every 3 years so as to prevent obstructing the water during high

river levels; this also serves to prevent excessive aeration and drying out of the forest layer.

The other bank of the Vistula River in Warsaw was planned in a completely different way. The Vistula Boulevard was designed as a highly urbanized space with an urban beach and a recreational and gastronomic program. The vicinity of the Copernicus Science Centre, whose modern form had an impact on the adopted aesthetic solutions, is an important element that influenced the spatial context of the implemented solutions. The entire project was designed by the Polish studio RS Landscape Architects on the area of 50 ha, directly adjacent to the riverfront. They adopted a functional layout that generated a very strong social resonance [36]. The previously neglected area has become one of the most visited spots in the Polish capital city. The design of the urban space is fascinating and draws attention to its interesting form. The use of high-quality materials in the design of the boulevards should also be emphasized. The whole assumption was to turn the boulevards into a certain form of a metropolitan walking artery, additionally located next to an expressway. In contrast to the Praga Path, artificial surfaces predominate here. Despite the fact that a strip of natural land (very narrow, depending on the current state of the river, often flooded) directly adjacent to the river was left undeveloped, the area is very strongly urbanized. It is basically covered with concrete and, despite its visual attractiveness, fails to offer additional pro-environmental or resilience benefits. This space is marked with an urban heat island phenomenon. As such, it stands in contrast to the Praga Path solutions in practically all aspects, except for its social and visual values. Though undoubtedly nice, this place, is disturbing in its approach, as the project is entirely focused on the aesthetic side to the very least. No protective measures were foreseen for the riverside areas in this section, which makes

the left bank of the Vistula River stand in strong contrast to the solutions on the right bank of the river (Fig. 6).

4. Discussion

The selection of solutions in the planning process for the transformation of waterfronts should refer to the categories of strategy for sustainable development, adaptation and re-urbanization. The integration of the actions specified in these three strategies provides the basis for planning transformations, which, in turn, can be an example of implementing Green Deal and resilience solutions. Issues contained in the above discussion are strongly related to designing with the view to the Green Deal assertions. Re-naturalization and design in the spirit of Eco Smart City are implemented in various places worldwide. Berlin's FlussBad by Realities United Studio (1998/2011), implemented in 2012 offers an interesting example of a similar solution on a slightly larger scale. This concept, based on the revitalization of a river in order to bring it back to its users, was introduced with the account of the resilience and reurbanization of the neighboring areas. Moreover, it involved a great respect for the natural ecological structure of the area. In 2017, this course of action resulted in FlussBad being listed as a top priority in Berlin's development strategy [43,44]. Unfortunately, not all such initiatives succeed, as exemplified by the initially highly praised Eco Boulevard project in Madrid. The final implementation of which resulted in strong public resistance and another wave of gentrification in the re-urbanized neighborhood. Given the non-transparent activities of local authorities and activists, some of the pro-environmental solutions planned in the project had to be abandoned, which resulted in the failure of the entire project. This example shows that oftentimes ecological solutions are forced onto the public, without taking the actual social expectations into account [45,46]. An interesting example of a waterfront organization is Mikhailovskaya Embankment in Novosibirsk designed by Adaptik-A and Strelka KB architectural offices. This 8-hectare area has been very strongly urbanized on the one hand in the areas directly adjacent to the river. On the other hand, behind the strip of concrete waterfront, previously degraded spaces have been denaturalized into ecological park areas. The whole concept presents a clash of thinking, similar to the two Warsaw examples described above. Definitely, more pro-environmental and ecological solutions were proposed by the designers SWA/Balsley/Weiss/Manfredi in New York. Hunter's Point South designed by them incorporates a park, a streetscape, and infrastructure system intended to accommodate solutions based on such diverse functional assumptions as purely recreational spaces and cultivated urban agriculture on 5 hectares of the waterfront area. This 2-phase development is an attempt at a contemporary view of the waterfront that combines ecological conservation and contemporary urbanism [47]. Yet another example of policy related to riparian land use is located in Tampere, Finland, proposed by Landscape architecture office Maanlumo Ltd. This area of 10 hectares was revitalized with the construction of a new housing estate. The area around Lake Näsijärvi has been transformed into three parks designed to restore the natural environmental

