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Principles of Designing Water Elements in Urban Public Spaces

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Abstract: When designing public spaces in large cities, a number of functional, communication, compositional, infrastructural, environmental and compositional factors should be taken into account, most of which relate to water elements. The appropriate location and form of water elements significantly affect the attractiveness and strengthening of the identity of places in cities. Fountains, artificial and natural urbanized watercourses, artistic installations and sculptures, as well as nature-based solutions that utilize water designed in public spaces significantly increase the social and aesthetic value of public spaces. The main aim of the presented research is to present a spectrum of solutions for water elements in public spaces of cities. The summary part describes guidelines and recommendations regarding the principles of designing the locations of fountains, watercourses and artistic objects that utilize water in public spaces in cities.

Keywords: city landscape; water; public space; spatial values

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1. Introduction

Water is one of the basic elements of resource management in cities and one of the most necessary at the same time. Research, including "Water and Cities: Ensuring Sustainable Futures" by OECD, indicates that the global urban population, struggling with water scarcity, is expected to increase from 933 million (one third of the world's urban population) in 2016 to 1.693–2.373 billion people (one third to almost half of the world's urban population) in 2050 [1–3]. This is a real problem faced by modern cities, which requires separate studies. This study focuses on typology and design principles with regard to the relationship between the functions of water features and their values in public spaces.

Rising temperatures in city centers, especially in the summer months, have an impact on the use of public spaces, the environment and human health. Appropriate heat mitigation measures are therefore an important issue in modern urban planning [4,5]. The advent of thermal comfort indices based on measurable environmental parameters (physical components) and the inclusion of human thermal comfort models (physiological components) capable of expressing the "physiologically equivalent temperature" perceived by humans in commonly understood units has conditioned urban climatologists' interest in urban climate research [6]. In urban areas, thermal comfort can be improved by "green and blue" infrastructure. The "blue" infrastructure formed by water elements is thus a suitable solution for creating cooling places in the urban environment.

Beyond natural water bodies, a whole spectrum of artificial installations can be considered (ranging from fountains, to sprinklers, to evaporative towers and to ponds). Among them, an especially promising blue mitigator is represented by dry mist systems, namely high-pressure water injectors able to pulverize the water into fine droplets of few tens of microns [7]. The advantage of these systems is their installation throughout the cityscape in strategic hot or vulnerable spots to alleviate the risk of heat-related mortality and morbidity with an expected higher impact than single massive water bodies. Furthermore, compared to water bodies, these systems can be controlled in capacity and can be triggered by specific events (temperature, humidity, wind speed exceedances or rain occurrences) not to provide evaporative cooling when unneeded or potentially counterproductive.

The protection and resilience of the structure of water systems is one of the basic goals of the European Green Deal policy and the system of shaping modern cities based on it in the spirit of the Eco Smart City [8–10]. The use of water elements and solutions also applies to the circular economy [11]. A number of social studies have been carried out which indicate the great importance of this type of solution (along with other elements of green infrastructure) in generally accessible urban spaces [12–14]. The studies published so far emphasize the positive impact of water elements in public spaces on human benefits including restoration and stress reduction [15–17]. Psychological studies, widely described in the literature, also indicate a large role of natural elements, including those related to blue infrastructure in highly urbanized areas, in shaping the well-being of users [18–20]. They are mainly associated with a noticeable improvement in mood and a slight reduction in stress [21]. Subsequent studies indicate significant health benefits associated with the occurrence of this type of object [22]. Particular attention is paid to aspects related to a slight reduction in heat at high air temperatures [23]. The above aspects are important because they are directly related to the dehydration of cities caused by many factors resulting from excessive urbanization [24–26]. They also draw attention to the need to use modern design solutions that provide greater protection against the negative effects of urban development [27,28]. In order to meet these problems, various types of policies are applied based on the development of water management in cities [29]. A sustainable approach to these problems is provided by the concept of green and blue infrastructure [30–32]. Solutions for planning water management systems are based on various interpretations of Nature Based Solutions (NBSs) [33–35], which are the basis of modern city planning in the spirit of Eco Smart City [36,37]. As part of this strategy of contemporary water resources and greenery management, the policy included in Blue and Green Infrastructure (BGI) is applied [38–40]. BGI is a multi-level multi-structure serving resilience as well as controlled and sensitive to its development processes [41–43]. The methods of protection and contemporary development of the structure of water elements are related to legislative solutions and their procedural implementation in the infrastructure, as in the case of the American Best Management Practices (BMP) developed since 1970 in the USA [44]. There and in New Zealand, the Low Impact Development system has been used (since the 1990s) [45]. In Great Britain, the Sustainable Urban Drainage System (SUDS) [46] has been used since the 1980s. The existing typologies representing the types of water objects used in contemporary design of public spaces are insufficient and require deepening, hence the main goals of the presented study [47–49]. It is assumed that water elements in public spaces are associated with values important for users, making a given place more attractive and better identifiable in the city structure [12,50,51]. The above research background indicates that there is a serious gap in existing studies on combining the impact of the values generated by water elements in public space with specific guidelines for the protection and design of such facilities in a comprehensive manner in cities.

