THE BLUE VEINS OF TEHRAN:

TOWARDS A SPATIO-SOCIAL CLASSIFICATION OF THE URBAN RIVERS

by

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ABSTRACT

Keywords: Urban rivers, small urban rivers, urban streams, classification, accessibility, space syntax, multi-river city, river-valley, Tehran, Darakeh, Darband, Farahzad, geomorphology, spatio-social

In the last few years, urban rivers have regained their value in society since the need for intra-city natural structures have increasingly been recognized in large cities. Understanding the city-river relations is a recurrent theme in the ecological, geomorphic, and hydrological studies. However, the urban rivers have less appeared as the subject of research studies from a social perspective, which is why the need for developing and enhancing knowledge in that area is felt even more urgent.

The social value of the rivers is tightly attached to their spatial attributes and their diverse forms of interactions with the city. Thus, to understand and explain the social dimensions of the urban rivers, their spatial qualities and characteristics must inevitably be studied. Difficulties in explaining the social peculiarities by the spatial attributes has led many studies to deploy Space Syntax as a tool to understand the social aspects of the river. These studies have mostly focused on the river cities with large scale rivers that conspicuously define the identity of their cities. There seems to be even less regards towards the smaller urban rivers which could also play their part in determining the social relations within the urban fabric.

Following the recent studies on the urban rivers, the aim of this dissertation is to discover methodological tools and approaches to define a spatio-social classification system to fill the void in understanding the rivers as social interfaces in the city. Due to the broad range of natural types of the urban rivers in various scales, this exploratory research exclusively focuses on the small urban rivers in Tehran and adopts a comparative analysis using Space Syntax methodologies. Furthermore, by integrating morphological and topographical features of the city in different sections of the rivers, the study endeavors to devise a new method to capture a wholistic view of the small urban rivers that could unfold how a multi-river city structurally evolves around its natural ecosystem and how it socially responds to its small rivers and streams.

The findings of this study revealed that a river's role can vary along its length depending on the level of contrast between the spatial networks of the sides of the river. The outcome of the exploratory geospatial evaluations highlight that although the topological features of the city do not have a direct correlation with the urban network, it does signify a pattern in the system that could influence the social structure of the network. Studying such patterns could lead to a classification of the urban rivers based on their social and geomorphic attributes which can facilitate the process of any future studies or urban developments along the intra-city rivers.

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Table of Contents

List of Figures

List of Tables

List of Charts

1. Introduction

1.1 The rivers in the urban context

Rivers are arguably the most important natural features that are present in nearly all large and, old cities, in different sizes and forms, as they provide the fundamental requirements for the human habitat (Knoll et al. 2017). These natural features were not only vital for human life, but they were also the cornerstone of societies. Today, in an urbanized world, the significance of the rivers mostly lies in their potential of making an interactive dialogue with the city on a social level (Keil, 2005).

In the last century, many of the intra-city rivers have been lost merely due to the absence of this kind of spatial connection to the urban fabric. The alarming impact of river losses on different aspects of the city, has raised sensitivity towards river management, conservation, and restoration projects in the past few decades. Consequently, classification systems have been deployed as a guiding standard to aid managers in different stages of urban river projects (Davenport et al, 2001). Multitude hydrologic, environmental, and ecological taxonomies of urban rivers have effectively contributed to successive restorations of intra-city waterbodies (e.g. Banihabib and Jamali, 2017).

Although the substantial value of the urban rivers has been increasingly recognized in these fields of study, failures in recreating a sustainable interface that links the two dynamic structures of the river and the city, indicates the lack of an in-depth understanding of the spatio-social aspects of the urban rivers. Therefore, this piece of work endeavors to highlight the social values of urban rivers *through the prism of space*[1] (Hilllier and Netto, 2002) relying on experimental geospatial methodologies for classification. The findings of this dissertation are based on studying the small urban rivers of Tehran – a megacity with a wide range of social and topographical features. This study aims to set the foundations for future developments in measuring the spatio-social dimensions of urban rivers in all civic contexts.

[1] Adapted from Hillier and Netto's publication in 2002, "Society seen through the prism of space: Outline of a theory of society and space". This article highlights the constructive and often overlooked role of space in creating and preserving society and tries to disclose society through detailed mechanisms of space.

1.2 Defining Multi-River Cities

Fluvial cities in the world are mostly recognized for their large rivers. Urban rivers like Thames, Seine or Danube evidently yield a conspicuous identity for their cities. These large-scale rivers often overshadow the role of the smaller tributaries like river Wandle or Brent in shaping London (Vanegas, 2019) and river Bièvre and Ourcq in shaping Paris (Letherland, 2019). Such river-cities – Which in this study are referred to as the "Mono-River" cities with one monumental river and many tributaries – may yield different characters from the cities with multiple small urban rivers with the same scalar appearances. It is argued that the small urban rivers and artificial watercourses like streams and canals – even in the absence of a largescale river – can also determine the character of cities such as Tehran or Amsterdam, although not collectively comprehensible as an identifiable landmark. Just like the "Mono-River" cities (like London and Paris), "Multi-River" cities (like Tehran and Amsterdam) have an intimate connection to their rivers and owe their identity to their small rivers. In this study, the Multi-River cities are defined as the cities with three or more distinct rivers or watercourses that have the same dimensional attributes and no outstanding or monumental river. Discovering a method to explore the extent to which the city corresponds to its fluvial networks – and the landforms created by them – could uncover and highlight the true character of a multi-river city. Studying this reciprocal interaction can be complex and puzzling due to disparities in structure. However, by categorizing the miscellaneous types of city-river relations we can overcome the difficulties in defining the nature of such urban developments.

1.3 Research questions

This research study aims to answer three main questions that are raised in the context of Tehran as a multi-river city:

1. How does Tehran as a multi-river city treat its rivers in terms of spatial and social connection? Are they treated as Links or Barriers?
2. How can the small urban rivers be classified according to their natural, urban, and social context?
3. How can the small urban rivers act as social interfaces within the city?

In the first question the focus is exclusively on the role of the small urban rivers traced in the formal, spatial, and social evolution of the city and the way the city responds to its rivers structurally. The aim is to discover the part each river plays in dividing the city as a natural barrier or integrating different parts of it as a linking feature. What is meant by connectivity here is the river's potential in facilitating both physical and social interaction between the sides. This is mostly detected through closely analyzing the spatio-social attributes of different sections of the city on their corresponding riverfronts.

The second question includes a comparative approach between the rivers and entails a methodological query. It involves discovering and quantifying the factors which identifies the river as a phenomenon that interweaves natural, urban, and social tissues of the city. The significance of this question lies in the need for a social understanding of the urban rivers and the lack of a spatio-social classification of the rivers which will be discussed explicitly in the next chapter.

This methodological query, within itself, calls for a third question regarding the social implications of the urban rivers to understand how the rivers work as a medium for society and the city. This question also searches for the ways in which the rivers enhance the performance of the city on a social level.

1.4 Introducing the case studies

1.4.1 Urban rivers of Tehran

Tehran with its rugged highlands is home to 8 main river-valleys (Vardij varish, Kan, Vesk, Farahzad, Darakeh, Darband, Darabad, and Sorkhehesar). These river valleys are densely packed in the northern districts of the city with higher altitudes. The northern parts of the city have taken an urban form from the major expansion scheme of Tehran in 1960s and have quickly developed with the growing population after the revolution in 1979 (Madanipour, 1998).

Searching for a contrasting set of representative case studies that can demonstrate the diversity of the city-river relations in Tehran, three main rivers of Darband, Darakeh, and Farahzad are opted for the purpose of this study within the districts 2 and 3 (Fig. 1.1). All these rivers have certain commonalities and distinctions which can be instrumental in comparing and sorting the river areas in the city.

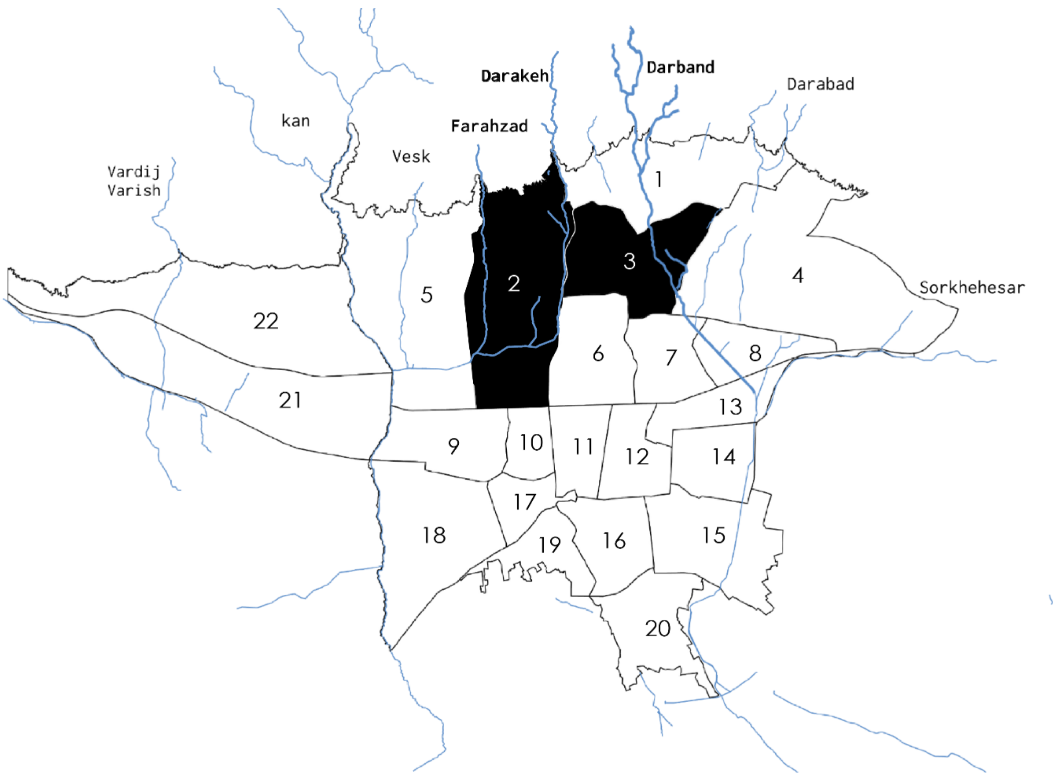


Figure 1.1 The map of Tehran district divisions along with its main river-valleys. The rivers of Darband, Darakeh and Farahzad in the black districts are the focus of this research study. Author