character of the area. Outside the urbanized areas, efforts have been made to create vegetated enclaves in a way that meets the principles of contemporary environmental protection. This implementation has been presented as one of the better contemporary solutions concerning economy and management in the vein of resilience [48]. On the other hand, Alex Krieger, professor at Harvard University, critically referred to the process of transformation of the Seaport District in Boston, which was realised at the narrow interface between water and land, the so-called "thin line". He expressed his views both at the conference "Waterfront in Post-Industrial Cities" [50] and in his speech at the conference "Redefining cities in View of Climate Changes" (11.2019) in Warsaw. According to Krieger, transformations within the "thin line" design present a too truncated understanding of Boston's waterfront and water-space relations in a city where land for urbanised areas has been carved out of water for 200 years [49,50]. His view is also shared by Anna Cook, principal manager of Port Planning for the City of San Francisco, who stresses how important it is to go beyond thinking only in terms of a clear line of contact [49,50]. Prof. Nyka concludes that designing waterfronts with careful consideration to site-specific topography, understood in a broader context than just the line of contact, can offer an opportunity to create unique solutions, contrary to trends towards uniformity and repetitive designs. This undoubtedly applies also to Warsaw, as a city with a rich history and traditions, characterised with ultimately a beautiful river with a unique character on a European scale. Spatial solutions for Warsaw should account for transformations of water frontage areas as provisions implemented in accordance with the Green Deal strategy based on analysis of transformations in close realignment with the rest of the city. The described methodology and analysis structure, along with examples of research data, constitute part of work on shaping the city's resilience. By developing the analytical model, an analytical structure for transformations emerges with which to implement landscape shaping solutions and resilience of the city. An evaluation method has been developed through a model of decision-making procedures based on action patterns for a data set arranged in a category structure. The projects presented above present a variety of solutions for public spaces and architectural objects under the common denominator of designing with respect for the water relations of a given place. An example of a floating garden permanently moored to the bottom of the Cybina River in Poznań is worth mentioning (Fig. 7). It is a light water island structure with native aquatic plants of water and air purification properties and a nesting basket for waterfowl. The installation for biodiversity and remediation was implemented as part of the *Connecting Nature* Project, commissioned by the Office of Project Coordination and Revitalization of the City of UMP, by the OnWater.pl Foundation from Wrocław, to create a model micro-greening system in the city [51].

5. Conclusions

As a result of the research work conducted on the basis of the author's analytical model for planning and integrated design purposes, conditions and possibilities in the climatic



Fig. 7. Floating garden on Cybina River in Poznań [51].

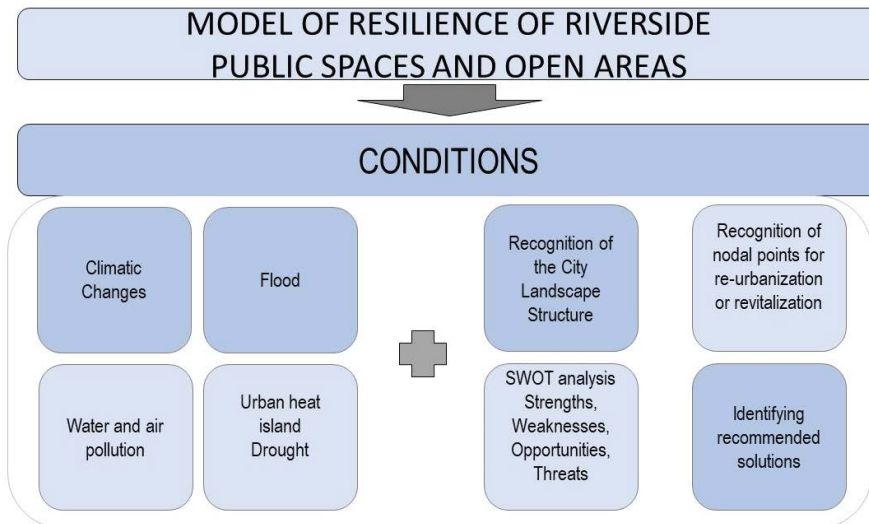


Fig. 8. Model of resilient riverside.

changes – flood criterion were created. The analytical and research process, as well as the analytical pathway in the inference part, is presented in schemes (Fig. 8).

Based on the analysis of the existing state and elements from the analytical model, a recognition of the city landscape structure was defined. Indicating the need for the development of a restoration project and for the management of areas that are at present degrading are only potential flood-plains and dyke strips. As a result of the analyses, areas that require a transformation in the process of revitalisation, re-naturalisation, and re-urbanisation were identified. After conducting a SWOT analysis, exemplary recommended solutions were selected.

