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Classification and architectural planning components of riverine areas in the city structure

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Abstract: The study is devoted to the interaction of riverine areas with the urban structure. The purpose of the study is to provide substantiation for the classification of riverine territories in the city structure and to establish the architectural and planning components of riverine areas.
The authors analyze global experience in the organization of riverine territories as part of urban development in the context of modern sustainable development programs. The results suggest that amid the increasing density of cities, changes in production interests, and climate change, there are trends in the regeneration of riverine areas. The study highlights the following trends in urban development: the creation of a system of recreational zones along the banks; creation of a network of city parks with different themes; incorporation of a spatial carcass into the structure; creation of public recreation centers, leisure complexes, and parking ensembles at the intersection of the urban and natural frames; rehabilitation and improvement of industrial areas; relocation of industrial plants situated among residential buildings to industrial areas; optimization of traffic and rational positioning of storage and maintenance facilities; development and organization of water protection zones and coastal protection strips. The conducted analysis of world experience confirms the need to find techniques to rehabilitate territories that are no longer effective while prioritizing the formation of a comfortable urban environment as a factor in raising their environmental and social efficiency.
Keywords: riverine territory, riverine city, coastal strip, coastline, water area, rehabilitation of riverine territories, city structure, urban development

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1. INTRODUCTION

1.1. Research Problem

Contradictions in urban planning have arisen due to several factors specific to the post-industrial city and have in turn influenced transformations of the city structure: expansion of the city [1], the predominance of automotive carcass over the pedestrian [2], uncontrolled functional development of areas along the banks [3, 4], and positioning of the industrial complex in the structure of riverine terri-

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tories [5]. To create an environmentally-friendly, harmonious [6], and comfortable environment and raise the quality of life, in connection with further development of urbanized subsystems, it is necessary to create spaces for the interaction of the natural and man-made carcasses [7, 8], preserve the hearths of natural landscapes [9], and shape the recreational frame of the city in connection with the water area [10, 11]. One of the most efficient techniques to preserve and restore environmental equilibrium in the city is the rehabilitation of riverine city areas [12, 13], which provides for the formation of a recreational strip along the water area and the organization of deep environmental corridors along arroyo zones in accordance with the morphological structure of the territory [14].

The rehabilitation of urbanized riverine areas based on appropriate urban planning solutions needs to become a component in the system of rehabilitation measures at various territorial levels: from nationwide [15] and regional [16] to local within specific cities [17, 18]. Particularly relevant to creating comfortable living conditions for the population is the local level [19, 20]. Sustainable development of cities involves the elimination of conflict situations through the interaction and coordination of social, economic, and environmental factors when making design decisions [21, 22].

The rehabilitation of riverine urban areas cannot be done without a comprehensive study of highly urbanized river valleys [23]. This research requires a systemic approach, in which the decisive and pressing aspects include a comprehensive study of the architectural and planning components of riverine territories in the city structure and the interaction of the river area with the urban space [24].

2.2. Literature Review

The concept of a riverine area has a few interpretations [25]. Most authors, researchers, and architects explore and model riverine areas proceeding from their environmental [26], compositional [27], and planning features [28]. Researchers identify the concepts of the riverine space [29], the types and parameters of riverine areas [30], the features of their interaction with the city planning structure [31], and their compositional and functional zoning and urban planning regulation [32]. A.T. Wessells and R.P. Lejano [33] consider riverine areas as complex ecosystems distinguished by exceptional fertility and a specific microclimate. Without their management, urbanization can disrupt natural equilibrium and cause disproportions in ecological development [34]. P. Pinto and M. Kondolf [35] and E.A. Fedchenko et al. [36] analyze riverine territories from a physical and geographical point of view and define them as lands located on a river bank, with a slope to its channel, and covering such structural elements of a river valley as the territory of the floodplain, slope and bedrock coast, river terraces, areas of possible flooding, the river's water protection zone, protective strip, and the border of riverine territories. S. Buchel and N. Frantzeskaki [37] and G. Mutlu Avinç and S. Arslan Selçuk [38] view the riverine territory as a unique urban planning subsystem that belongs to the structure of the urbanized environment and is adjacent to the natural component of the river.