1.4.2 Case study 1: Darband river-valley[2]

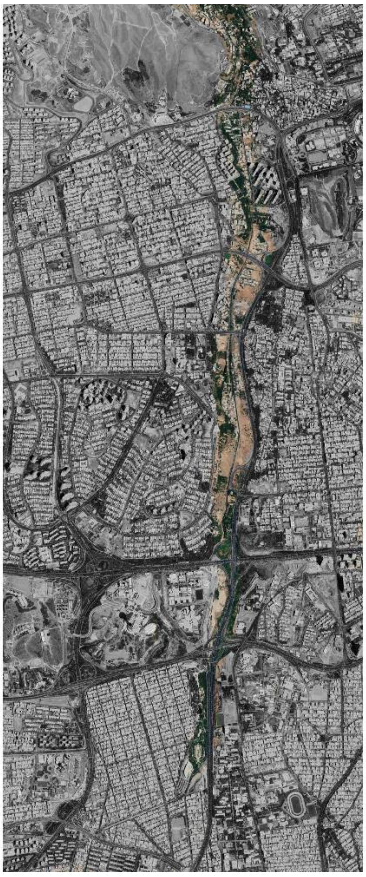
Darband river is the most prominent river of Tehran which is originated from Tochal mountain and is sourced from two rivers of Osun and Abshar Dogholu (Behbahani et al, 2003). Darband is famous for its recreational restaurants and hiking routes in the highest points of the city where it meets the mountains. After Kan river, this river is the largest by volume and length with the mean width of 10 meters and can be regarded as the most accessible arterial river that passes through diverse areas of the city. This river runs through many districts form North (District 1) to South (District 15) crossing most sectors in the East of Tehran along the way. Destructive flooding of Tajrish sourced from the Darband river-valley in 1987 became a turning point in Tehran's river management, and henceforth, the city's relation with its waterfronts was limited due to safety reasons (Tali and Nezammahalleh, 2013)(Fig. 1.2). During the urbanization process, the buffer zone between the river and the city shrunk and in the reconstruction after flooding of Tajrish, the river was leveled with the city, enclosed by flood protection walls.

Figure 1.2 Darband river overflow (Up-Left), Darband river flood fortification (Up-Right), Tajrish Flood destructions (Down). Image source ; http://onenewsbox.com/

[2] More information about this study can be found attached to the appendix of this paper under the name: "Syntactic convolutions of the river and the urban grid: An Analytical study of the small urban rivers in Tehran"

1.4.3 Case Study 2: Darakeh river-valley

Darakeh river is also well-known for its recreational facilities and hiking attractions in the mountains. There are multiple old villages which were organically shaped along this river (such as Darakeh, Evin and Vanak villages). Contrary to Darband river, Darakeh has preserved its natural essence as a river-valley during the modernization process of the city (Bahrami, 2018). This river is stretched along the marginal edge of district 2 parallel to the Chamran highway which is set as a dividing border between district 2 and 3 (Fig. 1.3). The character of the urban fabric in contact with this river is different from Darband river due to its topographical features. The steep slopes of the valley allow for the formation of wide green riparian areas – referred to as the green corridors of the city (Masnavi et al, 2016). Therefore, instead of compact dense commercial and residential blocks, the riverfronts are occupied mostly by several privately owned and spacious gardens.



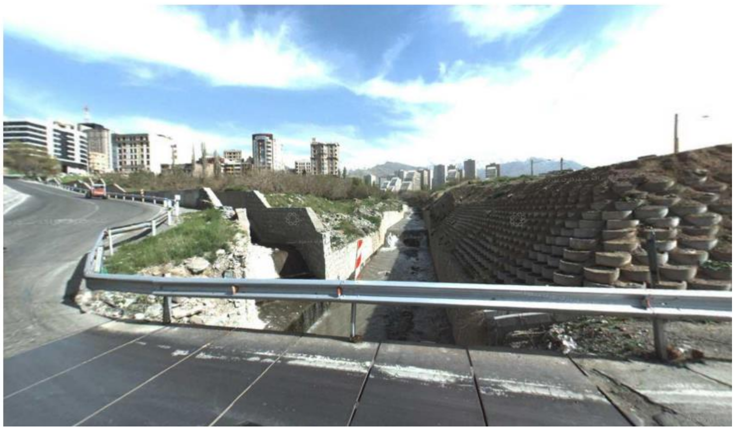


Figure 1.3 Darakeh river-valley (Left), Darakeh Recreational river restaurants (Right-up), Darakeh river in the urban context (Right-down). Image source ; map.tehran.ir

1.4.4 Case study 3: Farahzad river-valley

Farahzad river is relatively narrow and runs through a V-shaped valley on the westside of district 2. This river passes through the old Farahzad and Poonak villages. In the past, Farahzad riverbanks were mostly allocated for farming lands and gardens which are now replaced by densely massed urban grids and high-rise residential complexes. In 2006, an enhancement scheme was developed to restore and reform the river-valleys of Tehran that included the Farahzad river-valley. Nahjol-Balaqeh park was one of the outcoming projects of this scheme in the Farahzad river-valley with four planned construction phases (Fig. 1.4). Its first phase completed in 2009 (from Hemmat highway to Hamila boulevard), and the second phase was opened in 2013 (from Hakim highway to Hemmat highway), however, the third and fourth phases are still under construction and it is expected to occupy more than 35 hectares of the riverine lands (Moayyedi, 2010).



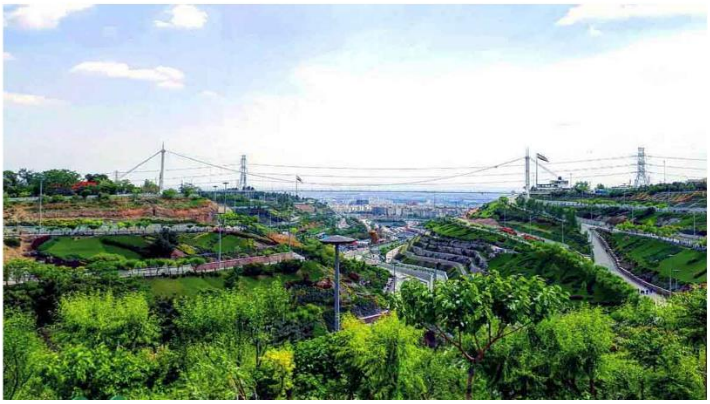


Figure 1.4 Farahzad river-valley (Left), Nahjol-Balagheh Park phase 1(Right-up), Nahjol-Balagheh Park phase 1(Right-down).
Image source ; map.tehran.ir

1.5 Research background and prospects

This dissertation can be considered as a continuation of a series of studies on the small urban rivers in Tehran. The preceding study on the Darband river extension in district 3 (Zargandeh and Pasdaran streams) and its relationship with the associated urban grid revealed much about the spatial and social performance of this urban river[3]. Analytical evaluations of the Darband river where also based on the spatial aspects of the surrounding urban network and social implications of the river. The study suggested that the Darband river in Tehran is like a loose string within the urban network that can work as intermediary route sewing the more globally connected roads to the more segregated streets and residential areas. It also scrutinized the orientation patterns of the building entrances along the river and indicated that the buildings that are oriented towards the river are more likely to promote commercial activities. The close observational readings of the riversides also revealed signs of social and individual space appropriations that emerge occasionally along the rivers' edge.

The outcome of the previous research project can inform this dissertation in studying other river-valleys of Tehran. Continuing the studies on the small urban rivers with more focus on the rivers Darakeh and Farahzad, this dissertation's ultimate objective is to define a framework for classifying the urban rivers based on their spatio-social and natural dimensions. This process begins by finding whether the city and the river engage in a reciprocal cycle and continues by questioning how the city defines and deploys each river in the system as a social interface.

The distinctive point about this dissertation project is the new exploratory method that combines the spatio-social dimensions of the city with the natural and topological features of the river as layers of a complex system. Tehran's topographical features could present methodological challenges that may be beneficial in devising an all-encompassing classification system for different city conditions in future studies.

