



TOWARDS A NEW TYPOLOGY FOR CLASSIFYING URBAN RIVERFRONT CHARACTER SECTIONS: INSIGHTS FROM EUROPEAN CITIES

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Abstract. Riverfronts in cities usually form different sections, expressing the city changing tonality or diversity of functions alongside the water edge. The diverse surrounding of rivers in urban areas requires a specific management approach, reflecting the needs of the individual riverfront sections. However, the management of urban riverfronts currently lacks a typology that would form the basis for this approach. This paper aims to contribute to the creation of a new typology of urban riverfronts, which can assist in sustainable development of river spaces while maintaining the riverfront's diversity. The research included four stages, namely identifying existing riverfront typologies; exploring them in the environment of four European riverfronts – Hamburg, Bremen, Bratislava and Vienna; identifying gaps in selected typologies; and formulating recommendations for development of a new urban riverfronts typology. The gaps in current typologies were concerned mainly with lack of specificity, lack of consideration for variations and qualitative parameters. The new typology of riverfront character sections can enable using tailored solutions and preserve the values related to a given place. It is an invaluable tool for precision of spatial management of riverfronts and planning in general.

Keywords: riverfronts, rivers, character, typology.

Introduction

Riverfront diversity

Urban riverfronts have gone through a gradual process of development, resulting in the creation of unique areas alongside the water edge (Petrtýlová & Jaško, 2022). Different types of riverfront sections are present in the urban as well as natural areas of river surroundings, varying in functions, design, identity as well as in their primary use. While one section of the riverfront might have been developing as a relaxed, recreational space, some others might have had a more active or formal character. Other sections might have gone through the transition from a highly industrial and inaccessible space into a residential or community area. All of these can be described as *waterfront character areas* (Petrtýlová & Jaško, 2022) or *riverfront character sections* – term better expressing the linear character of riverfronts. They are particular sequences in the complex en-

counter between the city and the river, delivering both functional and historical continuity as well as uniqueness to a given place.

The diversity of riverfront character sections varies across different cities, with each city exhibiting one or more of these segments. Each of the character sections of urban riverfronts has its own characteristic elements. These are natural or man-made features as well as physical or abstract aspects of the environment that contribute to each section's distinctive identity. Each riverfront character section might carry different meanings, symbolics and semiotics related not only to spatial/urban morphology but also to different social practices realised there. They might form an underlying pattern for specific place attachment and carry the city image in its highly imaginative way. Riverfront character sections play a significant role in the relationship between the city and the respective river and add substantial elements to the identity of the city. Typically, a greater number of character sections on the riverfront indicates a higher potential for diversity and vibrancy of the respective riverfront space.



Figure 1. Examples of European riverfronts: top left – Paris (Seine River promenade), top right – Gävle (Stadsträdgården Park at the Gavleån River), bottom left – Basel (old harbour crane pub at the Rhine River), bottom right – Prague (old ice vaults as café at Vltava riverfront)
Source: authors.

Additionally, for the purpose of this paper, it is important to acknowledge the broader context of European riverfronts. European cities have a rich history of development along rivers, with many urban centres tracing their origins to waterways. Rivers in Europe are often viewed as valuable assets that contribute to the cultural and economic vitality of cities and are cornerstones of identities and images of respective cities. Their riverfronts within urbanised areas are often characterized by diverse landscapes, abundant cultural heritage, and manifold urban development

patterns, reflecting the unique identities of each city (Fig. 1). From bustling waterfront promenades and tranquil riverside parks to revitalised port sites, these areas offer a specific urbanity with a wide range of recreational, cultural, and commercial opportunities. The architectural heritage along European riverfronts is often characterized by a mix of historic landmarks, industrial remnants, and modern developments, creating a rich tapestry of urban forms and functions. Additionally, European cities have implemented various strategies to enhance the sustainability and resilience of their riverfronts, including green infrastructure initiatives, flood mitigation measures, or adaptive reuse projects. Understanding the complexities of European riverfronts is crucial for sustainable urban planning and development on a local, metropolitan, regional and European scale.

River and urban semiotics

The semiotic essence of the river has been gradually shifting from the mere transport corridor and link with other cities through the major danger of floods to a polyvocal presence emphasising existential values and uniqueness. The modernist duel between man and nature has been significantly modified to partnership, moderated, and facilitated by various actors and stakeholders, including the public. 'Rivers are far more than moving water – this would be an inadmissible simplification. They are the inimitable interplay of a body of flowing water with its bed – the shaping of its banks and its surroundings. These features make each river a unique personality with its own character, recounted in legends, songs, and stories since time immemorial and still familiar to us today' (Prominski et al., 2017, p. 4). Encounter of the city and the river is one of the most existential interplays in the morphological, social, topological sense of the word and is always unique. Moreover, rivers are ecosystems that link cities and regions to their entire catchment areas (Prominski et al., 2017) – common values of responsibility, sensitivity and high ethical standards are preconditions for building a common regional identity, interlinking people living in the upper river with people living in the lower river or people living in riverside area with people living in regional backspace far away from the stream.

River plays a distinctive role in different concepts of urban semiotics. Urban semiotics considers a city as a text/metatext based on the grammar of spatial structures generating social meaning (see Jachna, 2004 or Jaššo & Kubo, 2015). City, as a human-made construct, has eliminated or at least redefined most of the natural elements, but rivers are still significant parts of the spatial semiotics of any given city. Various significations are related to river – it might be a natural border, the edge of a city district, traffic route and it might deliver feelings of harmony, relaxation, and community into the city urban environment. The role of river in the facilitation of social processes within the city community is versatile and manifold:

- River fosters and strengthens feelings of place attachment – psychological mechanism saturating the need for belonging and need for togetherness. River offers unique spatial quality and cannot be artificially made, emanated, or simulated. It significantly shapes the mental maps of inhabitants, in many cases being the dominant element defining their 'home' or 'living place', connecting the generations, healing the wounds (warfare, violent events) and providing an existential dimension to individual lives. River often represents unique emotional ties between the past and the presence – usually the urban environment including the waterfronts is constantly changing but the shape of river is due to its fluid character rather constant.
- River promotes building the social community and social cohesion – the specific and distinctive environment of river creates a social theatre where symbolic social roles might be externalised and lived (visitor, sailor, water sports insider, ...) and promotes repeating of rituals and regular behavioural patterns.

- River fosters the creation of a sustainable and resilient social milieu – a collective experience of mutual help during e.g., floods strengthens the cohesion and mutual solidarity of any given community. River is common horizon for individual life paths and careers. Memories related to rivers are often convergent among many social groups, making a river stabilising factor in mental landscape.
- River creates important imagery related to urban semiotics and aesthetics – a high degree of symbolism arising on the place where the natural environment (river) and man-made structures (architecture) are merging together are unique in their aesthetic and semantic synthesis. In many cases, the character of the waterfront or the architecture of riverside is defining element of a given city. Similar roles are played e.g. by bridges. They are often the borders of different semiospheres (see e.g., Kapusta, 2019).
- River delimits particular character areas / character sections (Petrtýlová & Jaško, 2022) which are fundamental elements of cognitive maps of the city – river always enables better orientation in space, secures the feeling of visual control of the space and makes movement across the city meaningful.
- River is the focus and one of the main topics in the discourse on ecological and environmental sustainability – river works as a multiplier of both negative and positive effects in terms of ecological management, ecosystem services and other environment-related managerial activities.