The riverine area can be considered an ecological stabilizer of the urban environment if it is freed from industrial zones and transport corridors, forming a system of green open spaces [39]. In this vein, E.S. Kravchenko and D.A. Protopopova [40] view riverine areas as potential reserves of the urban environment distinguished by a great dynamic of functions and a high natural and visual potential. The development of riverine areas requires a comprehensive strategy of functional zoning and the positioning of urbanized urban planning ensembles and natural landscape corridors in their structure. E.V. Guskova defines a riverine area as a contact zone between urbanized and natural objects adjacent to a river, which constitutes the foundation for the architectural planning design of the river facade and demands special approaches to their compositional development [41]. By composition and connections, the riverine territory can be interpreted as a natural-technical hydroecosystem, a socio-natural-technogenic system, and a natural-technical or natural-technological system [42]. Urban riverine areas by a degraded river are disturbed and degraded areas adjacent to a river bed that are severely transformed by anthropogenic load [43]. Structural components of the riverine territory include ensembles, complex objects, groups of architectural objects, landscape zones, and hydrotechnical and port engineering structures; buildings and structures serving as background objects; elements of equipment for recreational zones, small architectural forms, and objects of the object-spatial environment of the coastal territory [44, 45].

The goal of the study is to substantiate a classification of riverine territories in the city structure and identify the architectural planning components of riverine areas.

The research objectives are as follows:

1. to develop a classification of riverine territories and riverine cities based on riverine territories;
2. to establish the architectural planning components of riverine areas in the city structure;
3. to substantiate the need to find techniques to rehabilitate riverine territories that are no longer efficient.

2. METHODS AND MATERIALS

In the first stage of the study, the information sources necessary for the study were selected via the systematization method: articles published in the journals indexed in Scopus and Web of Science covering the research problem. The source base was limited by the requirement of free access to the materials.

The second stage consisted of three main stages: determining the object of study – in our case, riverine areas in the city structure; collecting materials on the chosen object through a desk study; and systematizing the obtained data. The selection criterion for the study objects was the availability of materials for analysis.

The third stage focused on exploring international experience in the urbanization of riverine territories; urban planning (urbanistic) analysis was employed:

- to determine the influence of the hydrographic network model on the formation of urban development on the example of large riverine cities in Europe and the USA (London, Berlin, Paris, Madrid, Los Angeles, San Francisco, New York, Chicago, New Orleans);
- to substantiate the classification of riverine areas and riverine cities by the type of planning structure on the example of large riverine cities in Europe, the USA, and the Russian Federation (Nantes, Madrid, Stockholm, Memphis, Seattle, Volgograd, Irkutsk, St. Petersburg);
- to substantiate the classification of riverine areas and riverine cities by the configuration of the water area on the example of large riverine cities in Europe and the USA (Prague, London, Cologne, Madrid, Amsterdam, Hamburg, Düsseldorf, Nantes, Rotterdam, Berlin, Amsterdam, Portland, Washington, Memphis, St. Louis, New York, Baltimore, Detroit, Boston);
- to conduct a comparative analysis of cities on the Volga and Danube rivers as the largest European rivers flowing through the Russian Federation and the EU to determine regularities and dependence on the river dominant. We used the following dependencies: SC – total area of the city; LRT – length of the riverine area; K – the rate of the development of riverine areas by urban structure (K=LRT/SC);
- to conduct a comparative analysis of European cities (Cologne, Düsseldorf, Hamburg, Liverpool, Manchester, Rotterdam, Copenhagen, Lyon, Zürich), establish a typology of spatial organization of riverine areas, and assess them on a 5-point scale (from "very low" to "very high") using the following criteria derived from urban planning research:

Interaction with water: improvement and landscaping, accessibility, design features;

Preservation of cultural heritage: the cultural component, changes of the city's image under the influence of renovation;

Revitalization – the incorporation of areas that have lost their original function into the socially active urban space;

Integration of public and private interests: for the strategic planning and design phase;

Integration of new riverine elements into the existing urban fabric as its integral part;

Prioritization in the practice of urban planning, compliance with the principles of sustainable development (interconnection of spaces and their functionality).