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[3] This study can be found attached to the appendix under the name "Syntactic convolutions of the river and the urban grid: An Analytical study of the small urban rivers in Tehran

2. Literature review

2.1 The city-river structural coupling and the issue of interface

The history of the river and the city has often been told as a story of domination over the natural world and how human interventions has exploited the rivers to the point where the natural cycle of the rivers is disrupted posing serious threats to their existence (Massard-Guilbaud, 2017). However, it seems that this narrative was only reflecting one side of this relationship, in which the rivers are the victims of an urbanized world (Shamsuddin et al., 2013). This is while the more recent studies on the urban rivers has reached a consensus over the fact that the river and the city have had a reciprocal interaction in history and their relation were more of a coevolution than domination (Knoll, Lübken and Schott, n.d., 2017). This coevolution can also be discussed in the notion of structural coupling (Maturana and Varela, 1980) that rises from an interplay between two dynamic systems of the city and the river. This concept suggests that the interacting systems repeatedly perturb one another's structure to the point where it leads to the development of a structural 'fit' between the systems (Quick et al, 2000), although this 'fitting' is not fixed within the organisms and rather it is an ongoing and recursive process that ensures the sustainability of the situated interaction in time. Furthermore, according to Luhmann's social readings of the systems theory, the structural coupling of two distinct systems requires a medium that is excluded from the permanent structures of both interacting systems and is embodied (situated) in an abstract threshold between the two (Luhmann, 1991). There have been many discussions about the essence of this entity which lingers somewhere between abstract and concrete states. Lefebvre tries to reconcile these notions in the idea of 'lived space' (Lefebvre, 1991). Ironically, the nature of space itself very much falls into that same (dualism) domain. The controversial role of space in working as a medium or mediator of socio-cultural meaning discussed by Palaiologou, Griffiths, and Vaughan (2016) complements Luhmann's idea of the medium in structural coupling and has an intimate connection with the dynamic relationship between the rivers and the city and the sustainable interface between them.

2.2 The city-river syntax and spatial sustainability

In studying the city-river interface and its spatial sustainability, space syntax could be an instrumental theory in conveying both representative and constitutive meanings, which cover a wide range of economic, socio-cultural, and environmental facets. The notion of spatial sustainability is a recurrent theme in the urban literature, however, there has been less regards towards the contribution of the form of the spatial networks to sustainability. According to Hillier, "The kind of structure brought to light by syntax seem already to be a product of interaction between environmental, economic and social factors, that is, between the three principal domains of sustainability" (Hillier, 2009). Therefore, Space Syntax could be an all-inclusive tool to explore the socio-economic aspects of the city-river interacting systems. Although it is worth understanding the constrains of using such methods in interpreting the topological aspects of the city-river relations (Pafka et al, 2020).

For Hillier, there are two concepts that seem to be naturally present in the generic spatial form of the self-organized cities which can contribute to sustainability. First, it is the notion of *Pervasive Centrality*, which refers to a multi-scale centrality that is not necessarily a hierarchy of locations but rather it pervades the urban grid with a clear spatial correlation (Hillier, 2009). And second, the concept of *Fuzzy Boundary*, which explains how the internally structured space relates to its external context in the form of an area boundary (Yang and Hillier, 2007). In the context of the urban rivers, traces of these concepts can be found in the way the city forms along the river and in the way it sets a threshold that implies a linear spatial corridor within the city without having a clear and tangible boundary. This, eventually, brings us back to the problem of interface that is intertwined with the meanings of boundary and threshold (Palaiologou et al, 2016).

2.3 Urban rivers in diverse fields of knowledge

Urban rivers have been the focal subject of research studies in diverse fields and disciplines with different perspectives. The city-river relations have offered challenging questions regarding the environmental and ecological issues as well as many social and spatial matters rooted in different aspects of urban, human, and natural sciences (Darby and Sear, 2008). The fact that this topic has multiple implications in distinct fields of knowledge shows the importance of studying this phenomenon to a greater depth. It also reveals how such a multifaceted subject can be difficult and challenging to study. The complexity of this research topic lies in the fact that the city and the river are both two intricate dynamic systems that can each be independently studied. Therefore, studying them together requires a wide range of background knowledge on many different aspects of the city and the natural rivers.

2.3.1 Urban rivers and restoration projects

There has been a growing literature on how to restore and recover the lost rivers of cities in the past few decades which has had less regards towards how these regeneration projects can effect and change the intrinsic relationship of the city and the river on a more holistic level. Although it is imperative for the restoration projects to know how to cope with the probable flooding threats (Darby and sear, 2008) and to understand how these interventions are affecting the quality of water (Xu et al., 2020) or the riparian vegetation and ecosystem (Hughes et al., 2008), it is possible that the ultimate outcome does not maintain a kind of a dialogue with the city on the spatial and social level which is substantial if the city is to work with its natural resources. Restoration projects are also a reliable source that can hint the failures and shortages of past examinations on the urban rivers and could lead to a more informed decision making in the future projects (Kondolf and Pinto, 2018).

2.3.2 Urban rivers in cultural symbolism

The close relationship between the human communities and the rivers, and the dependency of human life to water have sanctified the rivers to the point where they are not just the suppliers of energy and food, but they can be read as a symbol in diverse cultural contexts (Knoll, Lübken and Schott, n.d., 2017). This symbolism has many applications in the literature and art as an expression of society's collective state of thought and emotions. The way Charles Dickens depicts Thames as a symbol of redemption in the Victorian times, while mirroring the mistrust and uncertainty towards urbanization and modernity in the polluted river (Kneitz, 2017); or the way Persian poets like Hafez and Rumi have used flowing rivers as the symbol of age that can never return, or the way they used the clearness of its water as an indication for the clearness of mind, and many other implications as such, shows how the rivers can convey a supplementary meaning for each community reflecting its particular world view (Zulyeno, 2019).

2.3.3 Urban rivers and medical sciences

On the other hand, medical researchers studying the effects of the natural environments on human health have revealed that the riversides and riverine parks provoke different types of activities which have positive impact on average annual health and reduces overall mortality and any type of morbidity like type 2 diabetes, cancer, etc. (Vert et al., 2019; Völker and Kistemann, 2011). The benefits of the urban river are not just limited to physical health, but it is also proven to be beneficial for mental health in different ages. Observations of children of 9-11 years old and studies on the impacts of their growing up along the river Thames, has provided new insights into how being close to waterfronts can effectively change the children's state of mind (Tapsell et al., 2001). There have also been several experiments on how the regenerated waterfronts has promoted the society's overall sense of responsibility and belonging towards the environment (Smith and Moore, 2013).

2.4 Urban rivers and the problem of terminology and taxonomy

There are long lists of terms which are used to describe the rivers and their various types and characteristics. Terms like "stream", "river-valley", "estuary", "creek" and "brook" are all diverse types of natural watercourses which are distinguished upon different attributes and characteristics of their topological features. Among the myriad terms used for natural rivers there are few which classify the rivers within the cities (Davenport et al., 2001). Most often, even these few terms are assigned to the rivers depending on their hydrological conditions and structural attributes and do not refer to their urban dimensions (e.g. Xu et al., 2020).

"Urban river" is a broad term that constitute many possible subsets of the city-river relations. Despite the various studies on both urban and natural rivers, there seems to be a void in terminology and taxonomy in studying the spatial and social dimensions of the rivers compared to the ecological, geomorphological, and environmental aspects of the rivers. Urban rivers differ from the natural ones mainly for their close relationship with the human habitat (Hermida et al., 2019), therefore, they require a different vocabulary signifying this link (e.g. "Stream channels", "canals", "Flumes", "floodways" and "drainage systems" are terms mostly referring to man-made structures for different watercourses that can be witnessed inside cities). However, these terms will not satisfy the complexity of the city-river relations and only point out the human intervention and structural form attributes.

Although the waterbodies in the cities appear in all forms and sizes, their relation to the surrounding urban network is also considerable (Abshirini and Koch, 2016). There are various approaches in how to classify the urban rivers; from dividing the urban river projects into types, (e.g. "Scenic rivers", "Decorating rivers" or the "Landscape garden city")(Shi et al., 2018), to sectioning the rivers into separate hierarchical zones based on their accessibility or riparian land-use (e.g. Hermida et al., 2019), or classifying the rivers according to their age (Davis, 1890). In another approach, there are articles focusing on the connectivity and comfort of the urban rivers which have introduced methods to sort the rivers based on their relationship to their urban network context with regards to the type of contact with water and scale (May, 2006;

Kondolf and Pinto, 2017; Silvia et al., 2006). However, altimetry and urban dimension can define a whole new classification system which is yet to be developed.

In this wide interdisciplinary subject, terminology and taxonomy plays a critical role in understanding what the study is dealing with. In many city-river case studies, even differentiating between a river and a river-valley can be disputable and decisive. Therefore, choosing proper terms and suitable classification system are important, as they can convey the core information about character, placement, time, and many other aspects of the phenomena in question.

2.5 Urban rivers and the issue of scale

One of the more pressuring issues that may have close links to the terminology and taxonomy in studying different types of the rivers within cities is the direct influence of scale in all aspects of the city-river associations. Scale has several implications when placed in different contexts of the urban river studies. In some papers it is used to define the extent of a river's impact on its waterfront urban tissue (Abshirini and Koch, 2016), while in some others it is regarded as the physical dimension of the urban river objects and their proportional relations (Kodolf and pinto, 2017). The ambiguity of the matter of scale in this subject lies in the mismatches between the scales chosen to study the urban system and the scales measuring the river object. Therefore, selecting and defining a mediating scale is imperative to help resolve the scale issues in interpreting such complex systems. In the works of Kondolf (2017), Silvia (2006) and Pinto (2017), the issue of scale is discussed considering both urban dimensions and the length and width of the rivers in question. On a closer observation, Kodlof and Pinto have even depicted different types of city-river relations particularly based on the scale of the river and the consequential impact that it has on the way the riverbanks are working on the social level(Fig. 2.1).

