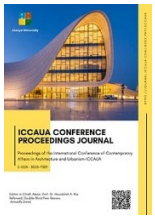

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Water Lines and Urban Design- Lisbon's 'Liquid Framework' as a Conceptual Tool to Shape a New Sustainable Balance

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A b s t r a c t

From Vitruvius's foundational architectural writings to Roman monumental infrastructure to Haussmann's renewed Paris, the human drive to manipulate water flow has determined cities' formal evolution. How can architecture today give shape to water sustainability? Departing from Moore's idea of spatial "liquid framework", this paper explores the interpretation of urban water and urban form as two intertwined city layers with an ever-tightening geometry and capillarity, continuously linked and synthetizing new urban and housing typologies. A conceptual matrix is proposed, unfolding water and urban design dualities. Lisbon's case study, like many related cities, can be described through this analytical model, in a two-direction temporal regard: looking back, a palimpsest of urban water's material and immaterial concepts overlapping in a downstream topography; and looking forward, a Mediterranean urban context facing future drought and flood risks, demanding opportunities for a new sustainable balance reconnecting natural flows with public space and built circularity.

K e y w o r d s : Liquid Framework; Urban Water; Urban Design; Palimpsest; Lisbon.

1. Introduction

"With the advent of the third millennium, the population of cities has surpassed therural, with over 50 percent of the world's population living in urban areas" (Husain & Nafa, 2020). The United Nations predicts that by 2050 the majority of the world's population will live in cities, many at increasing risk of exposure to flooding and water scarcity, including Lisbon and the Mediterranean context. The necessary reflection on models of urbanization and ongoing climate change is covered by a complex multidisciplinary scope that requires contribution and dialogue between different areas of knowledge (Amen & Kuzovic, 2018; Amen & Nia, 2021; Amen, 2022; Husain, 2024).

In the first recorded Treatise on Architecture, dated two millennia ago (1st century BC), Vitruvius dedicated one of his ten books to the theme of 'water', establishing it as a fundamental theme of thought related to architecture and as a tool for humanizing the territory.

The book is dedicated to explaining techniques for locating existing water reserves in unknown territories, to evaluate their different qualities, and also points out some constructive solutions with a relative degree of sophistication for the design of their artificial conduction over and under the natural territory, through exclusive circuits and the construction of specific support objects for this purpose.

"Rapid urbanization in many parts of the world has resulted in inadequate housing, social segregation and the deterioration of open spaces, all of which have had a negative impact on the quality of life for residents" (Husain & Salem, 2024), thus, In the present 21st century, the 17 Sustainable Development Goals have defined since 2015 a common goal for the global population, regardless of their geographical, political or level of prosperity, focusing the issue of development on a common agenda of well-being, sharing and responsible use of resources of the common home in which we live. Goal 6 "clean water and sanitation" clearly highlights the urgency of ensuring universal access to drinking water. At least half of the global agenda is complementary to this idea, referring to "sustainable cities", "responsible consumption", "health and well-being", "innovation and infrastructure", among others.

The reflection on how architecture and contemporary urban contexts use and relate to water is thus evident as a constant and timeless theme for human life - a fundamental vector defining the relationship with the territory and, increasingly, with the future. However, as stated by Morshed (2024), there has been insufficient reflection produced