- to establish the typology of the spatial organization of riverine areas in European cities (Cologne, Düsseldorf, Hamburg, Liverpool, Manchester, Rotterdam, Copenhagen, Lyon, Zürich).

In the fourth and final stage, the collected information was summarized and the obtained results were formalized and presented.

3. RESULTS AND DISCUSSION

3.1. Classification of Riverine Areas and Riverine Cities

The conducted urban planning analysis of riverine cities highlights four primary hydrographic network models that affect urban development (Table 1).

Table 1. Influence of the hydrographic network model on the formation of urban development.

No.	Hydrographic network model	Formation of urban development	Examples of cities
1	water area stretching across the city	two-sided urban development depending on riverbed width; predominantly transverse communication links	London, Berlin, Paris, Madrid
2	water area limiting urban development from several sides	urban development is formed in islands, providing access to the planning element from the main transport and pedestrian corridors of the urban fabric	Los Angeles, San Francisco, New York, Chicago
3	water area is an extensive hydrographic network that limits the city or stretches across it	one-sided, two-sided, and island urban development	New Orleans

Note: compiled by the authors.

The research process also involved creating a classification of riverine cities by the type of planning structure. Their structural models were established and it was found that the influence of river drainage led to the formation of three types of cities (Table 2).

Table 2. Classification of riverine cities by types of planning structure.

No.	Type of city	Planning structure characteristic	Examples of cities	Riverine territory compactness coefficient
1	extended	One-sided structure. Pronounced linear planning structure. The river is the main constraint in urban development planning	Memphis, Volgograd	1:4.2 1:4.8
2	compact	Two-sided structure. The river is the main connection between the two banks. A three-sided structure is formed if there is a confluence of two rivers	Nantes, Madrid, Irkutsk	1:1.2 1:1.8 1:1.4
3	mixed	Island location. The city is surrounded by a water area of a complex configuration. The planning structure is characterized by a multi-vector orientation	Stockholm, Seattle, St. Petersburg	1:2.9 1:2.6 1:2.8

Note: compiled by the authors.

The role of riverine territories differs across cities. An important parameter that depends on the shape of the city is the coefficient of compactness of riverine territory. For extended cities, this indicator reaches up to 1:5, for compact cities – between 1:1 and 1:2, and for mixed cities – about 1:3.

As part of the study, we developed a classification of riverine cities by the configuration of the water area, which distinguishes four main types (Table 3).

Table 3. Classification of riverine cities by the configuration of water area.

No.	Configuration of the water area	Examples of cities
1	Linear water area	Prague, London, St. Louis, Cologne, Madrid
2	Linear water area with a complex configuration	Amsterdam, Baltimore, Hamburg, Düsseldorf, Rotterdam
3	Confluence of two rivers (three-sided structure)	Washington, Portland, Berlin, Memphis, Nantes
4	Confluence of a river into a larger water body (two-sided structure)	New York, Detroit, Amsterdam, Boston

Note: compiled by the authors

3.2. Directions of Formation and Organization of the Architectural and Planning Components of Riverine Territories

A comparative analysis of cities on two large rivers, Volga and Danube (Table 4), was conducted to determine the zoning and development of riverine territories depending on the conditions of urban planning.

Table 4. Comparative analysis of cities on Volga and Danube.