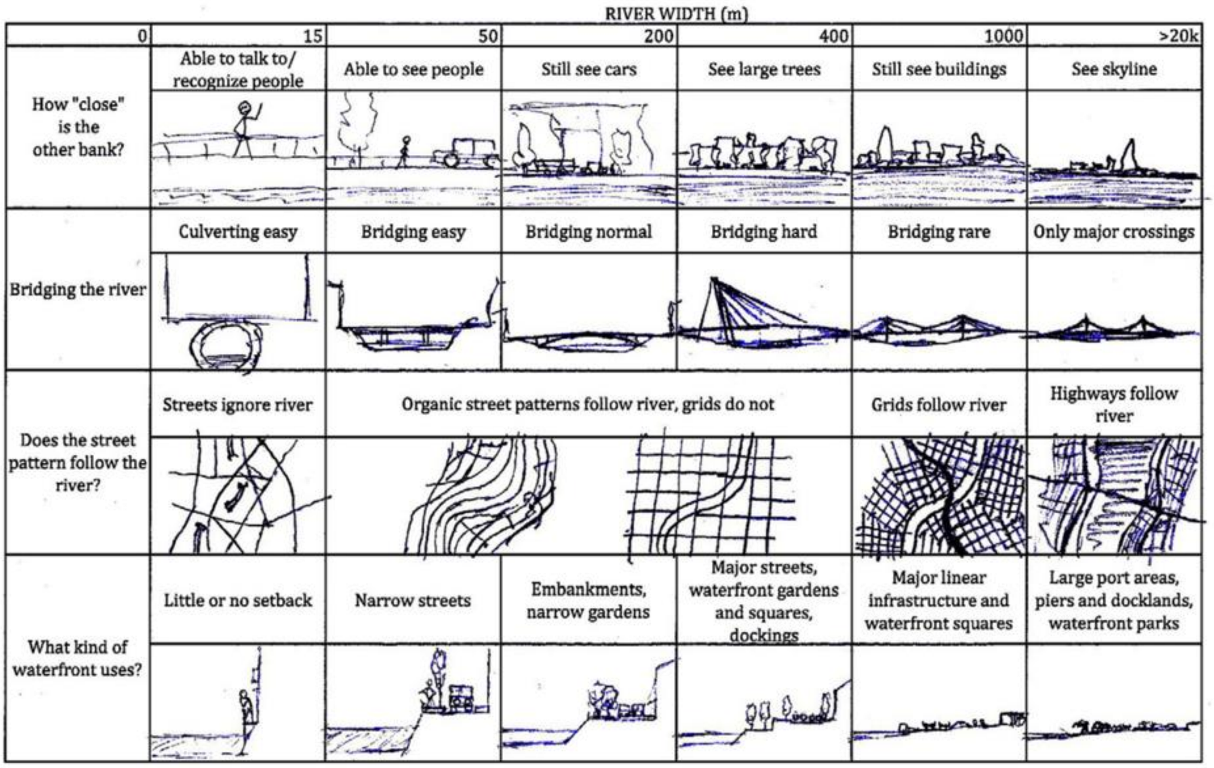


Figure 2.1 Kondolf and Pinto's depiction of different scales of city-river relations based on four phenomena.
Image source: G.M Kondolf, P.J. Pinto/Geomorphology 277(2017) 182-196

2.6 Urban rivers in Tehran

Most of the subjects discussed in the previous sections has been developed in similar research studies on specific cases in Tehran. The importance of the small urban streams and river-valleys in the megacity of Tehran has, lately, been recognized in the scholar investigations and municipal developments, which resulted in several restoration projects that are currently in progress throughout the city (Masnavi et al, 2016). Predominantly, the restoration projects are more leaning towards a recreational approach by reintroducing the urban green corridors, landscape preservation and creating public riverside parks (Payami and Laghai, 2013). But there is also a wave of water management projects aiming to reengineer the riverbeds to prevent flooding and control surface waters without any concern for aesthetic or amenity improvements (Banihabib and Jamali, 2017).

2.7 History of urban rivers in Tehran

Tehran was initially a small town laid on the foot of Alborz mountains near the Ancient city of Rey (Fig. 2.2) (Madanipour, 2006). Previous studies on the history of Tehran's urban rivers have shown that due to topological conditions this city was home to myriad streams and river-valleys running through its dispersed neighborhoods (Fig. 2.3), most of which were buried or vamped up during the urbanization process in the 1950s and some continue to work with the city on many levels (Mousazadeh and Izsak, 2018). Historically, Tehran was famous for its favorable weather conditions and abundance of water resources. Hence, with the inauguration of Ghajar dynasty, Tehran became the capital of Iran and has rapidly grown since then (Madanipour, 2006).

Figure 2.2 The map of the topography of Tehran along with the initial enclave core in 1930.
Map Source: Shirazian, Reza. 2017. "Tehran Mapping: Bank of maps and locations of old Tehran".

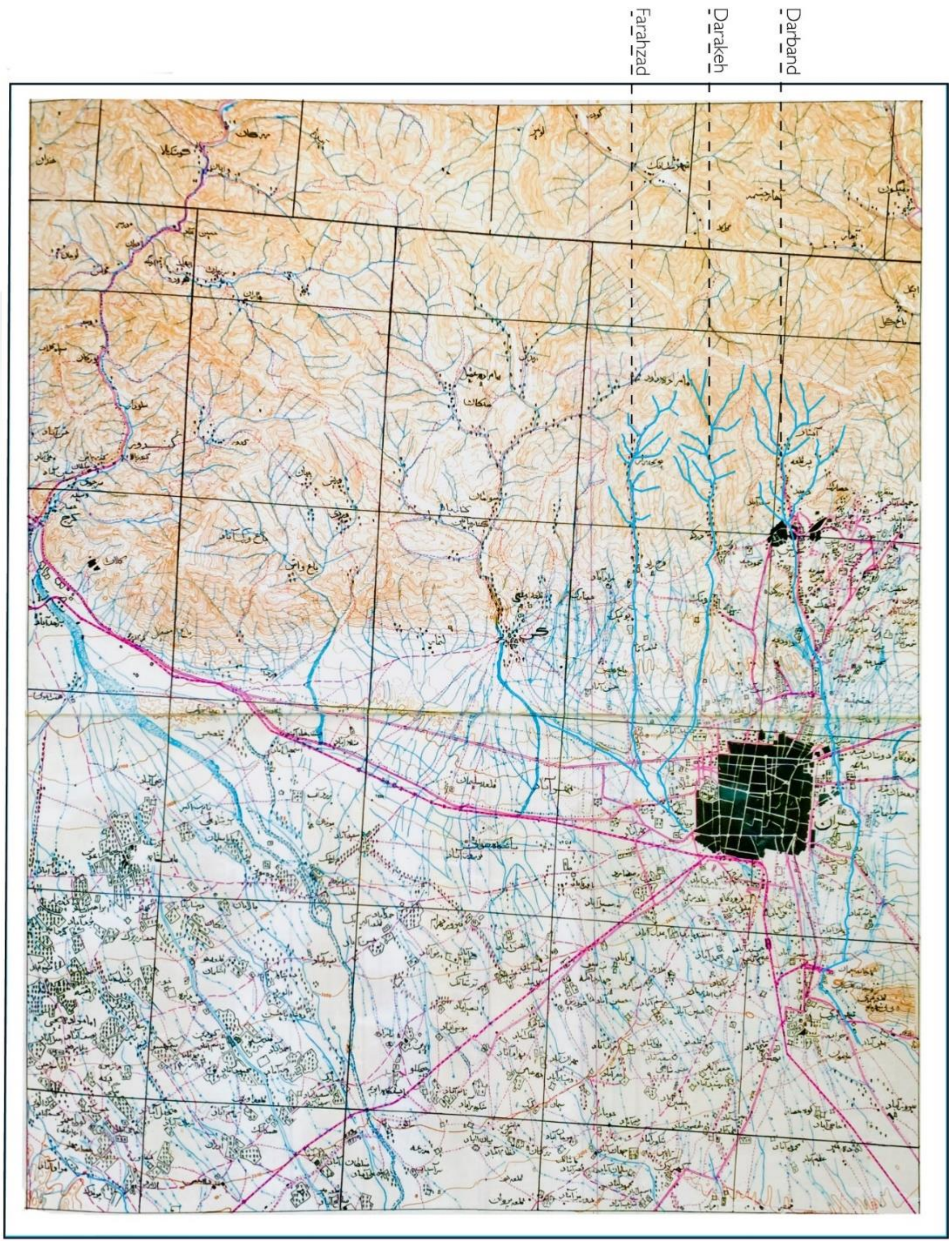


Figure 2.3 The map of Tehran with the natural surrounding rivers and streams in 1941, after expanding the enclave territory.
. Map Source: Shirazian, Reza. 2017. "Tehran Mapping: Bank of maps and locations of old Tehran". Edited by, Author

Tehran's initial expansion after the knocking down of its fortification walls, developed along its northern floodplains and stream-valleys[4] (Shirazian, 2017). These streams and river-valleys were closely attached to everyday life of the citizens and highly valued as they were the main resources of potable water for the city, and their riverfronts bestowed suitable conditions for royal resorts and recreational activities.

[4] Since the 1960s, three master plans have been prepared for Tehran. Despite the previous two master plans, the third plan was based on revitalization of the rivers and changed the attitude towards a decentralized urban growth where the river corridors were the main dividing north-south axis of a linear east-west expanded city (Khorshidifard, 2014). Today's district divisions and zoning plans comply with the general layout of the third mater plan.

Nevertheless, there were also downsides to the rivers since the city had to, occasionally, cope with the natural hazards of flooding and waterborne diseases.