by architecture theory addressing the "*hydro-ecological roots of the built environment*", generating an "*'absence' of water in* [architectural] *historiography*" and "*epistemology*" (Morshed, 2024).
In order to answer the main question "how can architecture today contribute to shape future water sustainability?", there must be a better understading of how the human drive to manipulate water flow has determined cities' formal evolution through time and technological "eras". What urban lexicons emerged then -and why - and what new urban lexicons can emerge in a sustainable urban system - and how?
Through a comprehensive literature review, a conceptual perspective is defined, rooted in the basilar work of Charles Moore, who pioneered an holistic architectural regard to water in the past century, exploring a wide range of dimensions and significance of water presence and performance in the field. The concept of *liquid framework* is inspired on Moore's study and thus developed into a conceptual matrix, unfolding the duality of two systems present in the built environment – urban morphology and water flows. This dual matrix, correlating concepts on urban water and urban form, informs and structures the development of a historical perspective, where urban typologies are transformed over time and through technological water revolutions (Sedlak, 2014), evolving from formal coexistance to present (almost) mutual indifference between urban water and urban form.
The main hypothesis is that the built environment can be interpreted as two intertwined urban layers - urban morphology and water flows - with an ever-tightening geometry and capillarity, continuously linked and synthetizing new urban and housing typologies. The secondary hypothesis is that this *liquid framework* idea can be a key concept in designing sustainable integrated solutions: the formal articulation between the urban form system and the freshwater infrastructural and landscape system in the built environment can be a fundamental design premise to achieve a model that goes hand in hand with the emerging redefinition of the scarcity value of this natural resource.
The objective of this paper is to define a conceptual and systematic perspective regarding the built territory and its relationship with water; and to apply it to the Lisbon case study. The expected contribution of this research is to deepen the knowledge on water and architecture's relationship in a integrated and multiscalar way and to develop a multidisciplinar perspective - anchored in a territorial basis through an urban morphology study - that may expand the theoretical context regarding the problematization of water scarcity in the contemporaneity, helping to formulate future possibilities for sustainable adaptation in urban planning practices.
The paper is represents a first methodological essay of an ongoing research and an opportunity to discuss in a specialized international forum the main approach of the study and identify where to improve. This paper is structured in five sections: introduction, materials and methods, results, discussion and conclusion.

2. Materials and Methods

Following a qualitative research approach, the methods applied to answer the research questions are theoretical and historical research. A conceptual and programmatic idea is identified on Moore's explorative writings on architecture and water: *liquid framework* (Moore, 1994. p77). A conceptual matrix is developed unfolding the "water line - urban design" duality, as two systems bridged together, each one progressively unfolding their sub-systems. A correlation of main concepts is expanded inside four quadrants: four main thematic fields such as geography, technology, urbanism, architecture.

2.1. The " Lesson of Villa d'Este " and Villa Lante

In his work *Water and Architecture*, Charles Moore (1994) states that "*the lesson of the Villa d'Este is that water is a natural material and, despite obeying gravity and natural laws, it can be 'persuaded', shaped and transformed*".
From Villa d'Este to Villa Lante, in the same work, Moore interprets the participation and presence of water in the composition of the Villa as a "*liquid framework*" that animates the garden as a whole, creating a "*harmonious body*" and a "*complete thought*".
Expanding on this *"liquid framework*" idea, considering water as a central element of inhabited space through time and scales, from the Villa to architecture and urbanism over time, we can intuitively develop two consequential ideas: 1) that an effective dialogue exists between societies' water use and their built environment's morphology; and 2) there is an architectural and urban identity and expression through form, subject to geographic, temporal, technological and cultural contexts.
The original formation of the city of Venice (origins in the 5th century) can help illustrate this idea. Reflecting the result of a combination of unique geographical and technological conditions at the time, its public space is composed of *'campi'* punctuated by central wells associated with underground cisterns, corresponding to the original infrastructure for collecting and distributing water. These 'campi' became structural typologies in the urban form and image of the city.
In opposition, we can perhaps mention as a counter-example the Indian city of Fatehpur Sikri, as an urban and architectural form devoid of the 'fundamental ingredient of civilization'. Built in the 16th century (between 1571 and 1573) with an imperial architectural expression that remains notable, as a commemoration of a military victory ("*city of victory*"), the city was the capital for a short period of about 10 years until it was left by the emperor and completely abandoned by the population shortly afterwards in 1610, one of the most pointed out factors being the scarcity of water, also associated with political decline.
From the use of water that shapes the urban image in Venice, to the rapid obsolescence of Fatehpur Sikri despite its urban and architectural form of imperial representation, we trace here what may be the beginning of an argument about the participation of water in the built environment: *"liquid framework*" and "urban morphology" are two interdependent systems that must form a "*complete and harmonious thought*" (Moore, 1994. p77).

2.2. Unfolding water spatiality

Morshed (2024) outlines the "*disciplinary production of 'land-centrism'"* - and its consequences on *"epistemological taxonomies of what constitutes 'architecture'" - by analyzing the "conspicuous absence of the spatiality of water in Egyptian, Greek, and Roman architecture in history textbooks".*

Accordingly, Garcia (2024), reclaims that architecture should "*expand*" beyong technicalities and be able to *"discuss transformations of the times, collectively and across disciplines"*: this statement was a major legacy of the *Fertile Futures Laboratory* where she was head curator, at the Portuguese Representation at the 18th International Architecture Exhibition *La Biennale di Venezia 2023*, focusing on an architectural multidisciplinary experimental reflection on seven Portuguese *hydrogeographies.*

Despite the mentioned statements and a growing awareness on the same direction, the architectural regard to the built world and "other urban layers", including organic and designed water flows, hidrology, biodiversity, thermodynamics, is systematically lacking a connection. The physical action-consequence relationship is always present when building solutions, but there has been an absence in the cultural dimension of the urban discourse that only more recently is being developed, addressing these less "land-centered" matters.