Water area	City	City structure	SC, km2	LRT, km	K
Volga	Volgograd	one-sided	859	67	0.1
	Samara	two-sided	466	200	0.44
	Saratov	one-sided	393	40	0.1
	Ulyanovsk	two-sided	317	40	0.12
	Tolyatti	one-sided	315	61	0.19
Danube	Budapest	two-sided	525	70	0.13
	Vienna	two-sided	415	48	0.11
	Bratislava	two-sided	368	74	0.2
	Belgrade	two-sided	360	86	0.23
	Ruse	one-sided	127	28	0.22

Note: SC – total area of the city; LRT – length of riverside; K – the rate of development of riverine areas by urban structure (K=LRT/SC).

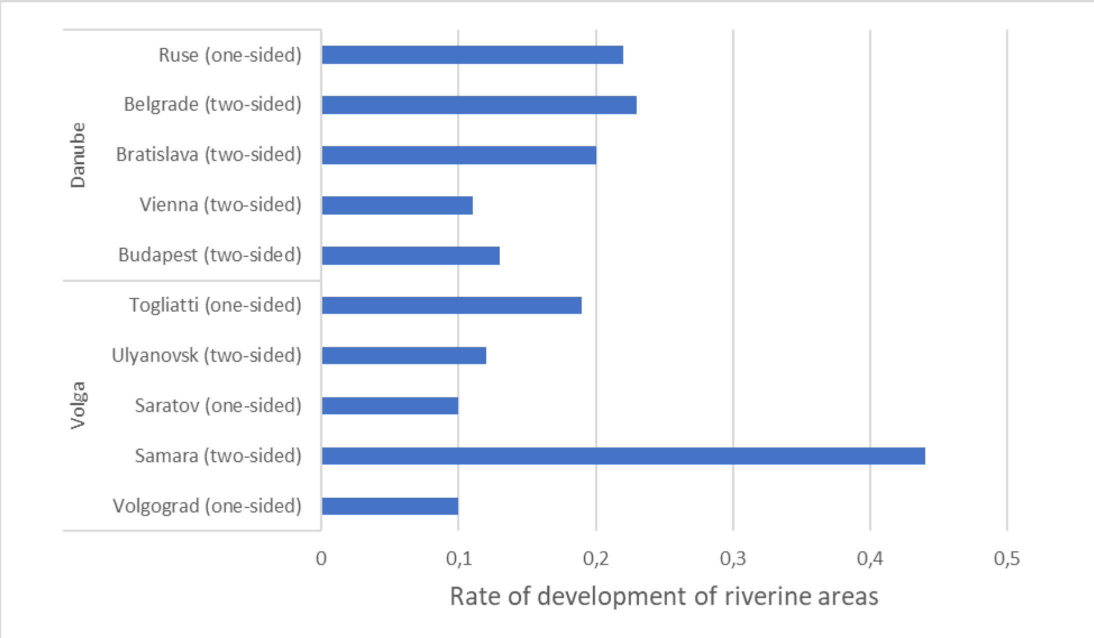

Fig. 1. Comparative analysis of the rate of development of riverine areas by urban structure on the Volga and Danube rivers.