Complying with the western technologies many of the fluvial water bodies were transferred into mortar culverts which some operated as a part of the city's sewage system[5]. By the late twentieth century, and with the sudden growth in population, the city has devoured most of its rivers, while expanding to accommodate modern urban infrastructure (Madanipour, 2006). The old villages along the rivers became part of the city, however, they have managed to preserve their organic structure and old identity along the way. Some of the most prominent of these villages – Namely Tajrish, Gholhak, Darakeh, Evin, Vanak and Farahzad – are still working as the local centers within the city (Fig. 2.4).

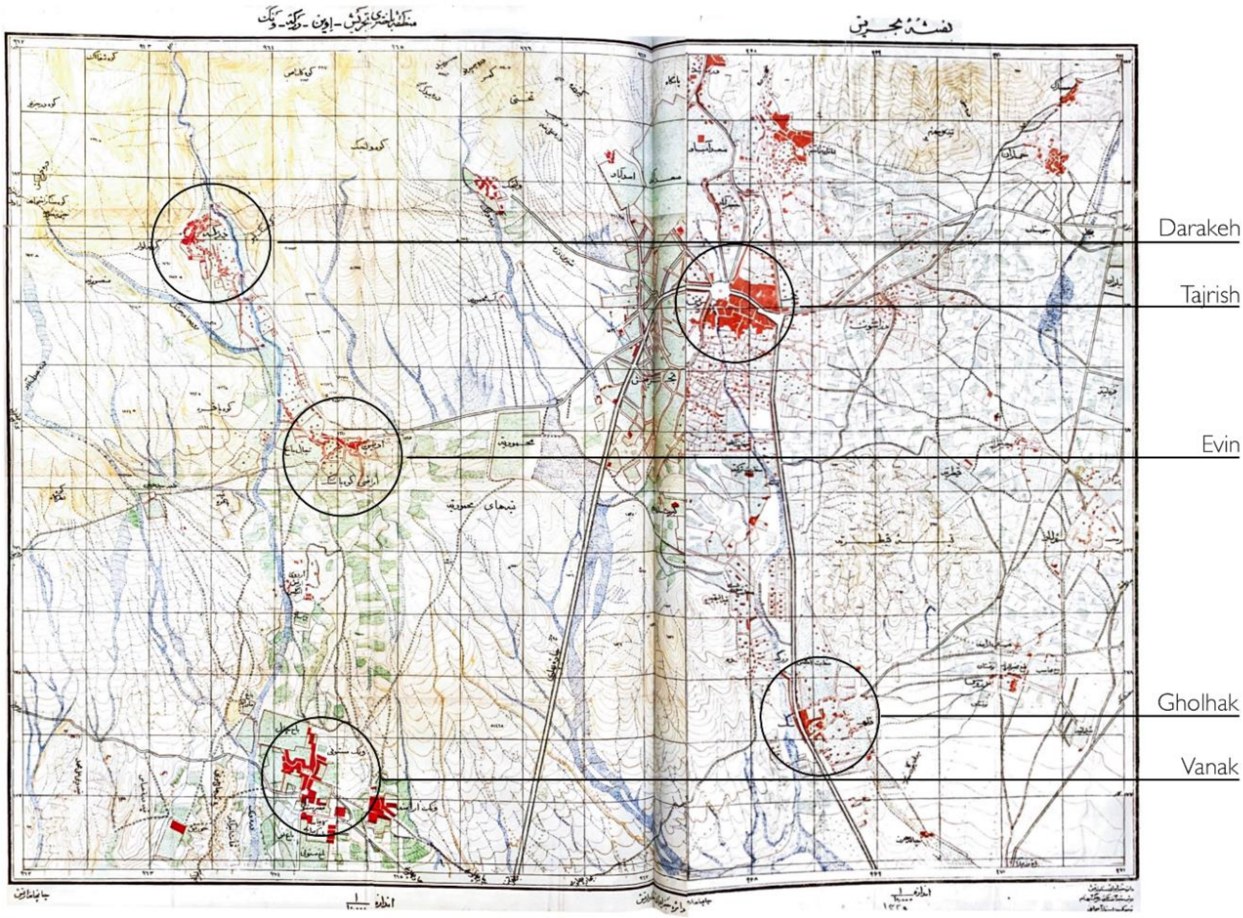


Figure 2.4 The map of northern suburbs of Tehran in 1950. The identified areas are the initial villages along the Darband and Darakeh river. Map Source: Shirazian, Reza. 2017. "Tehran Mapping: Bank of maps and locations of old Tehran"

[5] According to an old press publication in the mid nineteenth century – Vaqaye Itefaqieh, 1851 – the idea of piping and culverts, for preserving the water from contamination and ease of supply in Tehran, was initially proposed under the influence of London's innovative act of substituting wooden sewers with the low-priced iron pipes (Shirazian, 2018).

3. Methodology Rationale

3.1 Research Methodological Approach

In light of the recent studies on different aspects of the urban rivers, this research study aims to take a different approach on studying the city-river relation by reversing the focus looking at how the city is reacting to its rivers and how the morphological coevolution affects the life of the city on a social level. This transition from a river-centric view to a more social based city-centric view may offer an opportunity to discover and fill the gaps in knowledge of the urban rivers. To answer the research questions a configurational reading of the city is required to evaluate the performance of the intricate system of the urban fabric and the flow of movement along the river. Since the access to the river is mostly possible through the network of roads leading to the sides and the bridges that cross the river, the method conducted for this research utilizes a road-based analysis that could explain how the city connects to the rivers. Thus, using the space syntax methodology, a syntactical analysis of the urban layout, can shed light on the underlying strings linking the city to its rivers.

3.2 Classification Challenges and Solutions

Classification of the urban rivers could unfold many challenges due to the inherent discrepancies that lie in the characteristics of the natural and man-built environments. The curvilinear and protracted nature of the river and the radial expansion of the city is one example of these systematic mismatches that particularly make studying and classifying the urban rivers difficult. To overcome this barrier, it is imperative to study each system separately to understand the determining factors that influence the performance of each system on an individual level. Subsequently, by converting the measuring scales into an inclusive index the mutual factors in the interface begin to show how and on what levels the systems interact. Therefore, the methodology conducted for this research complies a step-by-step approach, from defining the study area to measuring the attributes of the river and the urban system, and eventually evaluating the combinatorial performances of the two systems in relation to one another. The following diagram briefly summarizes the rationale behind the methodology steps in the process to address different dimensions of the research questions (Fig. 3.1).

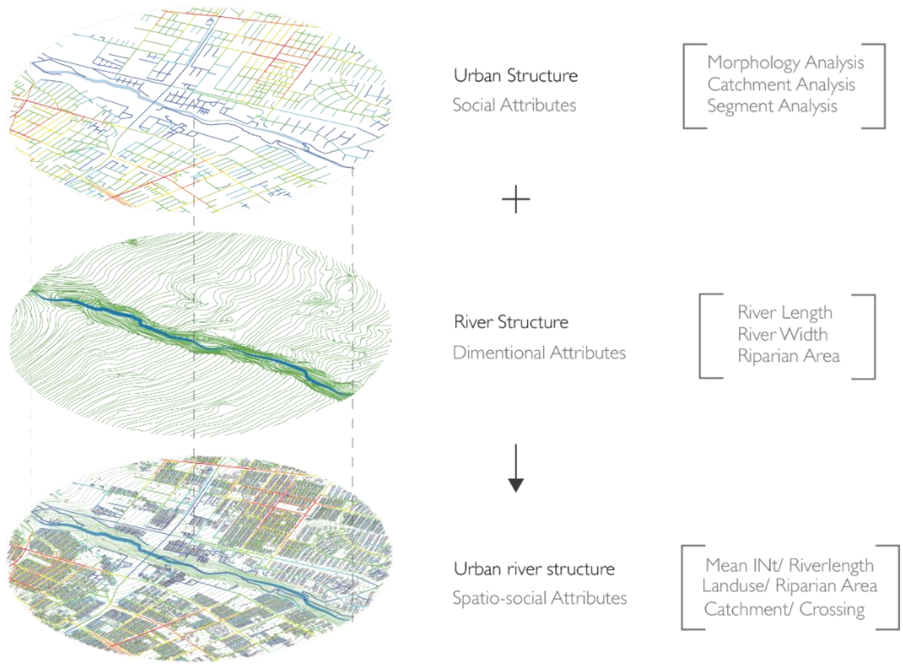


Figure 3.1 Summary of the methodology rationale. Author

As the reviews on the studies highlighted, the issue of scale is a lost yet important matter in studying the urban rivers, therefore, the study associates scale as a primary definition of the case studies which has an effective role in the way the city treats its rivers. In this context, the significance of scale concerns two aspects of the city-river relation. First, it is incorporated as the physical measurement of the river which includes the proportional size of the river's width and length as well as the extent of its riparian area. The physical size of the rivers is the first step in identifying and categorizing the rivers in the urban context. The second implication of scale involves the effective distance. This identifies the interface and its extent to which the river and the city actively interact on different levels. The way the city interacts with the rivers on a global scale is, evidently, different from the way it is perceived on a local scale. Incorporating the matter of scale in studying Tehran's urban rivers does not solely provide a base for comparing the rivers in Tehran, but also it can pave the way for future comparative research studies on urban rivers in different cities with diverse social, topological and morphological backgrounds.

3.3 Methodology Approach Regarding the River Structure

To a city or any urban environment, a river is always a territorial barrier, disrupting the continuity and the natural flow of movement from one side to the other (Silvia et al., 2006). Bridges are the only way of overcoming this barrier and maintaining the natural flow of transportation. The density of the crossings can be an indication of connection and fluidity of movement along the urban rivers. This, evidently, have an impact on the length and type of the contact with water and effectively alters the scenic perception of the river area. However taking into account the width of the river without considering how the riparian buffer zone can also impact the crossings can be misleading in many cases such as Tehran which its valleys and the flooding threats have inevitably expanded the safe zone between the city and the waterbodies. Therefore, the size of the marginal buffer zone between the livable area and the immediate vicinity of the water is also measured to ensure the inclusion of the topological constraints.