5.1. Basic conclusions from the land development analysis

Right bank: irregular shoreline with small fortifications, part of the area is in the Natura 2000 area “Middle

Vistula Valley”, high greenery and meadows of the bay with marinas and buildings related to water sports, tourism and recreation, silos, swimming pools, tennis courts, single gastronomic facilities, the Żerań Canal, single hardened roads, sand barre. A significant share of trees, clusters of fruit trees (plum, cherry, apple, and pear), ash-leaved maple, poplar, elm, willow (clusters on the shoreline densely grouped between the most Siekierkowski Bridge and the Łazienkowski Bridge). Between the Świętokrzyski Bridge and the Śląsko-Dąbrowski Bridge. Single willows, alder trees, birch, robinia, hawthorn, red oak, pedunculate oak.

In the elevation – islands: illows and fruit trees.

The municipal water and sewer company- (MPWiK), The path from the Grot-Rowecki Bridge to the Łazienkowski Bridge, the so-called the Praga Path.

Left bank: The coastline is reinforced with concrete fortifications at sections.

High greenery and meadows, MPWiK water treatment plant, recreational gardens with recreational buildings – free-standing buildings.

In the Urban Heat Island and Drought category, the need to improve water retention especially in the river catchment areas is indicated. In the process of designing waterfronts in this category, it is particularly important to introduce alternative solutions to paved surfaces in order to make them permeable to water and to use natural materials. The implementation of solutions adopted for the Praga Path described in this article is indicated and recommended.

In the category of water and air pollution, which is also important for waterfronts, possibilities were indicated for waterfront modification. The aim is to provide them with natural water and air purification sites with the use of vegetation effective in such activities, such as rushes, marked with high transpiration parameters and effectiveness in water purification, and willows. These species provide an example of plants that catalyze harmful compounds and give the effect of soil, water, and air purification. The correct choice of solutions in this category requires an analysis in the category of synergy of social and eco-system services, as well as in Green and Blue infrastructure category. Air and water parameters and quality should also be determined, both by examining the condition prior to changes and by defining the parameters to be achieved by the introduction of the chosen solution. As shown in the diagram below (Figs. 9 and 10).

In conclusion of the research work, it is reasonable to provide the basic criteria for defining resilience. According to the authors, it can be described as:

- the ability to absorb disturbances (the issue of flooding described in the above paper);
- the re-use of water and energy matter;

- similar basic structure and ways of functioning;
- absorption and naturalisation of pollutions.

According to the research team, the application of the presented method and data sets will enable the improvement of decision-making processes and integrated design in the process of selecting solutions from representative data sets. Graphically, the issue is presented in Fig. 11.

Recommendations in the summary of the research work

When designing transformations and development of the waterfronts in the analyzed area, the following should be accounted for:

- on both sides of the Vistula River, measures are proposed in the field of micro-retention to prevent drought and in the event of torrential rains;
- the shoreline should be designed by shaping bays, canals (with overflow and damming systems) to supply small water reservoirs formed for retention activities and shallow reservoirs to improve habitat conditions and biodiversity;
- it is suggested to design the reservoir to function as a swimming pond with the use of natural water cleaning solutions;
- by shaping the shoreline, it is suggested to introduce riparian and rush vegetation to increase biodiversity and habitats and the function of natural water purification;
- implementation of water gardens and floating stands with native vegetation for phytoremediation;
- the areas currently comprise wastelands or areas intended for sports and recreation functions with individual sports facilities and buildings;