Effective riverfront management

Effective management is a process which uses human, material, or financial resources efficiently, to achieve the set goal (Ullah & Khanam, 2008). In the context of urban riverfronts, management is the process of preservation, renewal and development of the riverfront resources in the administrative borders of a city. The components of riverfront management are PEOPLE – riverfront stakeholders, communities, institutions; PROCESSES – such as planning, zoning, regulation, maintenance, development, conserving, monitoring etc.; and PLACES – such as the river, riverfront, surrounding landscape and the urban fabric. The system of riverfront management integrates all three components.

Aesthetic and recreational opportunities, increased land values and economic development in river corridors can be achieved by effective riverfront management (Lerner & Holt, 2012). The goal of riverfront management is to achieve a balance between ecological, economic and social aspects of the water element within the city. In addition, effective riverfront management is strongly linked with the diversity of the riverfront. Urban riverfronts are too diverse to be managed as a single entity. Each type of riverfront character section requires a different set of management approaches, whether it is a natural riverfront area, a residential riverfront zone or an industrial port site. The unique character can be preserved while enhancing the riverfront's diversity and supporting the sustainability of the riverfront areas in cities. A system of effective riverfront management is important in the field of spatial planning, especially with regard to the following factors (see more in Petrtýlová & Jaško, 2022):

- Riverfronts frequently encounter the gradual diminishing of their natural and cultural heritage as a result of the destruction, redevelopment, and construction of new buildings, which do not retain the original character of the area. Riverfront structures often include remnants from the past industrial age which are considered obsolete, problematic or outdated when confronted with the current, highly volatile and fluid society.
- Interventions in riverfront areas are frequently externalised without a balanced perception of the riverfront as a whole; isolated, short-sighted and abrupt changes in riverfront structures do

not influence only the place of direct intervention but might compromise the relation between a city and a river, e.g., visually polluting adjacent areas, transfer and dispersion of negative impacts, inflicting spatial conflicts, etc.

- Unbalanced growth of riverfront sites in ownership of private sector with the unilateral preference of profit over quality of design deteriorates the quality of the riverfront. The conflict between the public and the private is sometimes escalating in riverside places due to the high visibility and prominence of riverfronts in the mental maps of citizens.
- The need for the preservation of functional variety alongside the river requires a passportization of urban landscape diversity – different types of riverfront character sections serve city organisms, compensating the lack of one trait by providing another. Cities with distinctive quality of relation towards rivers usually offer a smooth and balanced interface between and among various types of riverfronts.
- Riverfronts are too diverse to be managed as a single entity. General principles of riverfront management (e.g., PPS, 2009; Giovinazzi & Moretti, 2010; Riverlife, 2024) usually represent an approach too broad when taking into consideration the specific character and needs of individual riverfront sections. A tailored riverfront management system, reflecting the diversity of riverfront sections is therefore highly necessary.

Managing riverfronts, considering diversity

Riverfront management, apart from dealing with the management issues such as floods, excess runoffs, urban diffuse pollution, urban economy, brownfield redevelopment, land use and value or aquatic and terrestrial ecology (Lerner & Holt, 2012) should be also concerned with soft factors, e.g. local identity, place attachment diversity or character of the place. Even though the tools to measure these qualities are limited, they equally contribute to the balanced riverfront ecosystem. One of the tools that might contribute to more precise and sustainable riverfront management while addressing the soft factors is a riverfront typology.

However, to our knowledge, a uniform framework determining the typical riverfront character sections has not yet been established. Cities approach the differentiation between distinct parts of their riverfronts context-specific. While some cities simply distinguish between natural and urbanised sections of the riverfront in their strategic documents, others work with context-specific types of local riverfronts, and some might consider their riverfronts another part of the urban fabric, not distinguishing between the riverfront's specific character or even different riverfront sections. The concept of riverfront character sections represents an abstract framework while the characteristic elements of riverfront sections, on the other hand, represent more specific aspects of the space, to which a management system can be applied. A common framework can help uncover unique features and similarities across various urban-river interfaces. It can assist municipalities with tailoring the most effective management approach for specific types of riverfronts and help deliver them specific data or benchmark examples.

Riverfront typologies represent categorizations of different types of riverfront sections based on different types of characteristics (e.g., physical, functional, cultural...). They are mostly used in disciplines like spatial, landscape or urban planning, architecture, or waterfront management to help understand the specifics of different types of riverfronts or riverfront sections. Riverfront typologies are important for recognizing and managing the diversity of riverfronts and riverfront sections effectively. They contribute to sustainable and balanced spatial planning by informing tailored strategies, promoting conservation, enhancing resilience, engaging communities, and facilitating sustainable development. They can serve as guidelines for riverfront stakeholders

in framing the requirements for the location's development (e.g., *Riverlife*, 2024). Ultimately, they help to ensure that riverfronts are valuable, vibrant, and resilient assets for cities and regions.

The objective of this paper is to contribute to the development of a new typology for urban riverfronts, addressing a gap in the existing research. Currently, there is a lack of standardized typologies for managing urban riverfront sections, impeding effective planning and decision-making in riverfront development. Our research aims to fill this gap by formulating recommendations for a new riverfront section typology, which can guide sustainable development practices while preserving the diversity of river spaces. By providing recommendations, this paper addresses urban planners, policymakers, and stakeholders involved in the management and development of riverfront areas.

Methodology

The research consisted of four stages, namely identifying current riverfront typologies; exploring them in the environment of four European riverfronts; identifying gaps in the selected existing typologies; and formulating recommendations for the development of new urban riverfront section typology. The four stages are described in the following paragraphs.

To formulate recommendations for the creation of a new typology, existing typologies were explored. Analysis of multiple online sources was used including strategic documents of riverfront cities, online materials of organisations focused on riverfront development and research papers dealing with the topic of waterfronts or riverfronts. It was differentiated between two levels of riverfront typologies. The first level categorises riverfronts as a whole and the second one differentiates between riverfronts' individual sections.

After identifying existing typologies of urban riverfronts, the results were applied to four European riverfronts: Hamburg (Elbe River), Bremen (Weser River), Bratislava (Danube River) and Vienna (Danube River) (see Fig. 2). The selected cities and their riverfronts were chosen mainly based on their city-river relationship, distinctive character, and relatively varied spectrum of waterfront character sections. Additionally, the selected cities are located in different geographical regions, each with its unique environmental and cultural context. This diversity enabled more comprehensive understanding of how riverfronts may vary across regions, while the similar geographical context for Bremen and Hamburg enabled the exploration of possible similarities. Moreover, Hamburg, Bremen, Bratislava, and Vienna are situated along significant rivers (Elbe, Weser, and Danube), each with its own characteristics and importance. Studying riverfronts along these major water bodies provided insights into how the size and importance of rivers influence urban development. Again, the similarities between Vienna and Bratislava (the Danube River flowing through both cities) enable exploring similar factors presumably influencing different aspects of the riverfront development. Additionally, exploring riverfronts in cities with strong cultural and historical significance enabled an examination of how these elements contribute to the overall character of the riverfront. Altogether, the comparative analysis of the selected riverfronts allowed us to evaluate the applicability and effectiveness of the existing typologies across different urban and river contexts.