3.4 Methodology Approach Regarding the Urban Structure

Beside the topological features of the river and its riparian area, the configurational arrangement of the city itself has a fundamental role in creating and shaping the interface between the river and the society. Therefore, studying the urban performance on different levels in relation to the rivers can benefit the study in understanding how the city reacts. It is sensible to measure the attributes of the urban system based on the principals of the way people move in space, which is why in this context the research draws upon Space Syntax theories as the main methodology to capture the spatio-social behavior of the city along the rivers. The Land use and morphology of the urban fabric are other phenomena that contribute to or are the by-products of the movements in the city – The theory of movement economy (Hillier, 1996, 2007) – , which can also be influential in the interpretations of the parts of the city in contact with the rivers.

Furthermore, examining the compliance of the urban form from the topological lines in the river-valleys can provide another informative data that can explain the city-river interface in the common ground of topology. The city generally tends to avoid creating steep slopes in the network by bridging or breaking-down the system which can possibly affect the functionality and performance of the whole street network. Measuring these topological variances and its effects on the system are of todays' challenges and still unresolved (Pafka et al, 2020), however, this study endeavors to circumvent the major deficiencies of the process by devising a specific method suited solely for the particular objectives in this dissertation. Although it is worth mentioning that the limitations of this method include difficulties in acquiring the slope value in the precision level of a street segment. Nevertheless, the altitude level of the segments can be an alternative substitute if it is incorporated as a supplementary information alongside other values such as catchment or integration.

3.5 Methodology Overview

To conclude, the methodology rationale is to breakdown the classification process into three parts of: extracting the useful attributes of the rivers, analyzing the syntactical values of the urban system, and lastly, combining both to create a meaningful value that can indicate the socio-spatial characteristics of the rivers. In the methodology section, the variables used to identify the case studies and the parameters under these three steps are explicitly defined in detail. Using this taxonomical method, the study then draws upon the results to answer how the city treats the rivers in each part and whether they are considered as natural dividing barriers or as connecting joints between independent areas. Finally, it can lead to a comprehensive socio-spatial understanding of the city-river structural coupling.

4. Methodology

4.1 Defining zones along the rivers

Defining the boundaries of the research area in studying the urban rivers is problematic due to the protracted nature of the river which may considerably change the characteristics of the areas along the river and the urban fabric causing discrepancies in the results of the study (Frissell et al, 1986). Therefore, it is critical to break-down the urban river areas into smaller but more consistent zones by incorporating the river's area of influence. This ensures the inclusion of versatilities along the rivers. To apply a standard guideline for dividing and identifying each zone, two variables are considered:

1. Distance from the crossings and bridges on the river (Catchment Analysis)

2. Global dividing features of the city like the main highways and boulevards (Choice Analysis)

The first step in delimiting the river's area of influence is to identify the closest segments in a walkable distance from a crossing point on the river using metric step depth analysis or catchment analysis. This analysis uses the segment lengths to measure distance from a specific space in the network system. In this case, the catchment 1600m is opted to include the area within 20-minute walking distance of the river bridges. This would effectively narrow down the area of study to a limited corridor of streets along the river (Fig. 4.1).

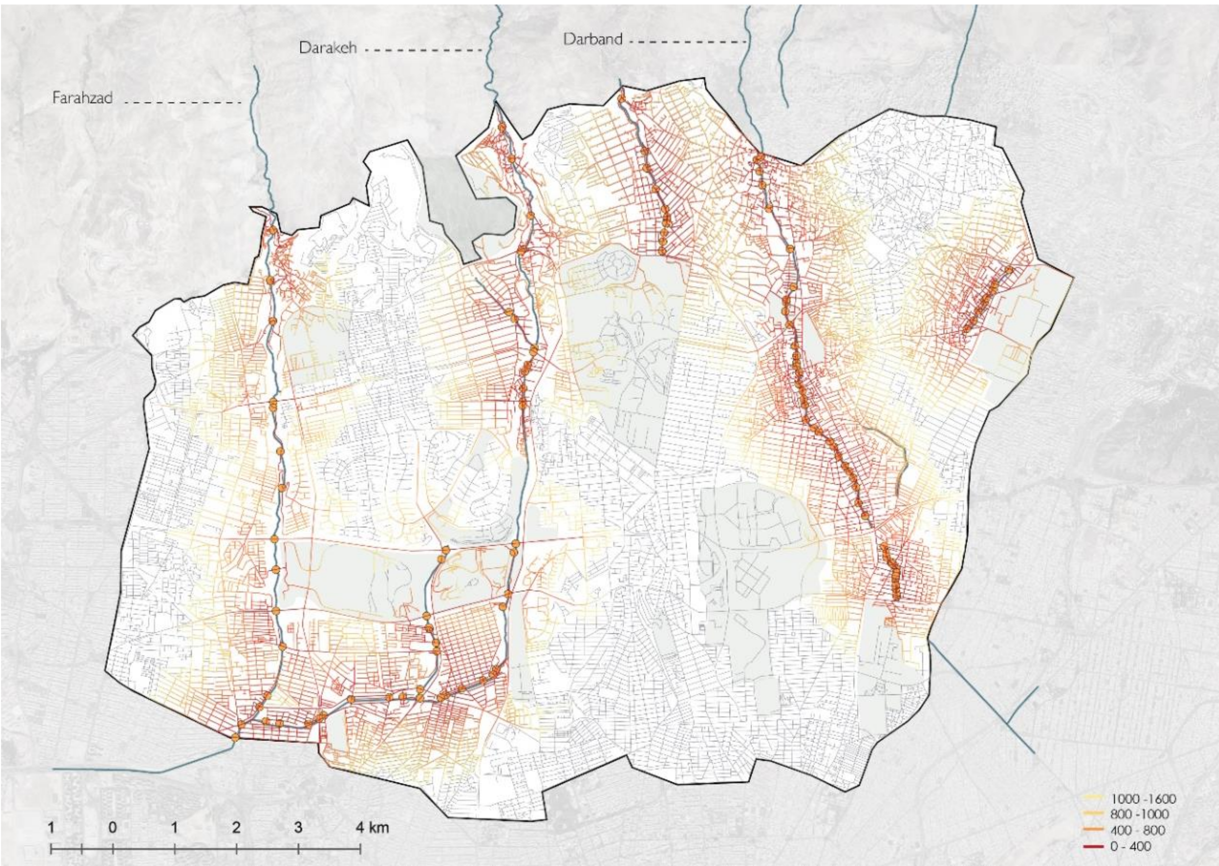


Figure 4.1 Rivers Catchment 1600m from the crossings. Author

The second step is to divide these corridors into separate zones by using another constraining layer that integrates the global divisions of the city based on the accessibility of the network. The indicator of accessibility in space syntax terminology is defined by two measures of Integration and Choice. Integration measures how close a space is to all other spaces in the system which captures a sense of to-movement in the system; While choice indicates how probable is to choose a space as a route from any space to any other space in the system that, ultimately, captures the through-movement (Hillier, 1998).

It is proposed that the streets with highest values in choice, are also a means of segregation, breaking the network into areas that are more locally integrated (Hillier, 2006). Therefore, the study uses the roads with the highest values of choice in the whole network as a subdividing layer on top of the river's catchment corridor to define the zone boundaries. Different radii of choice analysis 800m, 2000m, 5000m of the network system are run, among which, radii 5000m best illuminates the structure of these, thus is opted to define the river zones (Fig. 4.2). The road segments with choice values above 1.25 are identified as the dividing threshold of the zones (Fig. 4.3). The following figure outlines the river zone divisions based on the catchment 1600m and choice 5000m (Fig. 4.4).