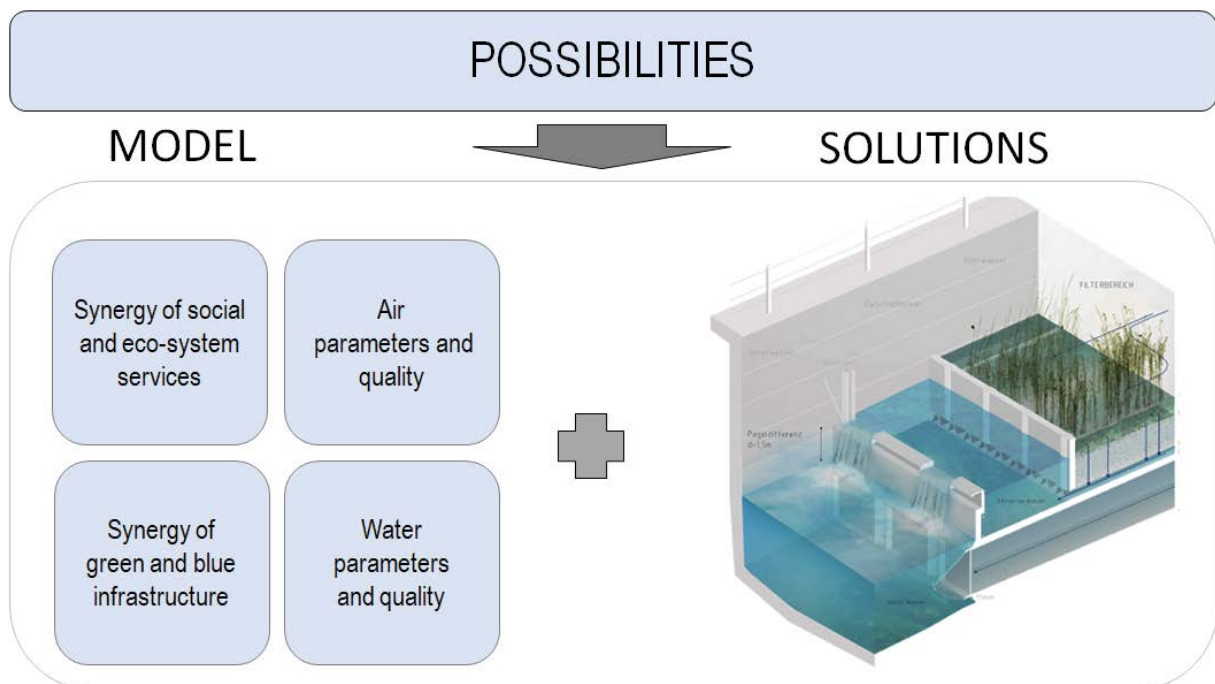


Fig. 9. Model of resilient riverside with example of recommended solution, Berlin's FlussBad by Realities United Studio [45].

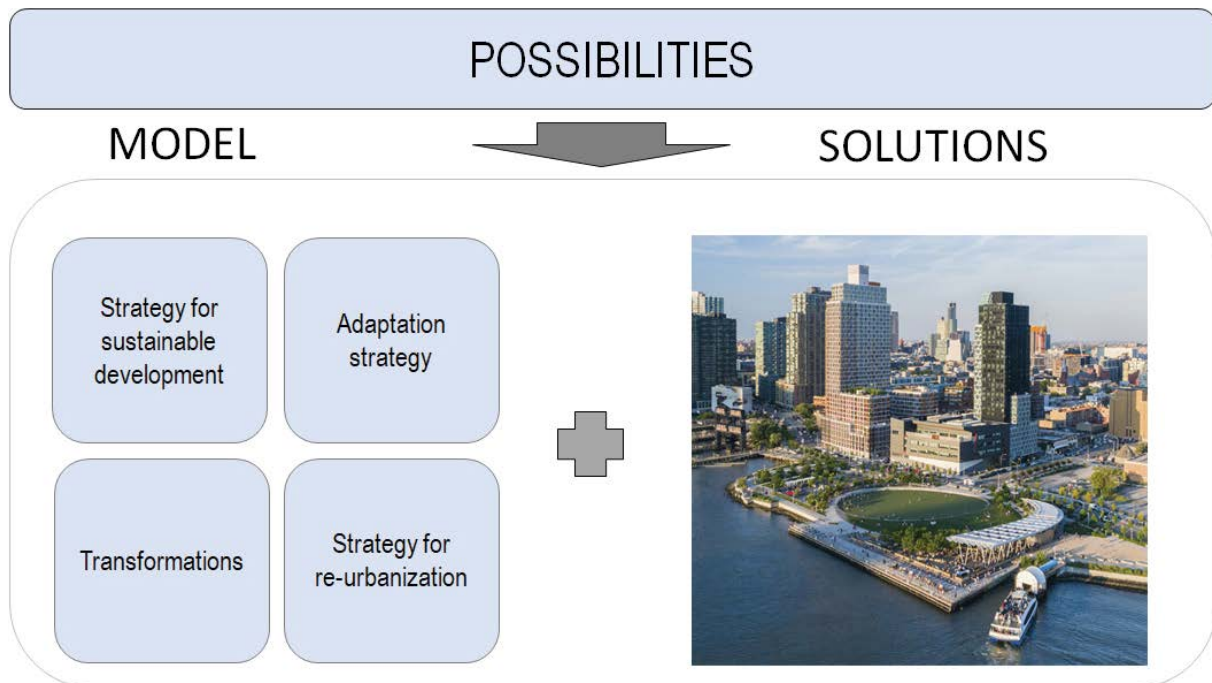


Fig. 10. Model of resilient riverside with example of recommended solution, Hunter's Point South Park, New York [48].