Table 1. Basic information about the selected cities

City	Hamburg	Bremen	Vienna	Bratislava
Country	Germany	Germany	Austria	Slovakia
Region	Western Europe	Western Europe	Central Europe	Central/Eastern Europe
Status	Federal state capital (State of Hamburg)	Federal state capital (State of Bremen)	Capital city	Capital city
Size (OpenStreetMap, 2024)	755 km ²	327 km ²	415 km ²	368 km ²
Approx. population (WPR, 2024)	1.7 million	0.5 million	1.7 million	0.4 million
River	Elbe	Weser	Danube	Danube



Figure 2. Location of the studied European cities
Source: authors.

The riverfronts were visited in person during the year 2022 and additionally explored through the online tool Google Maps, especially to deepen understanding of the spatial context of the riverfront in relation to the surrounding urban environment. In Hamburg, the visited locations included several areas on the river Elbe, various places in the Hafencity district and the Alster lakes. In Bremen, the research focused on places along the Weser River and Stadtgraben River within the Wallanlagen Park. In Vienna, the study covered most parts of the Alte Donau, Neue Donau, Donau, Donaukanal, and Wienfluss and in Bratislava, the research focused on the Danube River waterfront. After the site visits, the existing riverfront typologies identified in stage 1 were applied to the four riverfronts. The collected data were analysed to identify commonalities, differences, and trends among the waterfronts visited.

After applying the existing typologies on the four selected riverfronts, gaps in selected existing typologies were identified by gap analysis. Based on the gaps in existing typologies as well as on general findings throughout the process, recommendations were formulated in order to contribute to the creation of a new riverfront typology.

Results and discussion

Existing waterfront typologies

Two levels of riverfront typologies are recognised in this paper. The first level (A) categorises riverfronts as a whole and the second one (B) differentiates between their individual sections. Both levels, including examples of current typologies with specific categories, are described in the following paragraphs.

A) General riverfront typologies: There are no two identical riverfronts. They differ in countless features, whether it is the geographical context, relation of the riverfront to the urbanised area, size of the river, the ecological significance of the river, etc. When approaching the management of individual riverfronts, it is necessary to take these characteristics into account and treat riverfronts individually. The list of identified general riverfront typologies is outlined in Table 2.

B) Riverfront sections typologies: Riverfront sections of different types are present at most riverfronts. They differ in numerous features such as their primary function or use, the character of their edge, the location of the riverfront in relation to the urbanised area etc. The list of examples of riverfront section typologies is outlined in Table 3.

Table 2. Examples of existing general riverfront typologies

Size of the river (Gažová, 2017)	The size of the river exceeds the size of the settlement in terms of its parameters The size of the river and the settlement are in balance with each other	The size of the river is insignificant compared to the size of the settlement
City-river layout (Hamidah et al., 2016)	City divided by a river City on the edge of the river City divided by several rivers and tributaries Swamp city	Coastal city divided by a river Coastal city adjacent to a river Mountain town divided by a river City on a lake divided by a river
Significance of the river (Act SR, 2004)	Hydrologically significant watercourses	Small watercourses
Use of the river (Act SR, 2004)	Supply water courses	Other water courses

Table 3. Examples of existing riverfront sections typologies

Blue space edges (Breš & Krošnicka, 2021)	Single edge Double edge	Multiple edge Complex edge
Location of the riverfront in relation to the urbanised area	Riverfront outside of the urbanised area	Riverfront within the urbanised area
Character of the river space (IPR Prague, 2014)	Landscape character Urban character	Suburban (mixed) character
Urban blue space function (Breš & Krošnicka, 2021)	Natural environment Urban environment and Living	Urban environment, Industry and Infrastructure

Types of waterfront regeneration (Moretti, 2008)	New Urban Expansion Waterfronts and Great Events New Urban Waterfront Itineraries	Reuse of Port Areas Flood Defences Urban Riverfront Regeneration Urban Beaches
Waterfront use (Vallega, 1992, 2001)	Ecosystem enjoyment Fishing Tourism Recreation Entertainment Congresses	Media Transport and navigation Trade and finance Research areas Education and training Cultural heritage

City-river relationship within the case studies of four European cities

In the second phase of the research process, four European cities were visited in order to explore their relationship with not only rivers but also other water elements, as well as to explore the existing typologies in their environment. These included riverfronts of the cities of Hamburg, Bremen, Bratislava, and Vienna. In the following paragraphs, the findings from the site visits are outlined.

Hamburg is a city born on the river that has long considered the river as a substantial element of its identity. This is reflected in all of its waterfront sections. The city has successfully unified all semiotic elements of water, including rivers, canals, the sea, and lakes, into its urban and city development. In particular, HafenCity, a major developmental project of the 21st century, has integrated water elements into the city organism, further enhancing the city's character. Water plays a critical role in defining the character sections and serves as a link to their mutual interconnection, as well as a dominant trait of their urban imagery and spatial semiotics. As a result, the city's relationship with water is not only integral with its history and identity but also plays a vital role in its contemporary urban development. 'Metropolitan but also Maritime' was the unspoken headline of many urban developments in Hamburg, integrating the cosmopolitan motifs into the delicate local structures and peculiarities of this extraordinary city. River Elbe always played a pivotal role in positioning Hamburg as one of the principal actors on the international and global scene. River and water elements in general played the main role in Hamburg's story and were always the primary carrier for semiotic elements of the city.

Bremen has a close relationship with the Weser River, which runs through the heart of the city. The river has played a vital role in the city's history, serving as a transportation route for goods and people, as well as a source of economic activity through fishing and shipping. Nowadays, the city's waterfront along the Weser River is a significant focal point for social, cultural, and recreational activities. The eastern waterfront of the river Weser has the character of a 'levee', in the past used for the exchange of goods, nowadays a popular place, used by many pedestrians and cyclists. The higher level (street level) is used for activities such as Christmas markets or summer Beer Gardens. The waterfront promenade is called Schlachte and represents the former medieval port of Bremen. The Wallanlagen Park, which is located along the Stadtgraben River, also contributes to the city's relationship with the water. In recent years, the city has made efforts to enhance the connection between the river and the urban fabric by creating public spaces along the waterfront and promoting water-based activities. Overall, the relationship between the city and the river in Bremen is multifaceted and continues to evolve over time.