1.1. Main Theses

The main theses of this work are:

1. When designing water elements in the public space of large cities, functional, compositional, infrastructural and environmental aspects are taken into account;
2. Water elements designed in public space can take various forms, which can be classified;
3. The elements of water in public spaces contribute to well-being and are good for the general well-being of people, especially when the temperatures are high;
4. Such solutions in public spaces definitely increase their social and aesthetic values;
5. The installation of water devices in the city is very important for the physiologically equivalent temperature, which improves the heat feeling and human comfort;

6. Appropriate design of the water element may influence the cooling effect in its immediate vicinity.

1.2. Objectives

The main goals of this work are:

- Development of a typology of water elements in hardscaped public spaces of large European, North American and Australian cities;
- Identification of the value that different types of water elements bring to urban spaces in selected examples;
- Recommendations for the introduction of water objects in the public spaces of large European cities.

2. Materials and Methods

The study covers city squares in European, North American and Australian cities, which have been redesigned and reconstructed over the years 2000–2020 and are in the circulation of architectural discourse at least in the basic scope—a photo report from the implementation—a description of the details of the project, supplemented with elements projects and a description of the organizational context of the investment. Sources include websites:

- Landezine—projects in the "Squares and Plazas" category—from 2009 to 2021 (as of 16 November 2021)—a total of 301.
- ArchDaily—projects from the square category—a total of 117.
- PublicSpace.org (finalists and winners of the European Prize for Urban Public Space organized biannually by the Center of Contemporary Culture of Barcelona)—applications from 2000–2020, total number 357.

The following projects were selected: (1) containing broadly understood water elements, including underground devices for water retention, transport and infiltration and (2) included in hardscaped public spaces—squares, plazas, boulevards (gray areas, as in the typology of Stanley et al., 2012 [52]). Projects located outside the European, North American and Australian continents were rejected due to a separate symbolic code and significant differences in the use of public spaces. A significant part of the selected implementations from the above sources was described in several of them. Ultimately, the number of selected projects amounted to 44 separate projects, implemented in the years 2003–2020.

Each of the projects was assigned to the category of water devices distinguishing the used physical characteristics of water, resulting from the flow orientation in relation to the level, flow velocity, type of flow—laminar or turbulent—physical state, physical phenomena in water, water location in relation to the sidewalk, flow variability and flow interactivity. Then, a list of architectural features of the water system and emergent features of the site, resulting from the two previous categories, was compiled. Facilities in which several water treatments coexist were defined as hybrids of two or more primary types. Then, from each category, the most representative specimens reflecting the ideal types were selected. To these ideal types, defining features and supporting features were assigned (determining good design and thus maximizing the potential of devices and values of public spaces).