As Lepratto & Zanotto (2024) highlight: *"combining the tradition of morphological and typological studies (Muratori, 1963; Caniggia, 1979) with the more recent research on urban biodiversity is an interdisciplinary approach that remains underdeveloped yet holds great potential".*

In fact, while architectural focus has recently started to shift to the need to care for ecological balances in the face of planetary impact, i.e. water natural dynamics, we currently find more prolific research and reflection on other field areas with a sense of territory, such as geography and even technology.

Following the studies of Matthew Gandy and David Sedlak, water - and the society's attitude to water -, is an important element of civilizational evolution, being the Rome's majestic aqueducts the "first water revolution" (Sedlak, 2014) that first allowed for significant urban expansion with the associated cultural and knowledge development.

The Haussmann's Paris works are also referred as paradigmatic moment in urban history, the "second water revolution", according to Sedlak, where the implementation of a technological element, a new urban lexicon – sewers – absolutely changed the city's surface and urban image. The opening of new healthy avenues in the urban fabric meant a new image for the city while, below the surface, the true revolution was being built. This moment marked also the historical pivotal point where water flows in the urban space started to become fully invisible and dissociated with the composing elements of the city.

In order to rescue water spatiality from invisibility in the architectural discourse and reflection, a conceptual mechanism – an urban-water correlation matrix - is developed with the objective of "translating" into contemporary architectural "language" the emerging multidisciplinar studies addressing the past and future of water in the urbanization and urban planning, identifying the *liquid framework* underlying in the urban elements rationality.

3. Water lines and urban design: a two-system conceptual matrix

Here we present a first version of this *liquid framework* matrix, intending to define a correlational model for the universe of concepts that define each system.

Two systems are identified and unfolded together: water flows and urban morphology. The urban morphology branch is expanded at the first level following Giambattista Nolli ichonographic criteria where public space is represented as a map "white/negative" and private space and urban fabric are represented by "black/positive" figures. Urban fabric is represented by "housing" use in this matrix, since this is the main urban use filling the urban morphology and the one that allows for an broader scaled analysis, from macro-territorial scale to the housing unit.

The water branch is expanded under Gandy's idea that *"water lies at the intersection of landscape and infrastructure, crossing between visible and invisible domains of urban space"*, and in turn developed at more levels in each branch, aiming for a capillarity able to describe the ever-tightening geometry of these continuously linked systems. Each level unfolds into the next one, organizing an tree of material and immaterial concepts that compose the map of the problem in study.

The objective is to bring together a universe of concepts that not only are present in the analysis but also have specific defined relationships between themselves, considering the fields of geography, technology, urban morphology and architeture.