The city of Bratislava has several water features, with the Danube River being the dominant one, representing great potential for the city. Bratislava had for many decades neglected the relationship with the river. However, in recent years, the city has rediscovered the potential for mutual enrichment with the Danube. New initiatives resulted in the creation of versatile character sec-

tions highlighting the flexibility of the relationship between the city and the river. Currently, the interplay between both banks is starting to mature and accelerate. Bratislava's waterfront is unique in the diversity and clear division of its riverfront character sections, compared to other studied cities. The exceptional diversity of these sections has fostered the development of the city in many different directions, unlocking new opportunities for growth and renewal.

Vienna is a city that has successfully integrated its river into certain aspects of urban life, such as recreation and leisure activities. However, the city has maintained its unique identity based primarily on its main socio-spatial structures, in which the river plays only a moderately important role. The river has been somewhat sidelined due to the risk of floods and does not directly enter the historical structures of the city. Instead, small waterways like the river Wien and Donaukanal enter the historical centre directly, contributing to the overall urban morphology of Vienna. Urban metatext of Vienna is manifold and complex, leaving the river and water elements important, but not principal roles.

Gaps in current typologies

The identified typologies, divided into A) general riverfront typologies and B) riverfront sections typologies, were applied to the studied cities of Hamburg, Bremen, Bratislava and Vienna. Consequently, their gaps were identified.

A) Gaps in general riverfront typologies

Size of the river

Gažová (2017) describes differences based on the size of the river compared to the size of the settlement. Within her three categories - the size of the river exceeds the size of the settlement in terms of its parameters; the size of the river and the settlement are in balance with each other; and the size of the river is insignificant compared to the size of the settlement - the studied cities showed different results. In terms of the width of the river compared to the size of the city, the River Elbe exhibits the largest imbalance (ratio of 0.5), while the River Danube in Bratislava indicated the most balanced results (ratio of 0.8). However, when considering not only the physical parameters of the river but also the abstract significance of the river, all four selected cities fit into the category 'The size of the river and the settlement are in balance with each other'.

Table 4. Information related to the size of the rivers flowing through the selected cities.

City	Hamburg	Bremen	Vienna	Bratislava
River	Elbe	Weser	Danube	Danube
Approx. width of the river around the city centre	400 m	200 m	300 m	300 m
Size of the city	755 km ²	327 km ²	415 km ²	368 km ²
Ratio (width of river to size of city)	0.5	0.6	0.7	0.8
Classification / Size of the river category (Gažová, 2017)	The size of the river and the settlement are in balance with each other	The size of the river and the settlement are in balance with each other	The size of the river and the settlement are in balance with each other	The size of the river and the settlement are in balance with each other

Hamburg (Elbe): Even though the ratio of the approximate width of the river to the size of the city is the smallest of all four examples (0.5), the size and importance of the Elbe River are in balance with the city's parameters. Hamburg is a major port city with the Elbe River playing a significant role in maritime activities, trade, and transportation.

Bremen (Weser): Bremen's relationship with the Weser River is characterised by a balance. The river is significant for transportation and economic activities, but its size is not overwhelming in comparison to the city.

Vienna (Danube): Vienna's position along the Danube reflects a balance between the size of the river and the settlement. Even though the Danube does not run directly through Viennese main tourist attractions, it is essential for the city's identity. However, it does not overshadow the urban environment.

Bratislava (Danube): The ratio of the Danube River width in Bratislava to the size of the city is the largest out of the four examples (0.8). However, the city spreads on both banks of the river and Danube's parameters are not dominant in relation to the size of the city (Fig. 3).

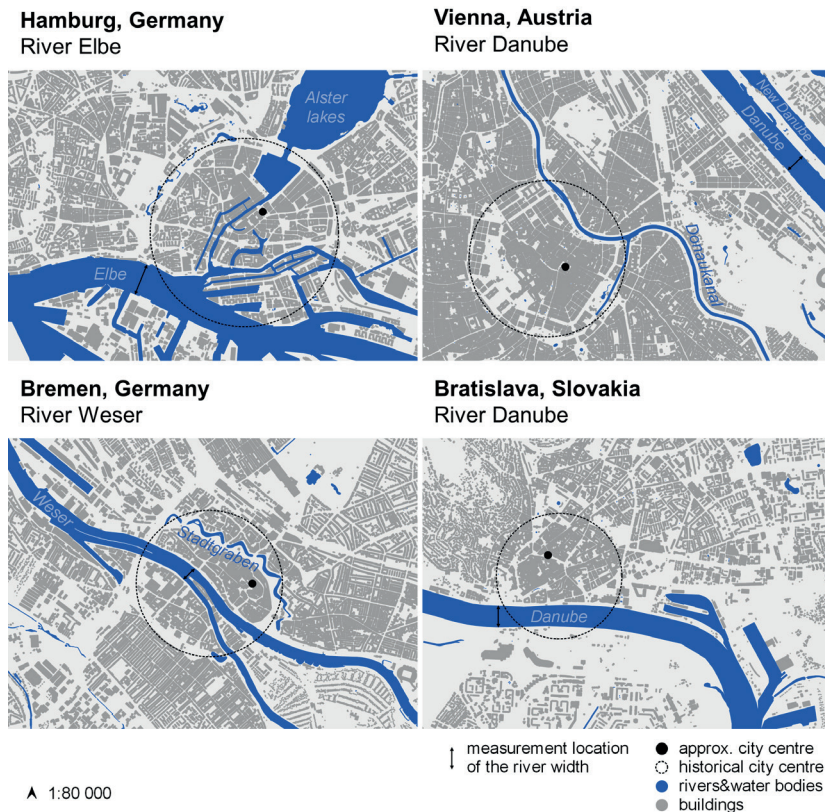


Figure 3. Selected cities and their city centres in relation to the size of their rivers
 Source: authors.

To identify gaps in the typology, several aspects were considered. The river often consists of several tributaries, arms, or various spatial variations with widths of different kinds. Therefore,

the typology may not account for cases where the size of the river varies significantly within a city territory, leading to oversimplification and potential misclassification. In addition, the typology focuses solely on quantitative parameters such as the physical size of the river and settlement, without considering qualitative aspects such as the mental significance of the river for the given city and its inhabitants or the environmental, economic, social, or cultural significance of the river.

City-river layout

Hamidah's et al. (2016) city-river layout typology includes categories of city divided by a river; city on the edge of the river; city divided by several rivers and tributaries; swamp city; coastal city divided by a river; coastal city adjacent to a river; mountain town divided by a river; and city on a lake divided by a river. Within this framework, the city-river layouts of the four European cities were examined.

In all four cases, the city centre is situated on one bank of the river. The distribution of city-districts spans both banks in all cases, contributing to a dual-bank urban fabric. Noteworthy variations emerge in the historical city centre layouts concerning the rivers (Fig. 4). According to Hamidah's et al. typology applied in this context, Hamburg's historical city centre is divided by several rivers and tributaries (mostly canals). In contrast, Bremen's historical city centre is positioned on the river's edge, a characteristic shared with Vienna and Bratislava.

Table 5. Information related to city-river layout of the selected cities.