Considering the multidimensional effect of water elements, the distinction of the value of public spaces developed by Matthew Carmona (2019) [50] was adopted, extending the classification developed by the Commission for Architecture and Built Environment with the health aspect. Thus, the following values are distinguished: exchangeable (of what is traded), usable (of direct use, in the case of public spaces, observed user activities), image (the identity and meaning of built environment projects, good or bad), social (supporting or impeding of the desired social relations), environmental (impact on the environment, including consumption of natural resources), cultural (cultural significance, including artistic value and symbolic meanings), health (impact on health an wellbeing).

These values can be derived from empirically determinable features of water objects indirectly—through feelings determining places recognized by environmental psychology and morphological/topological qualities—including, in particular, accessibility. Then we determined the influence of these basic features (and their combination) on the quality of places recognized in urban planning, which then generated place values. Important categories of place quality included: acoustic comfort, thermal comfort, psychological comfort (sense of security) [53], (perceived) affordances—possible activities [54], activities—observed activities [55], imageability [56], sociability, privacy [57], sense of interest [58], sense of pleasure [53,59,60], robustness [53,61] / responsiveness [62] —immersion [63]. Sociability [64] is understood as a density of social communication in public spaces. The matrix of relations between the empirical features of water elements and their surroundings, urban qualities and values is presented in Figure 1.

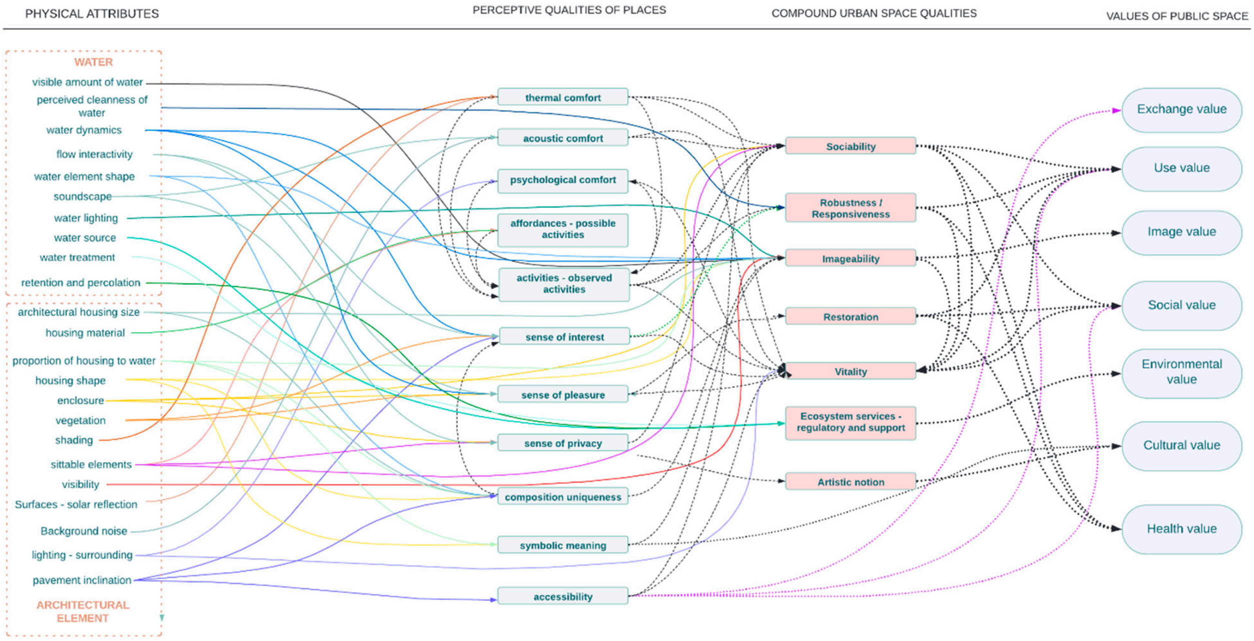

Figure 1. Matrix of the assumed relationships between physical features, qualities of a place and values of public space. Note: some space qualities are unidirectionally interdependent—e.g., sociability requires acoustic and thermal comfort, etc.