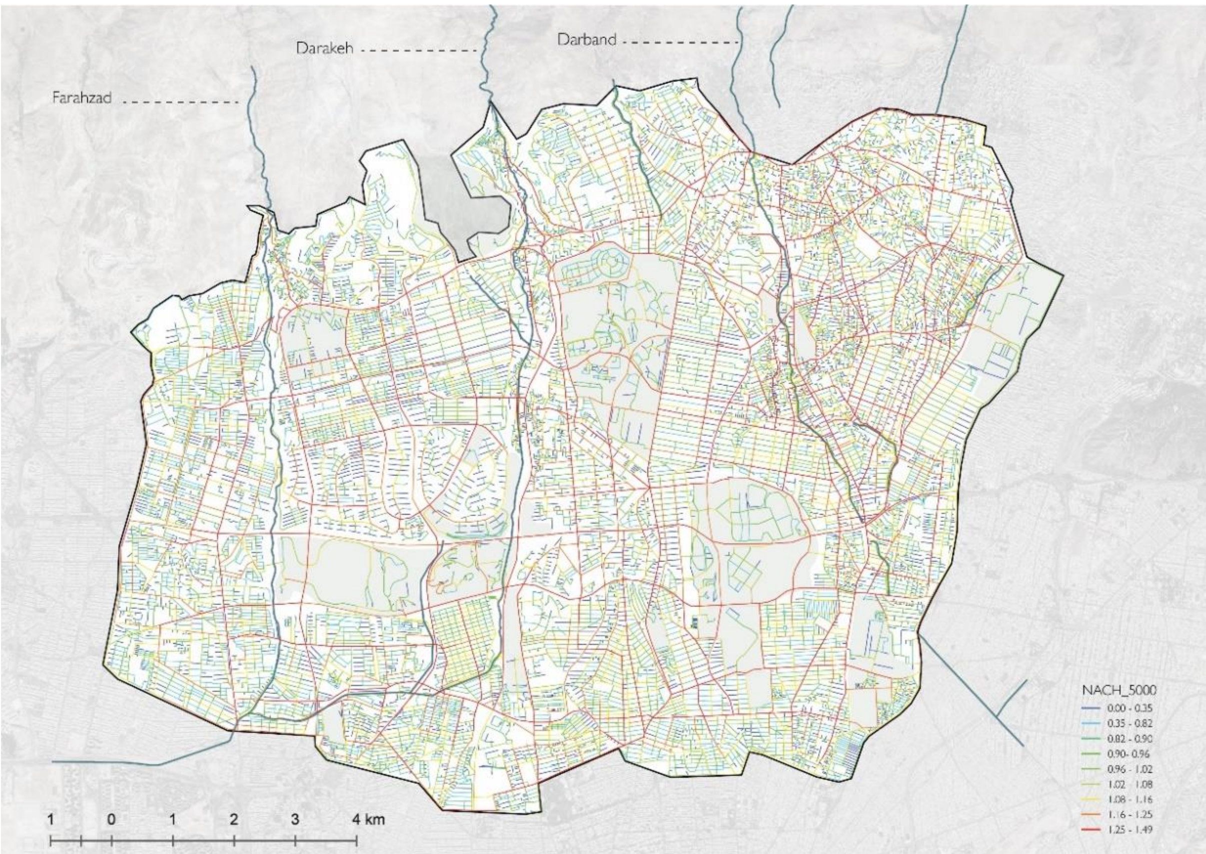


Figure 4.2 Normalized Choice analysis 5000m. Author

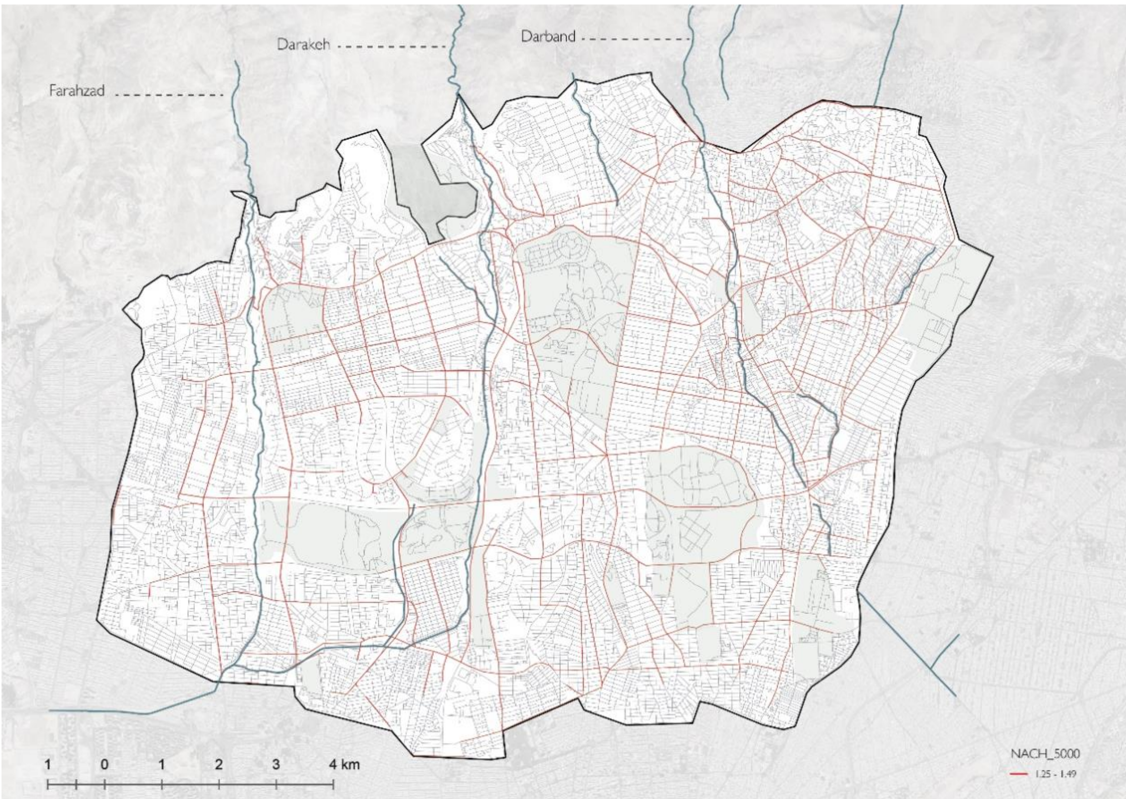


Figure 4.3 Colored segments are the segments with choice values higher than 1.2. These segments are used to subdivide the rivers. Author

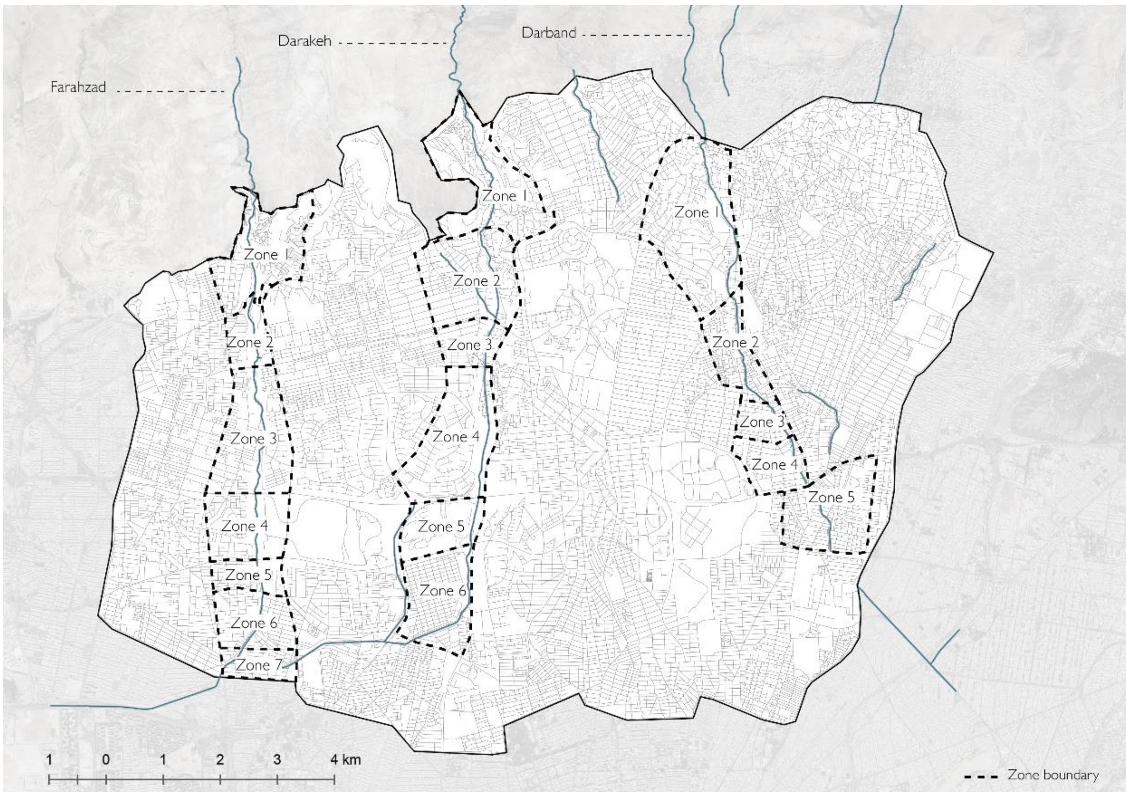


Figure 4.4 Defined rivers' zone borders resulting from superimposing Catchment 1600 and NACH 5000. Author

4.2 Methodology for measuring the river systems

To understand the river's spatial structure the dimensional attributes are measured. These dimensional attributes include the length, the mean width, and the natural riparian area of the river in each identified zone. Furthermore, obtaining the topological features of the rivers, like the river's slope or its mean altitude in each zone, can be revealing of the river structure. The main objective of extracting this information is to, first, identify the ecological type and characteristics of each river and, second, to acquire a common quantifiable unit based on which all other variables can be compared.

Measuring the length and width of the river is possible using the GIS of Tehran. However, measuring the exact boundary of the riparian area is not as simple, due to their fuzzy and indefinite boundary. For this reason, a method is devised to measure the natural riparian area of the rivers using the topology lines, satellite maps, and the urban edge. Since most of the rivers that possess a natural green corridor in Tehran are situated in the valleys, tracking the green corridors along the topological lines of the valley on the verge of the city can give a proximate outline of the riparian areas (Fig. 4.5).