City	Hamburg	Bremen	Vienna	Bratislava
River	Elbe	Weser	Danube	Danube
City centre position	right bank	right bank	right bank	left bank
Position of city-districts	both banks	both banks	both banks	both banks
Historical city centre↔river layout	historical city centre divided by several rivers and tributaries (canals)	historical city centre on the edge of the river	historical city centre on the edge of the river	historical city centre on the edge of the river
City↔river layout category	city divided by several rivers and tributaries	city divided by several rivers and tributaries	city divided by a river	city divided by a river
(Hamidah et al., 2016)				

The overall city-to-river layout illustrates distinctions, with some cities traversed by a network of rivers and tributaries/canals (Hamburg, Bremen) and others delineated by a single river (Vienna, Bratislava). In the case of Vienna, river elements include the River Danube, New Danube, Old Danube, Donaukanal and Wienfluss. In the case of Bratislava, the River Danube, Little Danube, and Morava are represented. Compared to the water network present in Hamburg or Bremen, however, the difference in the city-river layout was distinguished. Our exploration sheds light on the diverse urban and hydrological contexts shaping these European cities.

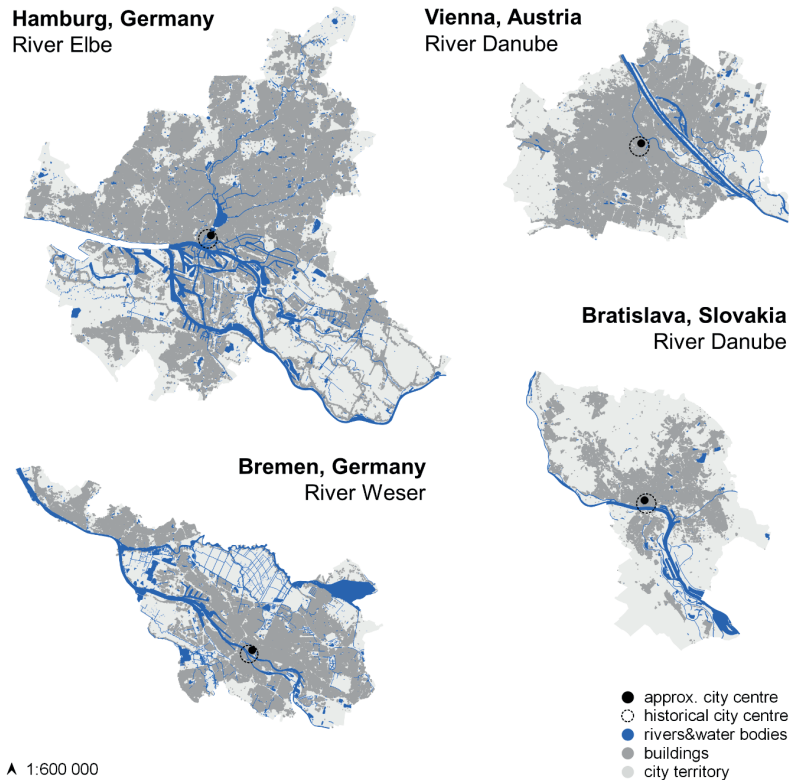


Figure 4. Selected cities and their city centres in relation to city-river layout
Source: authors.

Nevertheless, several gaps were identified in the typology. Individual categories included by typology do not cover the spectrum of spatial situations that might emerge throughout the case studies. Examined cities and rivers might exhibit specific spatial situations, requiring a combination of various categories or a completely new one (e.g. a coastal city at the edge of the river). The typology does not capture more nuanced variations or intermediate conditions that exist in existing urban environments. Furthermore, the typology primarily focuses on the physical relationship between the city and the river, but it does not account for variations in urban form, density, or development patterns.

Significance of the river & use of the river

According to the Slovak legislative Water Act of Slovak Republic no. 364/2004 (Act SR, 2004), the significance of the river can be tracked in two categories. These include hydrologically significant watercourses and small watercourses. All four examples of rivers within the examined cities are considered hydrologically significant watercourses in this context. Similarly, according to the same legislation, two categories of the use of the river can be distinguished. These include supply water courses and other water courses. All four examples of rivers within the studied cities are considered supply water courses.

Even though the typologies were created for the specific needs of the given legislation, some gaps were identified, which could further improve the studied classifications. The typology based on the significance of the river overlooks the diverse range of functions, values and benefits that rivers can bring to urban environments. The typology based on the use of the river does not capture the full range of uses and activities associated with urban rivers. It overlooks the recreational, cultural, ecological, or economic functions that rivers can serve within cities. Both typologies use broad categories that may lack specificity and nuance, potentially oversimplifying the complex relationships between cities and rivers. The typologies focus primarily on larger rivers and overlook smaller water bodies like streams, creeks, and channels, which might also play important roles in urban environments and contribute to the overall identity of a place.

B) Gaps in riverfront sections typologies

Blue space edges

Breš & Krošnicka (2021) describe urban blue space as a zone that integrates both aquatic and terrestrial elements, featuring at least one land-water edge. Urban blue spaces are typically demarcated from its surroundings by a physical boundary such as hills, buildings, walls, or forests. The authors identify several types of blue space edges:

- a single edge, where the blue space is bordered by a line of buildings, infrastructure, or greenery on one side, with an open view of the water or the opposite riverbank on the other side;
- a double edge, where the space is confined by barriers on both sides, creating a ‘waterstreet’;
- a multiple edge, where the space is enclosed by walls on several sides, forming a ‘watersquare’;
- a complex edge, which combines different edge types and forms a complex network within urban blue spaces.

The authors suggest that the amount and type of edges affect the compactness of the blue space’s interior and its landscape porosity.

Table 6. Information related to blue space edges of the selected cities

City	Hamburg	Bremen	Vienna	Bratislava
River	Elbe	Weser	Danube	Danube
Most present types of blue space edges (Breš & Krošnicka, 2021)	Single edge Double edge Multiple edge Complex edge	Single edge Double edge Complex edge	Single edge Double edge Complex edge	Single edge Complex edge

According to the typology, the riverfront of the Danube River may exhibit various types of blue space edges. In larger cities like Vienna, the riverfront has a combination of single edges (open views from one side) and double edges (buildings or structures on both sides). In the case of the city of Bratislava, the riverfront of the Danube exhibits mostly single edges, involving a riverfront area bordered by buildings, infrastructure, or greenery on one side, while the other side offers an open view of the river. However, complex edges can be found within the port areas of both cities.

Bremen’s riverfront along the Weser exhibits mainly features of single or double edges, depending on the urban layout. The linear character of the Weser River as well as the presence of buildings, infrastructure, or greenery on one or both sides of the river influences the spatial configuration. Similarly to Bratislava and Vienna, complex edges can be found within the port areas of the Bremen riverfront.

The riverfront of the Elbe River in Hamburg features diverse urban blue space edges. The riverfront exhibits single edges with open views, double edges with structures on both sides, multiple edges in some cases (a more enclosed space, surrounded by walls from many sides, forming a 'water square') and complex edges due to the network of various spatial configurations. Hamburg's extensive port areas also contribute to the complexity of the urban blue space and its edges.