In the next step, the characteristics defining the individual types of fountains distinguished according to the way of using the physical properties of water (morphological types) were determined. Then, the implications of each type for the various aspects of perception and topology (necessary housing) were determined. On this basis, categories of water devices were distinguished due to the dominant effect of water devices:

1. Relaxing—a dominant influence on the sense of pleasure, related to stimulating reflection and peace, individual activities and activities requiring a high degree of privacy—with the features of restoration spaces;
2. Spectacular—dominant influence on the sense of interest—associated with the possibility of intensive observation of the water system;
3. Entertaining—dominant influence on commitment (robustness/responsiveness);
4. Environmental—the dominant environmental function (Blue-Green Infrastructure functions).

On the basis of the dependency matrix, features defining particular morphological types and supporting features—maximizing their effectiveness—were determined. Supportive features were recommendations for the shaping of water features in public spaces to city designers and decision makers. The results are presented in the table entitled characteristics and typology of water objects in hardscaped public spaces (Supplementary Materials).

Then, the influence of water elements of individual morphological types on the values of public space was determined in the Carmona 2019 classification [50], created for cross examination with sector policies:

- Exchange value—moderate effect on increasing the commercial value of adjacent properties, in cases where it is an internal economic impact (return on investment);
- Use value—moderate positive—the potential to provide moderately engaging activities (observing, a short game, etc.), significant—the potential to provide engaging activities (longer fun, age groups of users);
- Image value—moderately positive—high potential to create a characteristic point crystallizing the mental map, significant—additionally high potential of a unique composition on a metropolitan and global scale;
- Social value—moderate positive—the potential of the so-called integration—enabling the establishment of permanent or temporary social relationships (neighborly, intercultural, etc.), usually through the participation of a significant number of users (>15) in engaging and enjoyable activities, including those based on play;
- Environmental value—moderately positive—limited in scale ecosystem services, including primarily maintenance (groundwater supply) and regulation (mitigation of rainwater runoff);
- Cultural value—moderate positive—the presence of symbolism, meaning embedded in culture, significant positive—additionally maintaining formal and informal cultural practices;
- Health value—moderate positive—the presence of a set of restorative place factors in the urban context—multisensory action (at least 2 senses—visual, auditory, tactile, etc.).

3. Results

3.1. Characteristics and Typology of Water Objects in Hardscaped Public Spaces

The typology described in the table (Supplementary Materials) presents an inventory of the main feature's characteristic for the identified water elements in urban areas—defining features. Its main goal is to comprehensively address the value that particular features of various examples of types of water use bring to public spaces. In the described study, the most important morphological and perceptual features from the user's point of view were also evaluated in relation to the qualitative scales of characteristic features of the objects. As a result of the research, the main functions that the discussed elements perform in public spaces, based on their dominating effect on users, were identified (functional types).

Recognized morphological types of water elements in hardscaped public spaces of cities are: 1. Basin fountain, 2. Cascade fountain, 3. Pavement fountain, 4. Urban trickle, 5. Reflective pool, 6. Water screen (2d, 3d), 7. Mist fountain, 8. Semi-natural pond, 9. Permeable tube, 10. Water square and 11. Swimming pool (Figure 2). These morphological ideal types can, and frequently do, form hybrid (compound) types—combinations of the basic types.

Subsequently, an evaluation of 11 types of elements was carried out that focused on dominant desirable effects associated with each type. These were related to aspects related to the three structural elements: water, architectural element (housing, its immediate surrounding and qualities of places emergent of the two former—see Supplementary Materials). In the case of water-related traits, the results of the research revealed nine basic morphological traits relating to both physical, directly observable with senses (vision, hearing, temperature, etc.) and technical issues. Two features—1.3. Water dynamics and 1.4. The shape of the water system—required additional elaboration in a more detailed way. During the analysis of the architectural element, 15 features were distinguished, which showed particular morphological and physiognomic aspects of the water elements in relation to themselves, as well as their location and urban context. These features have been clarified by indications of use (2.12. Sittability, B.2 observed activities—by type).