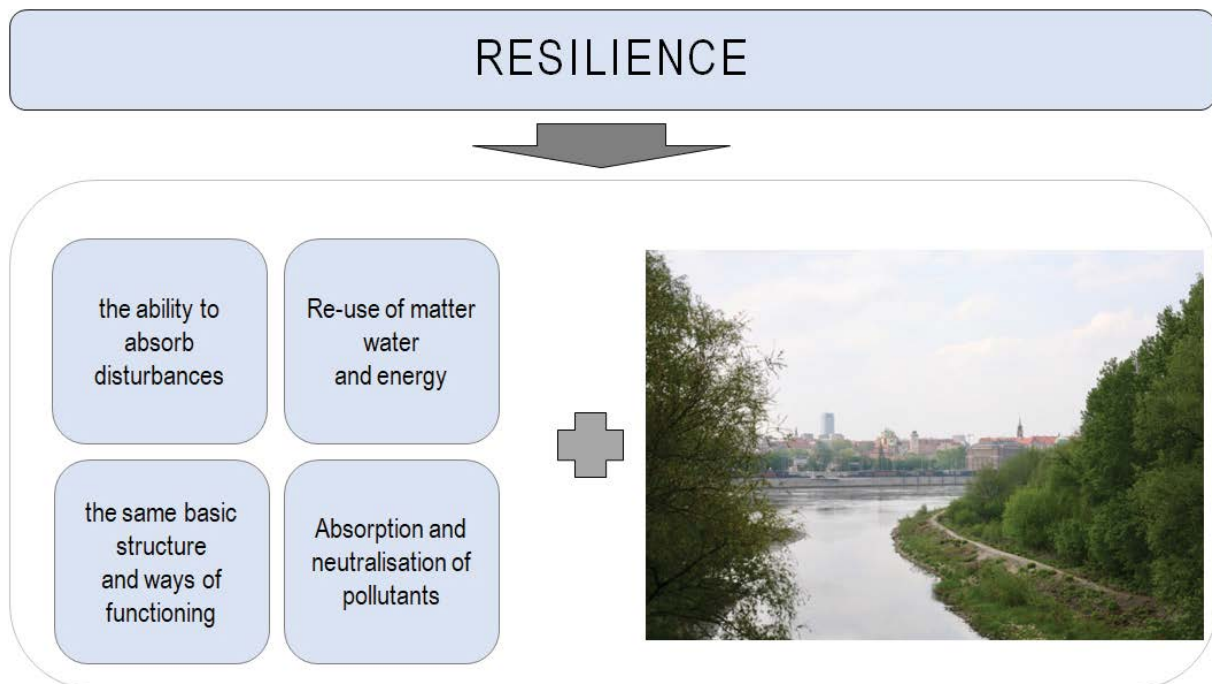


Fig. 11. Resilience-categories for conclusions, with example of recommended solution on the Vistula River, author's photo.

- it is proposed to introduce the function of biomass production by introducing the cultivation of energy crops such as basket willow (*Salix Viminalis* L.);
- when creating surfaces of pedestrian and traffic routes, platforms and piers should be introduced to enable the free flow of water and its infiltration. When the surface is built on the ground, natural materials and technologies of permeable surfaces should be selected;
- the regulation of the quay and functional and spatial transformations of the waterfronts should account for the analyzes of the city panorama, as well as the view axes and viewpoints in the urban composition of the transformed floodplains, which constitute an important area in the city landscape;

- it is recommended to designate areas to enable designing the area as a space for integration and creative activities, as well as non-invasive formation of surfaces, roofs, seats, and lighting to provide spots for safe rest in indicated places, channeling pedestrian traffic in accordance with the composition and urban and environmental guidelines;
- complementary tree plantings, with an account to complementing ecosystem services and the importance of adapting to climate change. Properly selected native species introduced in open areas may support micro-retention, shade the area by reducing the effect of drought and slow down the flow of water in the event of a flood wave.

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