The typology provides clear and distinct categories for classifying different types of blue space edges based on their physical characteristics. However, the typology may oversimplify the diverse range of edge conditions found in urban environments. This could limit the applicability of the typology to capture the complexity of urban blue spaces.

Location of the riverfront in relation to the urbanised area

Rivers, as natural, meandering pathways, flow through the landscape, traversing through multiple cities. Cities along a river can be viewed as connected beads on a string, forming a continuous set of urbanised islands. Rivers therefore form both natural and urbanised riverfronts. Administrative areas of most of the European cities include both types. The main differences among them lie mainly in their environmental value, function, or interactions with their surrounding environment.

As for the selected cities, administrative areas of the cities of Bratislava, Vienna, Bremen and Hamburg include riverfronts outside of the urbanised area and the riverfront within the urbanised area. However, it's important to note that the distinction between riverfronts outside and within urbanised areas can vary in each city or depending on a specific locality. Additionally, some areas may exhibit a blend of both natural and urban features along the riverfront. These can be considered gaps in the respective typology. These factors would need to be further examined and described in order to make a clear assessment of the respective areas' presence throughout the studied cities.

Nevertheless, to compare the ratio between riverfronts outside and within the urbanised areas in the selected cities, publicly accessible data from Openstreet map contributors (2023) were used. Selection of land use types of forest, nature reserve, meadow, and scrub, as the categories closest to the natural character out of the available categories, were shown in the context of the studied cities (Fig. 5). Human-altered land use categories were not shown in the map. These include categories such as allotments, cemetery, commercial, farmland, farmyards, grass, health, industrial, military, orchard, park, quarry, recreation ground, residential, retail and vineyard.

In the context of water elements in the administrative borders of the studied cities as well as the layer of buildings representing the urbanised areas, it is possible to determine the types of riverfront according to the discussed typology: riverfront outside of the urbanised area and riverfront within the urbanised area. Even though all four cities include both discussed types of riverfronts, there are some visible differences in the layout of the natural areas in relation to the riverfront.

From the perspective of the natural and human-altered areas' presence alongside the riverfront, the city of Bratislava features a balanced ratio with a relatively large presence of forest land use in the vicinity of the river around the city centre. On the other hand, the city of Vienna exhibits natural areas near the riverfront including forests and natural reserves mainly at the edge of the city. The river Danube in the central part of the city is surrounded mainly by human-altered land use such as parks, grass, recreational grounds or allotments, a large part of which includes the Donauinsel area. The city of Bremen shows a similar layout, however altering the land use of forest near or at riverfronts with meadows and nature reserves. In the context of the dense

water network within the city of Hamburg, natural land use areas are present only on small parts of the riverfront, almost exclusively in the peripheral parts of the city.

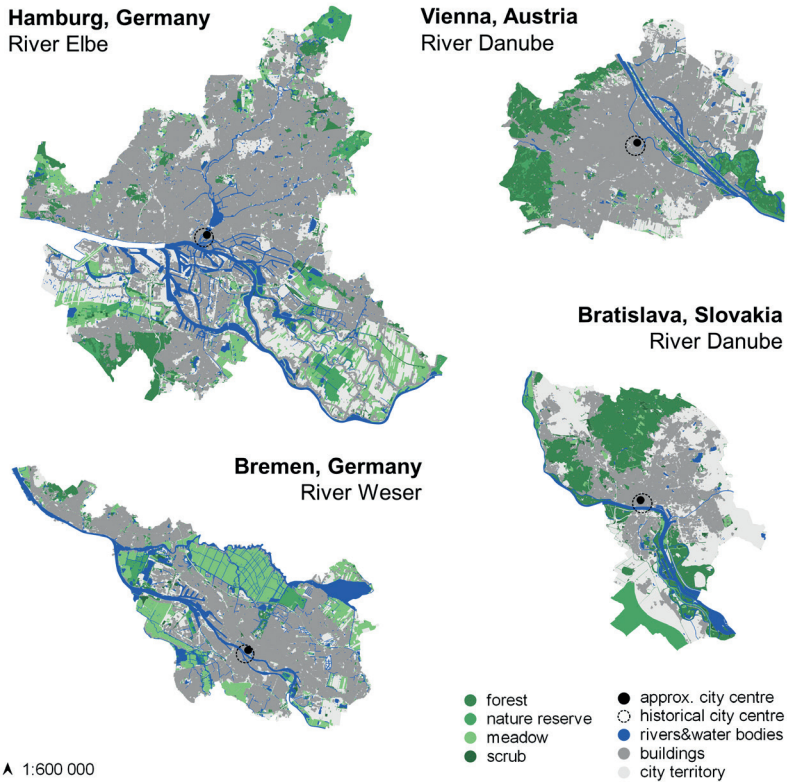


Figure 5. Selected cities and their natural areas in relation to their riverfronts

(Note: Human-altered land use categories are not shown in the map. These include allotments, cemetery, commercial, farmland, farmyards, grass, health, industrial, military, orchard, park, quarry, recreation ground, residential, retail and vineyard.)

Source: authors.

Character of the river space

Similarly to the location of the riverfront in relation to the urbanised area as discussed in previous paragraphs, the Department of the public space, IPR Prague (IPR Prague, 2014) in its river strategy *Concept of Prague's banks (Koncepte pražských břehů)* distinguishes between river space of landscape character, urban character and suburban (mixed) character. Landscape character is defined as free and undeveloped land, which can have different intensities of use, from wilderness in the form of wetlands and floodplain forests to well-maintained city parks in the central area. The urban character is mainly defined by the continuously built-up area. In places where the development directly touches the actual flow of the river, there is usually a riverfront, or a 'levee system' typical for Prague's riverfront. The suburban (mixed) character is an environment that has urban, natural or landscape attributes. Specific zones with sports clubs and shipyards or gardening

settlements along the water course are typical. In some cases, it may be a mixture of single-family homes and small-scale agricultural production.

The typology of the river space character offers a straightforward, comprehensible description of the three types of river space, all of which were identified in all four studied cities - Bratislava, Vienna, Hamburg, and Bremen. However, some weaknesses were identified. As stated in the *Concept of Prague's Banks* document, this typology excludes areas in the vicinity of important transport structures with no other use. Furthermore, this typology is concerned with the wider river space e.g., not only the riverfront itself, but also areas whose character is directly influenced by the connection to the river, or which itself influences the river in some way. Additionally, the typology may not adequately capture the diversity of riverfront environments, particularly in areas where the boundaries between landscape, urban, and suburban character are blurred or overlapping. Nevertheless, this typology offers a useful base on which the new riverfront sections typology can build.