Compound perceptive (cognitive, affective and interpretative) qualities of places created by the water element types were derived from the physical attributes through inductive logic as mediating phenomena constituting the values of place. For this purpose, they were divided into several groups, defined successively from A to P, indicating the most important spatial, pro-environmental, social, functional and perceptual aspects. Each of the listed features arranged as described above was evaluated, which showed the desired features of each of the 11 types of water elements. The indicated desirable features identified in the study are at the same time an indication for designers and constitute comprehensive guidelines for creating and locating water elements in public spaces.

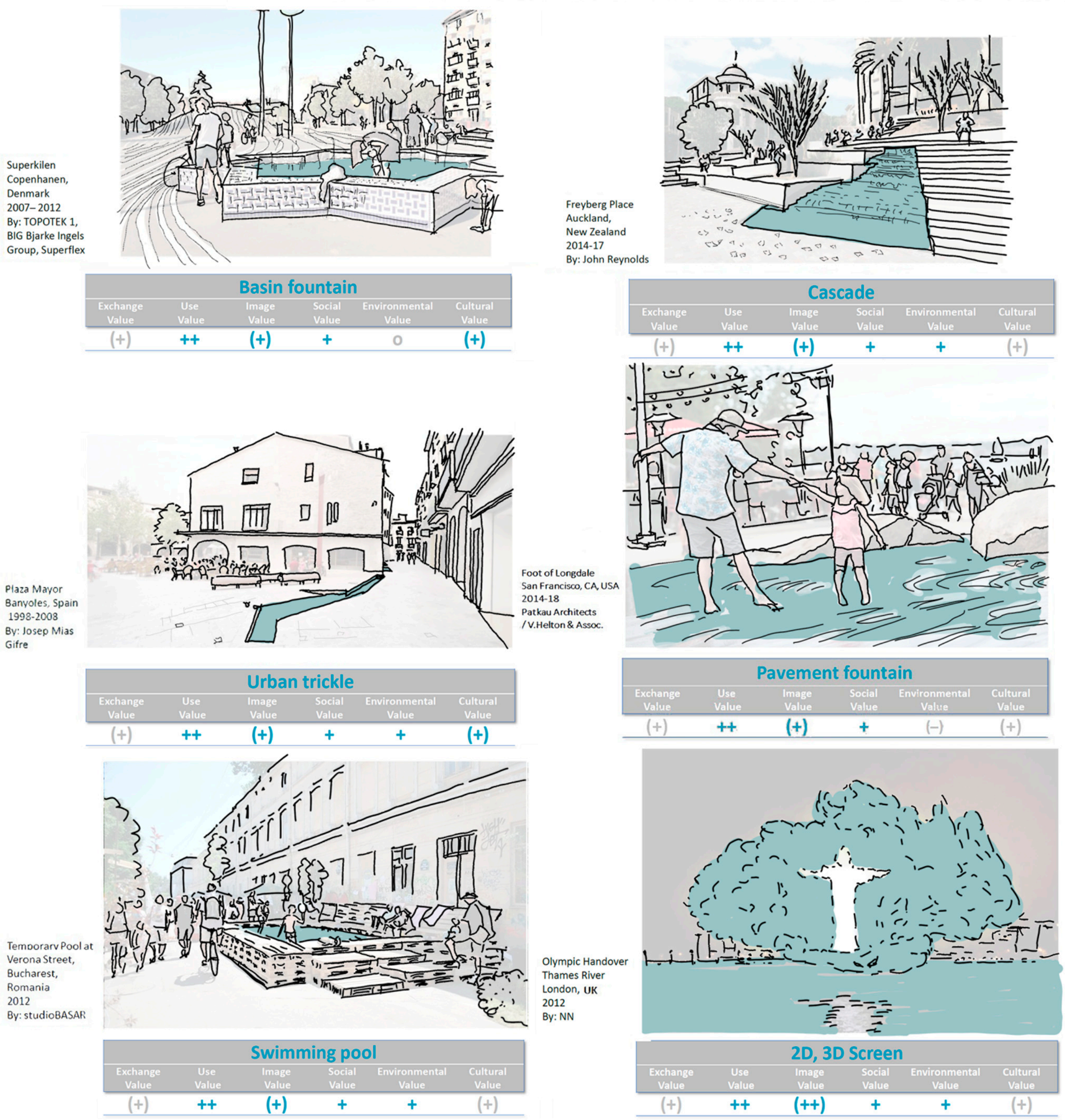

Figure 2. *Cont.*

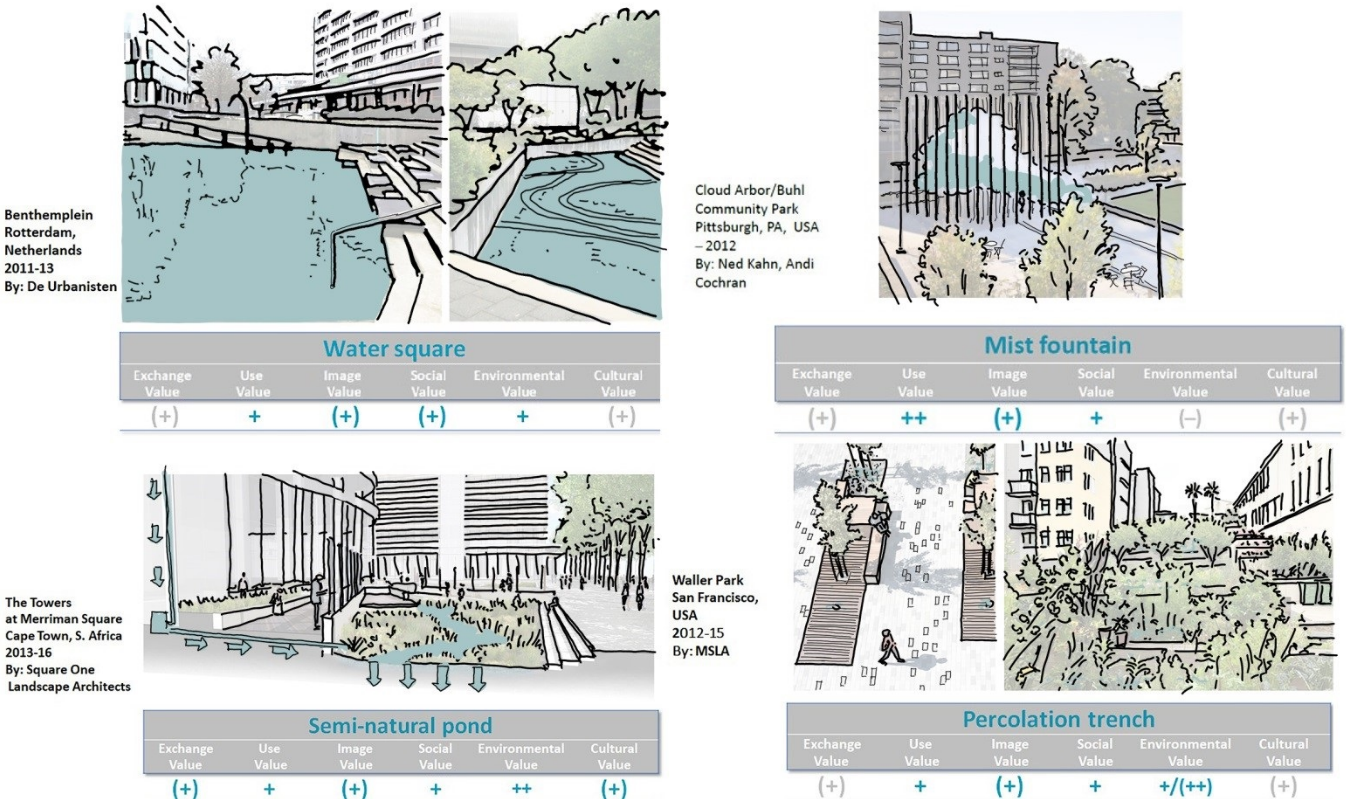

Figure 2. Identified morphological types of water elements in hardscaped urban public spaces, summary of their potential influence on values of public space, denotations: +—moderate positive impact on the value of public space; ++—significant impact on the value of public space; −—moderate negative impact on the value of public space; (x)—values in parentheses—significantly dependent on detailed design.