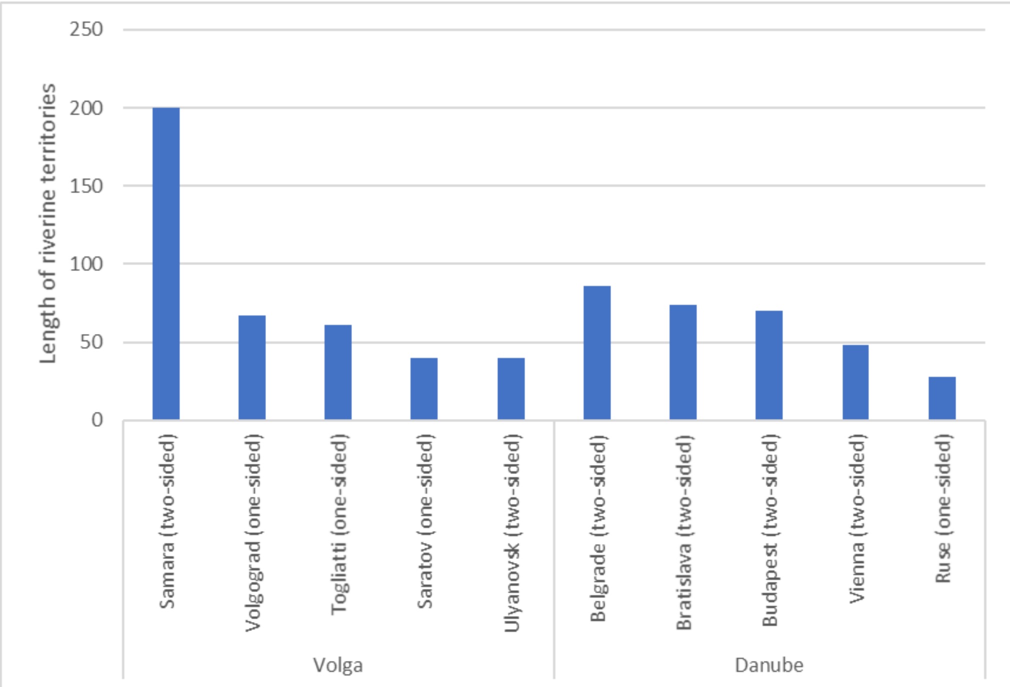

Fig. 2. Length of riverine territories in cities on the Volga and Danube rivers.

Fig. 1 shows that for the Volga river, the predominant type of development is the one-sided structure of cities with the rate of development of riverine areas by urban structure K ranging from 0.1 to 0.44 and the frontline of riverine territories LRT from 40 to 200 km (Fig. 2).

Cities on the Danube river are predominantly characterized by a two-sided structure. Their coefficient of riverine area development by urban structure K falls between 0.11 and 0.22, and the length of the riverside Lrt is between 28 to 86 km.

The conducted analysis of common characteristics of the studied cities and identification of their position in the water area give insight into the regularities and dependencies on the river dominant. Cities on the Volga river, owing to their historical development from the sector type of the city to the circular, preserved the radial-ring planning structure. Cities formed at the confluence of large rivers develop the main core in their structure that gravitates towards the water area, thereby fixing the main river facade.

Cities with a large internal water area and both river banks developed (Samara) are marked by more intense development of riverine areas than cities with a small internal water area and development on both river banks (Ulyanovsk, Budapest). A smaller internal water area with both riverbanks developed is incorporated into the city's planning structure, providing its continuity through such connecting elements as bridges and embankments. Furthermore, two-sided multifaceted development on both sides of the river facilitates the development of the environment.

Similarly, cities with a large external water area and development on only one river bank (Tolyatti, Ruse) are marked by greater development of riverine areas, in contrast to one-sided cities with a small internal water area (Volgograd, Saratov). In this respect, a large external water area in case of one-sided development creates a planning limitation of one of the directions for urban development. In the conditions of urbanization, a large external water area also results in a high saturation of the coastal zone with various objects. In this case, urban development is unilateral, directed towards the water area, with increasingly high-rise buildings deeper into the city.

The combination of a large internal and external water area (Belgrade) results in the most complex planning solution. The structure of development within the large water area is limited to one-sided development with the number of stories in buildings increasing closer to the city, and the inner smaller water area is included in the city's planning framework, being open and interconnected in the same direction.

In this study, we also analyzed several European cities based on the established criteria, including Cologne, Düsseldorf, Hamburg, Liverpool, Manchester, Rotterdam, Copenhagen, Lyon, and Zürich (Table 2, Fig. 3)

Table 5. Criteria analysis of the interaction of urban space with water area.

City	Criteria						
	Interaction with the water space	Cultural connections	Revitalization	Interaction of the public and the private	Integration into the urbanized environment	Interconnection of spaces	Functional saturation
Cologne	4	5	5	4	3	3	5
Düsseldorf	3	5	5	5	3	5	5
Hamburg	4	4	5	5	4	4	5
Liverpool	2	1	3	2	1	2	4
Manchester	5	2	3	3	2	3	3
Rotterdam	3	4	4	4	5	5	5
Copenhagen	5	5	3	1	2	3	3
Lyon	5	5	4	2	5	5	5
Zürich	5	5	5	3	5	5	4

Note: compiled by the authors.