Urban blue space function

Breš & Krošnicka (2021) recognize three main blue space functions. Their typology consists of the following types: Natural environment; Urban environment & Living and; Urban environment & Industry & Infrastructure and explains what kind of activities or uses are present within the individual functions (p. 94):

The environment-oriented category includes activities such as scientific research on coastal habitats, protection of the cultural and natural environment and pollution prevention, agriculture and mariculture, and exploitation of natural resources such as fauna, flora, and the water itself. Urban living space refers to an inhabited urban environment characterised with more intensive spatial development such as communication space dedicated for individual or public transport, various services including commercial use of space, cultural and educational functions, recreation, greenery, and residential function. The third includes industrial use providing such functions as industry and port activity, technical and hydrotechnical infrastructure, energy production and mining, waste disposal as well as post-industrial brown or grey fields.

While the typology clearly defines the three functions of the blue spaces and includes a wide spectrum of typical activities and uses, after applying the typology to the studied cities and their riverfronts, we identified some gaps. The typology's broad categories do not adequately capture the diverse and nuanced characteristics of the riverfronts in each city, e.g. various types of port areas, revitalised port areas / residential developments at brownfield sites, different types of urban riverfronts such as central parts of riverfronts as opposed to more marginal parts of urban riverfronts, infrastructure sites within the natural environment etc. Furthermore, the typology focuses primarily on functional aspects related to the environment, living spaces, and industry or infrastructure, neglecting other important dimensions of the riverfront, such as social, cultural, and economic aspects.

Types of waterfront regeneration

Moretti (2008) categorizes waterfronts based on their regeneration processes into several types. The *New Urban Expansion* type involves constructing riverfront areas from the ground up, often reclaiming former industrial or port areas, with examples like Spandauer See and Rummelsburg in Berlin or Hafen City in Hamburg. *Waterfronts and Great Events* category refers to the development

of new urban spaces, both residential and industrial, driven by significant temporary events like the Expos in Seville (1992), Barcelona (1992, 2004), Genoa (1992 and 2004), Lisbon (1998), and London (2000). *New Urban Waterfront Itineraries* involves public use along the waterfront leading to innovative changes along the banks and surrounding areas, such as pedestrian paths, exemplified by London's Thames River Banks and Barceloneta beach in Barcelona. The *Reuse of Port Areas* category pertains to the regeneration of former port areas, revitalizing city centres by bringing them back to the water, as seen in Rotterdam's waterfront. *Flood Defences*, illustrated by Vienna's Donaulinsel, includes infrastructure for flood protection that later provides opportunities for urban expansion and new uses. *Urban Riverfront Regeneration* involves integrating various aspects of urban life where the riverfront has the potential to become a central public space, as demonstrated by the Cheong Gye Cheon canal in Seoul. Lastly, *Urban Beaches*, like Paris Plage along the Seine River, serve as public spaces akin to urban plazas.

While Moretti's typology provides a framework for understanding different approaches to waterfront regeneration, its applicability and relevance may vary depending on the specific context and characteristics of each city's riverfront. Not all categories may be applicable to the cities of Bratislava, Vienna, Hamburg, and Bremen, however, each city exhibits at least one category typical for its context. In the case of Vienna, the category of *Flood Defences* is characteristic, particularly with the example of the Donaulinsel. The construction of flood defense infrastructure along the Danube River has not only protected the city from flooding but has also created opportunities for recreational and cultural activities. For Bratislava, the category of *New Urban Expansion* may be the most applicable, especially considering recent development projects along the Danube River, which involved reclaiming former industrial or port areas for new urban uses. The category of *Reuse of Port Areas* is evident in Hamburg, particularly with the Hafencity redevelopment project. Former port areas along the Elbe River have been transformed into mixed-use neighbourhoods with residential, commercial, and cultural amenities, revitalising the waterfront while preserving its industrial heritage. The category of *Urban Riverfront Regeneration* is relevant to Bremen, especially with the example of the Weser River waterfront. Efforts to enhance the quality of public spaces along the Weser River, such as promenades, parks, and recreational facilities, have transformed the riverfront into a central axis for urban life, connecting the city with its waterfront heritage. Certainly, there are several gaps of this typology including the limited fit of some categories, the diversity of local contexts, and the unique challenges and opportunities associated with each city's riverfront regeneration process.

Waterfront use

Vallega divides the waterfront based on the waterfront use (Vallega, 1992, 2001). Vallega's categories are Ecosystem enjoyment; Fishing; Tourism; Recreation; Entertainment; Congresses; Media; Transport and navigation; Trade and finance; Research areas; Education and training; and Cultural heritage.

Application of Vallega's waterfront framework on the studied cities helped to identify the framework's gaps. The research showed a lack of consideration of various functions on the waterfront in the framework including residential or purely natural character on the waterfront as well as areas outside the city centre fulfilling a buffer function in relation to water. The gaps relate to the designation of Vallega's framework to coastal areas rather than urban river environments. Additionally, the framework is focused on the waterfront functions rather than the character of an individual section, therefore its categories are quite detailed and often describe individual objects with specific dominant use (e.g., Media category including uses such as Book publishers, TV stations etc.)

rather than a more general description of an area such as Administrative or Commercial including multiple uses. This way Vallega's categories are not clearly divided on the waterfront but are intermingled with each other, often appearing as fragments rather than the whole waterfront sections.

Conclusions and Recommendations

Rivers play a substantial role in shaping the identity, semiotics, and urbanity of European cities, with their versatile potential contributing to various aspects of city development. Urban semiotics of any given city or urban place is constantly evolving and the river plays an important mediatory role in this process. We are not able to easily change the physical parameters of the river but by changing the urban environment, behavioural patterns, and dominant contents of social practice on the riverside we change the role of the river in human mental maps.

Urban riverfronts are too diverse to be managed as a single entity. Riverfront management, however, currently lacks appropriate typology, which would enable to divide riverfronts into individually manageable sections, addressing their diversity. Character sections of rivers significantly contribute to the unique urbanity and identity of cities, shaping their urban morphology, spatial syntax, and visual appearance. Diverse character sections of the given river express the city changing tonality, diversity of functions as well as the quality of social atmosphere. The typology of riverfront character sections is an invaluable tool for the precision of spatial management of riverfronts and planning in general. It reveals hidden similarities and peculiarities of different types of interfaces between the urban environment and river and enables to find optimal ways to further develop these specific places in concordance with both the authentic identity of the place and the newly arising needs of further city development. The research was focused on the unique character of riverfront areas with the aim of contributing to the development of a new, universal typology for classifying character sections of urban riverfronts. This was done by studying four urban riverfronts in European cities, including Hamburg, Bremen, Bratislava, and Vienna to which the existing waterfront typologies were applied.

Given the novelty of the approach taken in this study – to categorize riverfront character sections – the existing literature available for comparison is limited. While previous research has explored various aspects of urban riverfronts, such as their economic, social, and environmental impacts, few studies have specifically focused on developing typologies for characterizing different sections of riverfront areas. Therefore, the results of this study represent a significant contribution to the field, providing valuable insights into the diverse nature of urban riverfronts and the potential for developing more comprehensive typologies to better understand and manage these important urban spaces.