3.2. Limitations

The study included a significant number of realized public space improvements. The typology was created on basis of projects realized and covered byrenowned landscape and urban design sources. Nevertheless, there are plenty more of known modern water management systems, including nature-based solutions, that were not present in the surveyed projects. Their implementation possibilities and values of public space that they contribute to is yet to be analyzed.

Water elements—their design in the urban environment—are always influenced by the climate zone, the architectural structure of the city and the historical contexts of the place. The efficiency of water elements in terms of regulating thermal comfort is affected by temperature, humidity, wind force and shading of the space—especially trees. In the case of lawns, this efficiency of the water element is negligible. The surfaces around the water element also contribute to the efficiency, which has a very fundamental effect on the efficiency of mostly water showers or misters. Therefore, if we do not address the impacts on human biometeorological well-being, water features in cities have more of an aesthetic nature. In the case of shallow water elements, on the other hand, at maximum temperatures, warming may occur instead of cooling the surroundings from this element. Thus, the surface and surroundings will not cool down at night when that is expected. As for water products for water retention, for reducing flood flows or conditions in the urban environment, we are not talking so much about the attractiveness of the environment.

The elements of the water co-create the place and, as one of the factors, co-create the values that have arisen from the construction of these places (Table 1).

Table 1. Water features in urban squares and their contribution to public space values. Categories of values as in Carmona, M. (2019) [50].

	Exchange Value (Can Be Traded)	Use Value (Activities)	Image Value (Identity, Meaning, Good or Bad)	Social Value (Supports or Undermines Social Relations)	Environmental Value (Supports or Undermines Environmental Resources)	Cultural Value (Has Cultural Significance)	Health Value
basin fountain	(+)	+	(+)	(+)	(−)	(+)	(+)
cascade fountain	(+)	(+)	+	(+)	(−)	(+)	(+)
pavement fountain	(+)	++	(+)	(+/++)	(−)	(+)	(+)
urban trickle	(+)	+	(+)	(+)	(−)	(+)	
reflective pool	(+)	(+)	+	(+)	(−)	(+)	(+)
mist fountain	(+)	++	(+/++)	(+)	(−)	(+)	
screen (2d, 3d)	(+)	++	++	(+)	(−)	(+)	
swimming pool	(+)	++	(+)	(+)	(−)	(+)	(+)
water square	(+)	+	(+)	(+)	+	(+)	
semi-natural pond	(+)	+	(+)	(+)	++	(+)	(+)
percolation trench		(+)	(+)	(+)	+/++	(+)	(+)

+—moderate positive impact on the value of public space. ++—significant impact on the value of public space. −—moderate negative impact on the value of public space. (x)—values in parentheses–significantly dependent on detailed design.

4. Discussion

This article attempts to comprehensively present the role of water elements in urban systems. Referring to the value system, it tries to continue the research carried out in this field, developing the methodology developed so far [50,52]. The currently described systematics of water elements in public spaces in cities, as described so far, is related to their location and their technical structure [56]. In addition, the listings of these types of facilities focus on health issues and issues related to the resilience of urbanized areas [12,15,16]. The water elements in the urban space are described separately in relation to the behavioral aspects [19,20,22]. Other studies tackle issues related to the values in space with regard to equipping public spaces, also with water elements [65,66]. Many taxonomies related to furnishing public spaces focus only on their aesthetic features [67,68], including those focusing on the shaping of water elements in cities [69,70]. More comprehensive studies, mainly issues related to the profits related to the pro-environmental and climate action in urban areas, are examined [71]. Contrary to the cited classifications, the above study focuses on the user and the most valuable aspects for him, related to the location of facilities that use water in shaping public spaces in cities. In the case of specific studies indicating the features of water elements in terms of their importance and evaluation, a similar study was carried out by Vernon and Tiwari in relation to parks [72], where they noted that some features related to perception constitutes a kind of special impact and should be emphasized as guidelines when designing. The need to evaluate and demonstrate specific desirable features on the basis of comprehensive studies of existing elements in public spaces are also indicated by guidelines related to the planning policy of new facilities in some countries, e.g., in Australia [73,74].