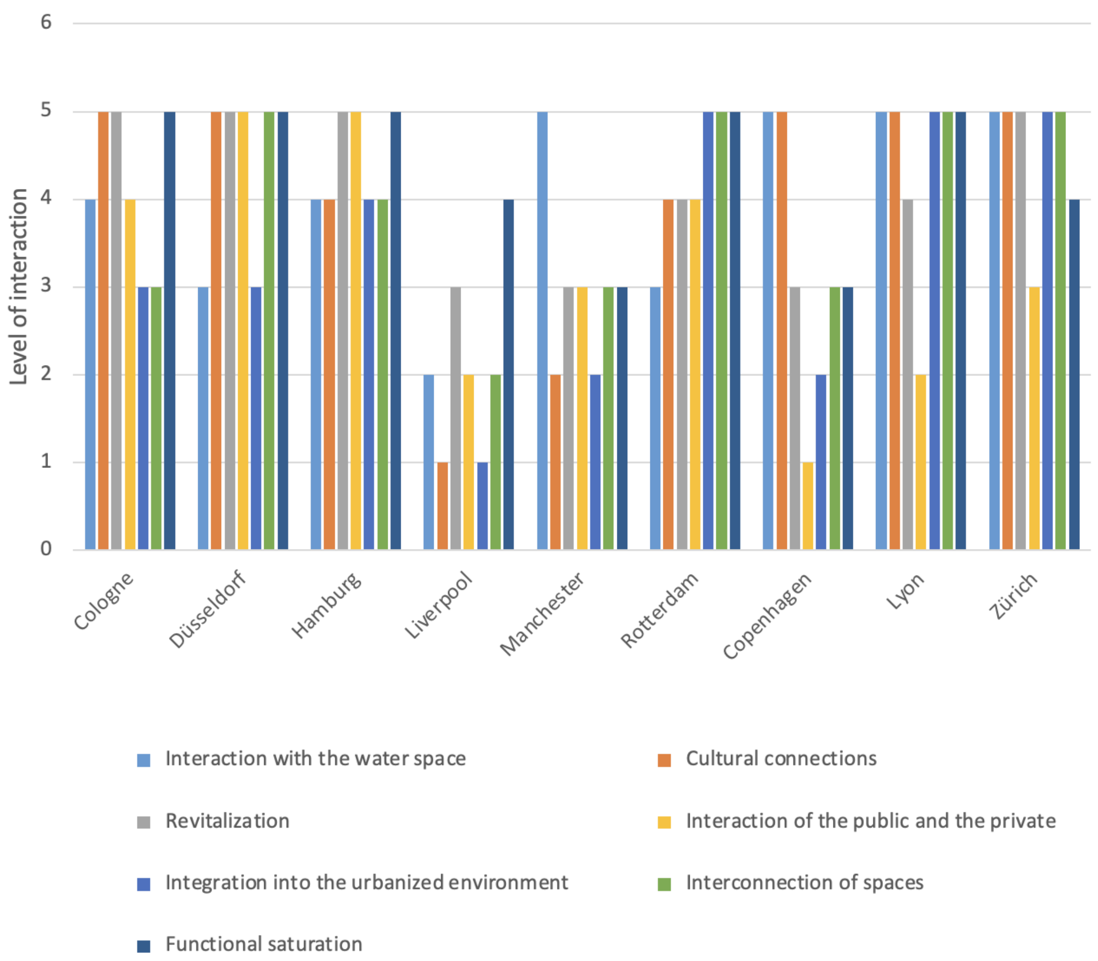

Fig. 3. Criteria analysis of the interaction of urban space with water area.