Our research enhanced understanding of the river's role in city development, showcasing diverse outcomes of the relation between river and city across various European cities. We can see various patterns of changing attitudes of the city (and its inhabitants and managerial bodies) toward the river. The transformation of the Hafenspeicher area in Hamburg went far beyond the optimal use of the former brownfields, it strengthened and improved the position of Hamburg in international competition and calibrated its distinctive identity. Recent new approaches and projects in Bratislava highlighted the intrinsic nature of ties between the city and the Danube River and offered new perspectives to perceive Bratislava as a city on the river. Vienna's perception of the Danube has shifted from cultural clichés (e.g., waltz on the Danube) to recognizing its role in environmental stability or ecological challenges. Bremen's relationship with the Weser River has

evolved over time, reflecting shifts in urban planning and community engagement. The city has revitalized its waterfront, reinforcing its identity and promoting public access and recreational activities along the Weser.

Riverfront is often displaying the essential elements of the city imaginary, thus representing the metaphorical 'personality of the city' and city identity in general. Although the encounter between the river and the city is always unique and essentially non-repeatable, the typology of riverfront character sections enables to focus on the most important definition traits of a certain section and thus deliver functional and historical continuity to the interface of the city and river. Precise typology of riverfront character sections enables to use the tailored solutions and preserves the values related to a given place, enhancing the spectrum of activities. Current riverfront typologies contain several gaps, mainly:

- Lack of specificity. The examined typologies usually provide broad categories, lacking a more detailed refinement in order to incorporate a broader range of urban-river contexts.
- Lack of consideration for variations. The river, riverfront, or urban environment can vary in numerous aspects throughout the administrative area of the respective city. The defined categories in typologies might not be applicable for the full length of the river, riverfront, or riverfront section.
- Lack of qualitative parameters. The studied typologies rarely focus on other than the physical parameters such as the size of the river, the river's edges etc. However, they rarely consider qualitative parameters. These can include environmental, economic, social, cultural and other aspects of the river.

Based on the gaps found in the existing typologies, recommendations for a new riverfront character section typology were formulated:

- The riverfront character sections typology should be based on a thorough combination of quantitative (data-based) and qualitative methods (interviews, questionnaire on the semantic essence of a given riverfront section, observation of social practice and other behavioural methods) in order to include quantitative as well as qualitative aspects of the riverfront sections, including environmental, economic, social, cultural etc., and enable sustainable management of riverfront character sections and the city as a whole.
- The process of development of a new riverfront section typology should engage a wide range of stakeholders, including the public (incl. local communities, businesses, property owners, inhabitants, etc.) and the experts (including local government, environmental organisations, conservationists, etc.). This is essential for developing a comprehensive and inclusive riverfront sections typology that addresses the needs and aspirations of all stakeholders.
- The typology should be flexible in terms of incorporating contextual factors, such as regional characteristics, cultural heritage, environmental conditions, or local development policies, to be able to be used in various contexts and accurately capture the unique character of each waterfront.
- The individual categories should be specific enough to incorporate a broad range of urban-river contexts and they should consider all possible variations emerging on the riverfronts. Less common or marginal parts of riverfronts such as riverfront areas in the vicinity of transport structures should not be excluded from the typology.
- Waterfronts can fulfil different meanings and serve different roles, depending on their local context (e.g., the Elbe river, canals in the Hafencity, the Danube in Vienna etc.). Therefore, when creating a typology of waterfront character sections, it is essential to differentiate between various roles of riverfronts and manage them accordingly.

- Similarly, within the categories of the riverfront sections typology, it should be differentiated between urbanised parts of the waterfront and the mostly natural parts on the outskirts of the city. These riverfronts require significantly different management approaches.
- The typology should address the complexities of ecological conservation and restoration along urban riverfronts. It should account for the interplay between built and natural environments, biodiversity conservation, habitat restoration, and ecosystem services provision.
- The typology should enable to evaluate the ecosystem services within specific sections of a specific riverfront. By implementing the evaluation, it is possible to support the sustainable development of the territory, support the preservation of valuable ecosystems and effectively use the benefits that riverfront areas bring to the city and its inhabitants.
- The management of riverfront character sections, as an inseparable part of the new typology, should be interdisciplinary as well as participatory – waterfronts are focal points of many inter-linked activities and social practices and are often places where the principal values compete, and the civic culture is created and born. Typology should focus not only on physical and functional aspects but should take into consideration informal and participatory planning mechanisms externalised there.
- The identity of a place plays a crucial role in how memorable the place is and how people form a relationship with it. Riverfront management should take this factor into account and work to develop and enhance the identity of a place. The typology should differentiate between abstract and physical characteristic elements of each riverfront section type and include them within the management system.
- The typology of riverfront sections should enable to improve the connectivity among various types of riverfront along the river. The sequential character of a river rarely allows abrupt changes in its embankment profile, in most cases one type of riverside is smoothly transformed to another one. Typology emphasises the need for a smooth interface and transition between various types of riverfronts.
- Finally, the new typology should build on already established principles for successful waterfront development. They include key objectives that respond to the complexity of waterfront spaces and their natural, social, or economic values, including the protection of the city and its inhabitants against floods; supporting and improving the ecological values of the river and its surroundings; setting a balanced functional use around the river, ensuring high-quality and lively public space in the vicinity of rivers; ensuring access to the river and contact with the river for people; preferring alternative forms of transport in the waterfront area; preserving important historical elements in the area of the river; and preserving significant views.

The research focused on four European waterfronts and identified gaps in existing typologies. It has delivered recommendations for the development of a more comprehensive and contextually relevant riverfront section typology. While the findings offer valuable insights which show numerous trends that need to be addressed, it's important to acknowledge certain limitations in the research methodology. Firstly, the selection of the four European riverfronts, while diverse in geographical location and cultural context, may not fully represent the range of riverfront typologies found across different regions. Representatives from different regions, such as Southern Europe, Francophone Europe, or Scandinavia, could offer additional perspectives and contribute to the development of a more comprehensive typology. While our study provides a starting point for understanding urban riverfronts in Europe, future research could benefit from expanding the sample size to include a wider range of cities, thereby enhancing the applicability and robustness of the typology. Furthermore, the sole use of online sources for gathering information about existing

typologies, without the use of alternative methods for data acquisition may have introduced biases or limitations inherent in the available data. Additionally, the in-person visits to the riverfronts may have been constrained in scope or influenced by external factors such as weather conditions or time constraints. Lastly, the gap analysis conducted to identify limitations in existing typologies may be subject to varying interpretations of the data. It's important to consider these limitations when interpreting the results.

Moving forward, it is essential for future research to build upon these findings and further explore the nuances of riverfront character sections to inform effective urban planning and development strategies. In the next research, it is recommended to build on the formulated recommendations and form a new typology of riverfront character sections in combination with a management system specifically developed for each of the character section categories.

To summarise, character section typology is an innovative contribution to the research of multidimensional relations of city and river. It enables us to compare similar types of waterfront or riverside sections in cities and to adapt successful proceedings from one city to another. Overall, this research provides a foundation for further exploration and development of a more comprehensive typology for urban riverfront character sections, which can support riverfront management strategies that promote sustainable development and enhance the relationship between cities and water

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