While this study examines the influence of various water elements on the emergent qualities of places, and not the earlier and ongoing processes of place creation. It should be, at the same time, noted that the very process that enables citizen involvement is thought to be crucial in general success of the design of the water features and public spaces that contain them [75,76].

5. Conclusions

Taking into account the above research and the results of the comprehensive analysis carried out, it is worth pointing to several aspects that should be particularly taken into account when designing new water facilities in public spaces:

1. All recognized morphological types of water features in public spaces increase the value of these places. The role of water elements in public spaces can perform multiple functions, from purely aesthetic to fully functional, improving the well-being of people. The main conclusion of the study is the great positive importance of the presence of water-related design solutions in these types of spaces. The study shows that they increase the value of publicly accessible places in various aspects. None of the above-mentioned solutions was sterile and did not bring any additional significance; the mere existence of these objects increased the value of the described places. Hence the basic recommendation resulting from the study is that water elements should be designed in public spaces because they significantly increase the value of these places.
2. Water elements in public spaces should be designed in such a way that the pro-environmental profit is combined with the aesthetics and composition of the element to the specificity of the place. The presented research shows the correlation of these objects with the user, which builds an additional value system in public spaces. The distribution of these values is interesting, especially with regard to issues related to the exchange of services, aesthetics and environmental profit. The results of the study showed that what brings the effects of increasing biodiversity and is generally a pro-environmental action does not necessarily maximize the image value of a place (visual preference, etc.). The quoted conclusion indicates that when designing water elements in public spaces, the composition issues should be at least as important as ecological activities.
3. Water elements in public spaces can improve the physiological well-being of users when properly designed. Another recommendation related to the design of water elements in public spaces is their high socio-functional value related to the improvement of people's well-being. It is especially visible in highly urbanized spaces and in places with higher temperature amplitudes. The use of such solutions significantly affects the aspects related to the well-being of users, despite the conclusive lack of significant cooling effects, while maintaining the biometeorological significance through the very awareness of the existence of water elements in the space positively influencing the perception of such places. By creating thermal comfort in the city, it will support the assets of pedestrians, tourists, cyclists, etc., and can lead to the encouragement of the population to spend more time outdoors and on the streets. This can be beneficial for cities in terms of tourism, socially, economically and environmentally.
4. Water elements enrich the composition of public spaces. Properly designed, they improve the key features of public space, such as imaging, vitality, mobility, solidity and comfort. These types of objects, properly designed and located taking into account the wider spatial context in a given place, causes that the values of this place are automatically higher. It should be remembered that the use, image and social and cultural values of urban water features largely depend on their type, size, structure, location and surroundings.
5. Water features contribute to the identification of places in cities. This type of element causes them to become pedestrian attractors, serving as characteristic points or landmarks depending on the visual impact and size. Consequently, they significantly increase the diversity of the city's spatial structure, which in turn affects the orientation and consequent ease of movement around it.
6. Water components in public spaces should be designed to be part of the urban resilience system. The design of such facilities should be linked to a broader policy on the environmental footprint and quality of the city's blue and green infrastructure. Properly selected types of pro-environmental values brought by such solutions should be particularly taken into account in projects located in spaces of dense historic urban tissue, or in other highly urbanized places. Last but not least, it is necessary to take into account the quantity and quality of water used in the design.
7. Water elements in public spaces should be designed in a holistic manner. In order to maximize the use value of the water element, its design should take into account:

all possible uses (safety), interactions (weather) and legibility of the intended uses (affordances). It should also be aesthetic, adapted to the existing spatial context and, as far as possible, fulfill cultural functions. It does not change the fact that, as far as possible, these facilities should be designed to fulfill as many pro-environmental and social functions as possible.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14116877/s1, Characteristics and typology of water objects in hardscaped public spaces: defining features and the resulting qualities of the place (plain text), and their desired features (highlighted text)—recommendations for shaping and locating

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