The development of the examined cities is marked by the following trends:

- creation of a system of recreational zones along the shoreline;
- creation of a network of city parks with different themes;
- incorporation of a spatial carcass into the structure;
- creation of public recreation centers, leisure complexes, and parking ensembles at the intersection of the urban and natural frames;
- rehabilitation and improvement of industrial areas;
- relocation of industrial plants situated among residential buildings to industrial areas;
- optimization of traffic and rational positioning of storage and maintenance facilities;
- development and organization of water protection zones and coastal protection strips.

For instance, after the reconstruction of the Rhine river shoreline (Cologne), the compositional role of the Cologne Cathedral in urban development as a critical part of the multifunctional core of the city center changed. Arterial roads separating blocks from the river shore were put into a tunnel and new expressway roads bypassing the city were built. Recreational pedestrian areas were organized on the first level. The underground space was also used to further saturate the heart of the city with new functional elements.

The Elbe river basin near Hamburg performs an important function as an international inland port. Maintenance is carried out periodically to mitigate pollution and ensure the health of the river ecosystem despite heavy commercial use. Public space spans about 28 hectares and extends over 10 km along the coastline. Each project meets sustainability standards, including new infrastructure, rehabilitation, and improvement of industrial areas.

The original goal of the Copenhagen City Planning Plan was to create recreational areas and build an efficient transportation network. For many years, regeneration projects along the water area have been focusing on improving the quality of the harbor water. The goal was to channel the flow of street life into the harbor and turn the old sea promenade into a place the public would gravitate to, which was ultimately achieved by architectural planning methods.

The Grand Lyon Master Plan strategy implemented in the city of Lyon focuses on making riverbanks and entrances more attractive and taking industrial plants located in residential areas to industrial areas. Renovation of the Rhone Promenade, a densely built-up area of the city center, is aimed at creating recreational spaces and building a connection between the city and the river.

The GrunStadtZurich project (Zürich) aimed at improving the way of life in Zürich by concentrating recreational spaces along the embankment of the Limmat river and identified five types of open spaces – parks, lakes and their proximity, riverside areas, forests, and individual areas.

In terms of typology, riverine areas in the considered cities have deep, linear, and local node spaces within them (Table 6).

Table 6. Typology of spatial organization of riverine territories.

No.	Type of spatial organization	Form of spatial organization	Spacial organization function	City
1	deep space	square	historical: mass actions, celebrations, theatrical events, trade; modern: interchanges, parking lots	Zürich
2	extended linear space	embankment	historical: walking areas, alleys, recreation places, beach, cafe, water station; modern: motorways, irregular car parks, separation from the river	Cologne, Hamburg, Lyon
3	local node space	park, public garden	historical: open green recreation area, theme parks; modern: reduction of free space in favor of development, a space without functions	Rotterdam, Copenhagen

Note: compiled by the authors.

The study provides substantiation for the classification of riverine territories in the city structure, identifies architectural and planning components of riverine territories, and shows the influence of the hydrographic network model on urban development. The world experience of the interaction of urban space and river water area was analyzed and a classification of riverine territories was conducted based on the type of planning structure and the configuration of the water area. A comparative analysis of riverine cities was conducted, showing them to be attractive for the development of many functions, particularly residential, public, and industrial. The compositional and planning features of riverine cities were established.

Overall, drawing on international experience, we can highlight three directions in the formation and organization of the architectural planning components of riverine areas: urbanistic, landscaping, and integrated.

The urbanistic direction creates an artificial environment and a rhythmic architectural and spatial composition. Embankments created by this principle are geometric in structure. Natural components are incorporated into their structure but serve only as a part of the architectural appearance. Staying concise, they act as accents, create rhythm, and bring in a landscape component. The projects include residential buildings, commercial premises, and parks. The suburbs are integrated into the urban environment and the new embankments expand the space, comprehensively creating a sense of community and spatial integrity. Examples of the urban direction in the formation and organization of architectural and planning components of riverine areas include:

- The coastal zone of Los Angeles. The master plan envisions several programs for the revitalization of the river: monitoring the water level in the river, cleaning the bed, improving the quality of water, and developing public spaces along the river, such as parks, biking trails, and beaches;
- Baltimore. Renovation of the city's embankment began in the 1960s and consists of hundreds of projects and developments, as well as already implemented projects;
- The Riverwalk coastal zone in Chicago. The embankment spanning 24 km is renovated, coupled with the organization of various types of spaces and multistep leisure;
- Embankments of Hafencity, Hamburg. The project consists in the reconstruction of the port area, 10 km of the promenade.