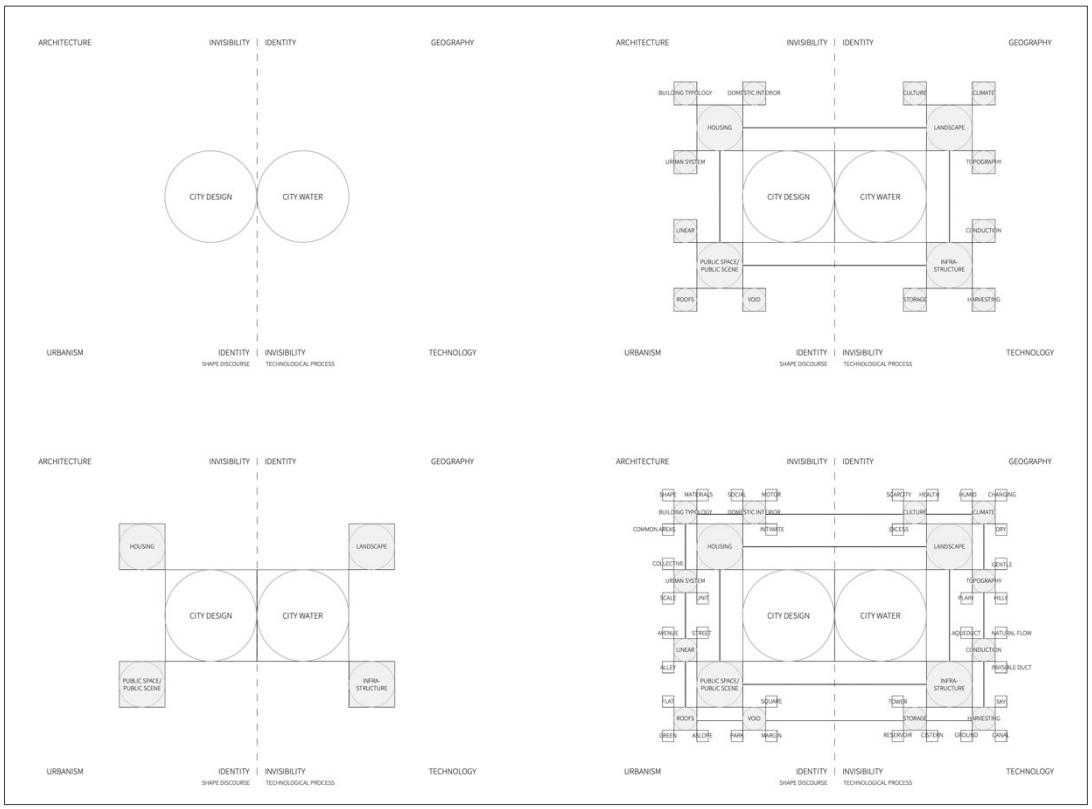

Figure 1. Conceptual matrix unfolded (Developed by Author).

3.1. Lisbon's urban and water palimpsest

In accordance with the approach to the theory of territory set out in the plan from to the catalogue of the exhibition *Carrilho da Graça: Lisbon* (Graça, 2015), the architect proposes a vision of natural topography as the first order of the city's form, in which notable buildings are located on ridge lines or plateaus, and the city's routes and public spaces are often associated with valley lines, defined by the natural topographic path of water.

If at first the relationship between urban form and natural elements is direct and expressive, the modernization of urban space through progressively more sophisticated infrastructural systems together with the hygienic principles of city production brought new expression.

The first order demonstrates graphically a very close correlation between urban morphology and topographic landscape.

Figure 2. Lisbon map, coding topographic ridges (red) and valleys (blue) in city's morphology. Author: Architect Carrilho da Graça (2015).

3.2. Urban lexicon transitions

The Lisbon aqueduct was built in the 18th century as a water infrastructure with intentionally impressive architectural expression on a territorial scale - a new technology associated with a new cultural and symbolic

conception of the city. It was related to properties on a broader scale in the mosaic of the city's periphery - production farms, convents, among others.
With the opening of Avenida Infante Santo in the 1950s, the longitudinal direction of the existing valley was given priority, as an important road artery and axis of development for future construction, to the detriment of the transversal relationship that the aqueduct created over the local landscape.
Consequently, this aqueduct branch was partially demolished in 1949 to make way for the works on the new Avenue, with sections remaining semi-buried on the side slopes of the valley, as well as the public fountain, which is still there.
This (infra)structure, with an architectural program and imposing placement in the landscape, remains in some areas of the city as a scenic element, without a utilitarian character but with a strong evocative, cultural and heritage character, representing not only a water distribution technology but an important architectural element of the city of Lisbon and is a testimony of the palimpsest that the water technological and urban lexicon transitions imprint in the city morphology.

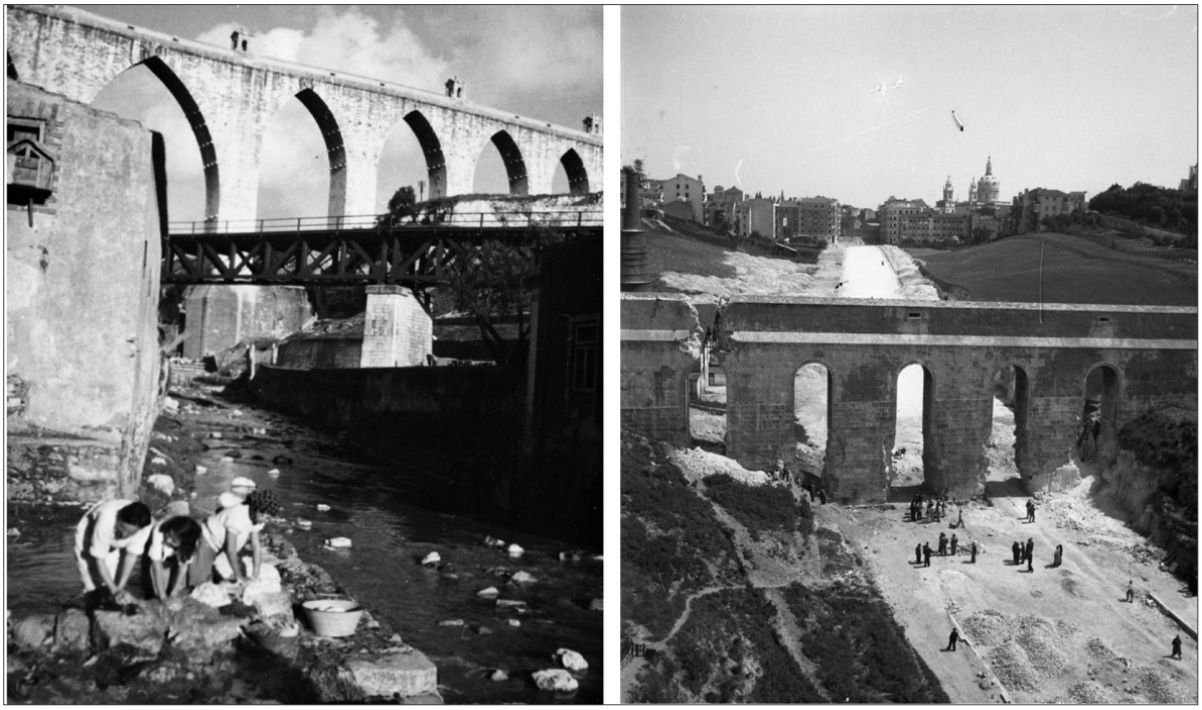

Figure 3. Historical photographies documenting water transitions in Lisbon's urban space. Lisbon Municipal Archive.

4. Discussion

Although this essay represents a first approach to the study that may still be perfected and further contextualized, the *liquid framework* concept is presented and translated by the *urban-water matrix* into architectural discourse from theoretical reflections on urban water by authors from other academic fields. The manipulation of water flow has determined cities' formal evolution through time and "water revolutions" (Sedlak, 2014). A correlation with existing urban lexicons is tested, bringing us closer to the main question of how can architecture today contribute to shape future water sustainability. Some limitations on this study are acknowledged, since this can be interpreted as an outline for future continuity work and deeper methodological research and densification are demanded. The future steps will be to confirm these matrix's concepts and their relationships, or substitute some tree branches by concepts that prove to be more suitable. Once confirmed, the following step will be to bring these analysis into cartography, highlinghting the variables on the map in order to obtain a specialized visualization for the *liquid framework*, and identify systematic opportunities for urban-water integration.

5. Conclusion

From Vitruvius's foundational architectural writings to today problematization of urbanization in the face of planeatery resources scarcity previsions, water remains a central aspect, a physical element demanding technological solutions that are always translated into architectural forms, wether by intentional representation or by utilitarian invisibility. The water revolutions are defined by technological transitions that acquire cultural meaning and architectural expression, through new urban lexicons. This interdependence can be described through a matrix that helps establish a conceptual bridge between water system and urban morphology.
The example analyzed of Lisbon's Avenida Infante Santo allows us to observe two contrasting moments of the same territory, evoking themes such as the influence of infrastructure on the urban landscape, the cultural dimensions of each configuration and the resulting layered urban palimpsest.

From the methodological essay it is possible to conclude that, within the scope of the study about the presence of the water element in the city, there is a direct correlation between technology, geography, culture, urban morphology and architecture, areas that necessarily integrate the equation to be solved towards sustainable development. The liquid framework concept aims to address water material and cultural presence in the built territory, highlighting this hidden layer from urban morphology in order to foster architectural reflection on solutions and new urban lexicon designs that may bring sustainable balance.

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Conflict of Interests
The Author(s) declare(s) that there is no conflict of interest.

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