The primary goal of the landscaping direction is to reproduce or preserve the existing natural environment and create conditions close to natural. A distinguishing characteristic of this direction is that nature in it can be both natural and artificial, with maximum approximation to natural forms, which become part of the landscape, harmoniously complementing its architectural elements. The landscape direction in the formation and organization of the architectural planning components of riverine areas is showcased by:

- Reconstruction of the Thames Basin, London, in the framework of the Barking Riverside program, which was adopted to create a diverse environment under fairly tough urban planning conditions. As a result of the program, almost half of the territory remains free of development, replaced by public spaces and environmental zones reserved for the conservation of local flora and fauna;
- Reconstruction of the Loire coastline in Nantes, which follows the principles of ecological stabilization of landscapes and maximization of natural context, allowing to create a coastline that exists as a self-regulating ecosystem with preserved vegetation.

The integrated direction (integration of the urbanistic and landscaping directions) provides the most flexible and promising approach to the renovation and development of riverine territories as part of big urban planning projects and to the combination of natural features and components with architectural methods. Renovation in this framework relies on a comprehensive analysis of the territory. If the industry is taken outside these territories, the old building is dismantled, the ecological condition of the territory is assessed, and then the stages of its renovation and restoration measures are developed. The reconstruction of buildings also includes certain stages of rehabilitation, as a new function may arise depending on the strategy of urban development. The integrated direction in the formation and organization of the architectural and planning components of riverine areas is represented by:

- the Pompidou riverine zone, Paris. The project concept provided the creation of a new public space with floating botanical gardens, cafes, sports grounds, play areas for children, and recreation areas;
- the MadridRio riverine territory, Madrid. Reconstruction of the coastal zone with expressways built along it and the highway hidden in a tunnel. The project covering about 700 hectares succeeded in improving the ecological situation in the city, restoring its integrity, and raising its attractiveness.

Our analysis of global experience dealing with post-industrial riverine territories concludes that the renewal of city embankments can be seen as a principle of the predominant economic development [46] of post-industrial cities across the world [47].

Overall, urbanistic design is predominant in coastal areas [33]. This is explained both by the loss of the natural features of the landscape in the process of urban planning development and by the need to account for an entire range of factors relating to the architectural environment, current requirements for stabilizing shores, water protection, and navigation. These conditions impose strict functional, engineering, and technological limitations [48]. However, the principles of environmental balance [49] necessitate the development of landscaping with a focus on maximizing the preservation of natural landscapes, compensating for the loss by the methods of modern landscape architecture [50], and creating unique architectural landscape objects that contribute to the preservation and development of originality of the cityscape.

4. CONCLUSIONS

Our findings give reason to conclude that the interaction of various directions and renovation of riverine territories should be used as a tool to harmoniously incorporate riverine areas into the contemporary structure of the city in the context of sustainable development of the urban environment. Furthermore, these measures offer the following opportunities:

- the high visibility of transformations within riverine areas, which are the face of the city, allows renewing the city's image and raise its attractiveness as a tourist center;
- strategic planning of the city's green networks with the inclusion of pedestrian and cycling directions in the structure supports the creation of a comfortable urban environment and allows the population to regain the missed opportunity to connect with the water area;
- expansion of the city through the rehabilitation of riverine territories provides for the creation of a comfortable environment.

The limitations of our research include the availability of materials for analysis.

A prospect for further research is the analysis of priority and perspective directions for the rehabilitation of rivers and riverine territories.

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