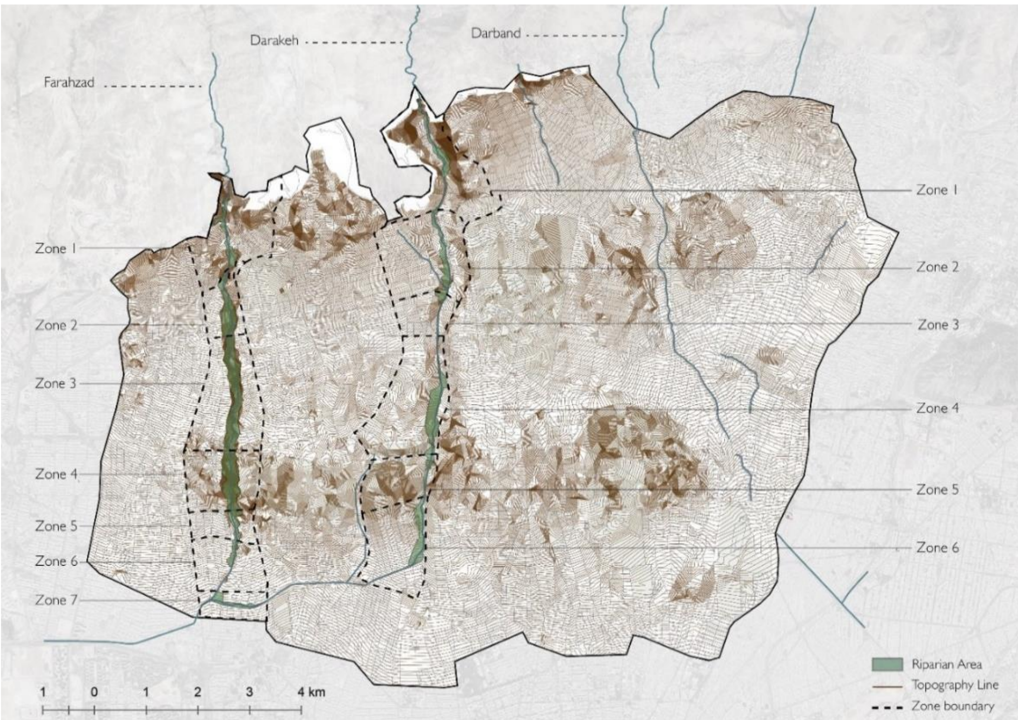


Figure 4.5 Riparian areas identified by tracking the turning points of the contour lines onto where it meets the street segment network. Author

4.3 Methodology for evaluating the city system

The main analysis of the city system is based on the street segment network in each zone using mean integration (M_INT) and mean choice (M_CH) values. The method conducted for the city system integrates segment length into the formula to calculate these values per total length. This would facilitate comparisons between zones and between rivers in the next steps. These values are calculated for three different stages for each zone. Initially, the segments in the immediate vicinity of the river within catchment 400m – 5-minute walking distance – are considered to compare the performance of the urban network system in close contact with the river. Subsequently, these values are evaluated for the segments in each side of the river to obtain a better understanding of how the structure of each side is promoting movement in each zone. A multi-scale analysis of 400m, 800m, and 1600m radii is run for each parameter of integration and choice to render an overall model of the urban fabric along the rivers with more precision.

Another contributing factor in determining the socio-economic movement in the city is the Land use pattern. There seems to be a relationship between the morphology of the riverside and the kind of land uses more prevalent in that area. This relationship was explored in a previous study of the Darband river area by analyzing the orientation of the buildings towards the river. Although this relationship is also true for the "River-valleys", which are the focus of this dissertation, the type of land uses that dominate the river areas are different from the type more pervasive in the rivers that run in the same level of the city fabric like Darband river. The land use type along these rivers tend to support activities that are associated with the natural green corridors, like parks, private gardens, or garden restaurants etc. However, what interests this study is not solely the number of these land uses in each zone, but their land occupancy per riparian area in each zone. Therefore, in this stage, the type and area of these land uses are also gathered from the land use attribute table of Tehran in the vicinity of the river-valleys.

4.4 Formulating the combined system

The last stage of the methodology is combining the gathered information about the river and the city and devising a new frame of reference for the urban rivers in general to facilitate evaluating and comparing the rivers and eventually pave the way for their spatio-social classification. This stage is the most important stage of the research since it reveals how the urban rivers are integrated into the city from a spatio-social perspective which has rarely been done in the past studies of the small urban rivers.

As pointed out in the last section, to construct a formula that could integrate all the determining factors which could capture the spatio-social nature of the urban rivers, a scalar unit is required, based on which, all the values can be transferred to one single unit and subsequently be compared. In this dissertation, the proposed scalar unit is the length of the river in each zone. All other values are then transferred onto this unit to standardize and make comparisons possible. The values that are measured per river length are: Crossings Density, Level of contrast, Green Land use Area and Mean Altitude.

Crossings Density counts the number of crossing bridges on the rivers in each zone per length of the river. This shows the possibility and ease of movement between sides of the river and how physically connected the riversides are in each zone.

Level of Contrast is measured according to the mean integration and choice per meter for each side and can indicate the average level of accessibility and flow of movement. This would effectively show how different the two urban fabrics perform on each side of the river. Ultimately, both values are subdivided and trajected onto the river length to visually present this difference between sides and zones.

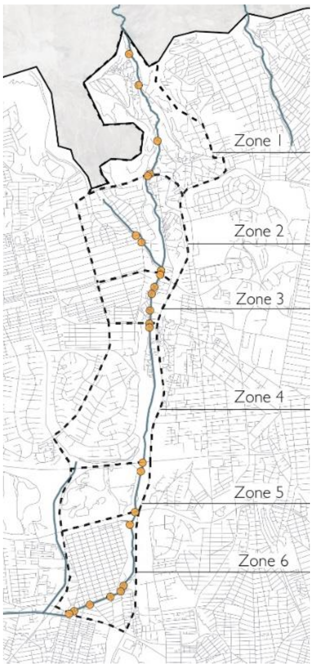
Green Land use Areas are calculated per riparian area in each zone to identify how much of the river's natural riparian is used for an urban function and to what extent.

Mean Altitude of the segments in each zone is compared to the mean altitude of the river to obtain the level of urban compliance with the topography of river-valleys. This comparison is presented through a scatter plot which is solely used to shed light on the relationship patterns between all the segments in zones, their altitude level, and mean integration and is not deployed to present a direct correlation.

5. Analysis and Findings

5.1 Darakeh river-valley stage 1: River attributes

Following the methodology steps in the last chapter, natural dimensions of the river is measured along with its mean altitude in each zone. The summary of these dimensional attributes indicate that Zone 4 is the largest in terms of river length, width, and riparian area (Table. 1). The number of the river's crossings are also counted per river length to identify the density of the bridges in each zone. The results show a higher density of crossings in zone 3, while zone 4 has the least number of bridges in relation to its long river length (Chart 1).



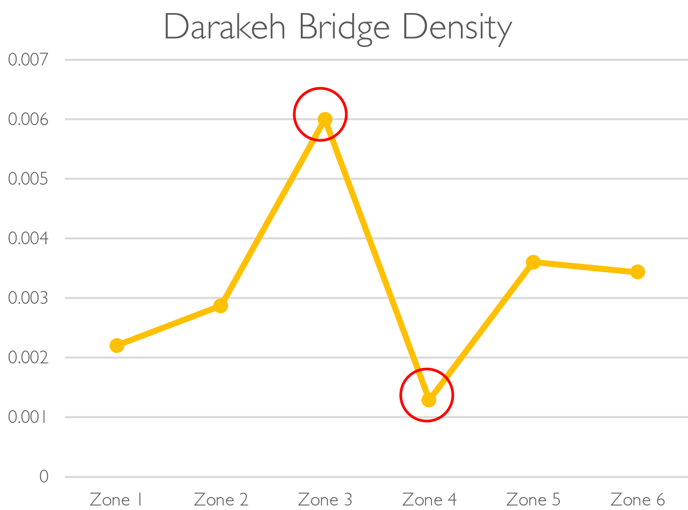


Chart 1. Darakeh river Bridge Density. The vertical bar indicates the density of the Crossings per River Length in each zone (n/m). Author

Darakeh River Zones	River Length	Mean Width	Riparian Area	Mean Altitude
Zone 1	2.266	6.5	155796	1718
Zone 2	1.742	6.2	174146	1598
Zone 3	0.833	5.6	44139	1580
Zone 4	2.324	7	287628	1459
Zone 5	0.833	6.3	56517	1405
Zone 6	2.328	6.7	190962	1354

Table 1. Darakeh river's Dimensional and Topological attributes summary

5.2 Darakeh river-valley stage 2: Urban analysis

In the next step the attributes of the city are measured using space syntax methodologies. Initially, the total number and length of the road segments in the network are extracted to identify the scope and proportion of the segments in the immediate vicinity of the river (Catchment 400m) in relation to the whole zone segments (Table. 2). This table shows that in most zones – apart from zone 3 – less than half of the segments are within 5 minutes walking distance of the river.

Darakeh River Zones	Total Segment Length	Total Segment count	Catchment 400 Segment count	Catch400/Total
Zone 1	12132	734	332	45%
Zone 2	12888	550	142	26%
Zone 3	8742	216	124	57%
Zone 4	4658	430	58	13%
Zone 5	3608	203	22	11%
Zone 6	22183	547	270	49%

Table 2. The summary of urban **Segment Count** and **Segment Length** for each zone of **Darakeh** river area. Author

Subsequently, the Integration (Fig. 5.2) and Choice (Fig. 5.3) analysis are run and compared for three different radii of 400, 800 and 1600 for a collection of segments in 5 minute walking distance of the river to evaluate the performance of the urban system on local areas within the catchment of the river in each zone (Table 3). Chart 2 suggests that the integration value generally rises coming down along the river from north (zone 1) to south (zone 6). However, this rising is not consistent for higher radiuses of 800 and 1600 and slightly drops in zone 5. On the other hand, Chart 3 indicates that the choice values vary along the river with a sudden upswing in zone 4 for the radius 1600 in the close vicinity of the river.

Darakeh River Zones	M_INT 400	M_INT 800	M_INT 1600	M_CH 400	M_CH 800	M_CH 1600	M_Altitude 400
Zone 1	0.75	0.58	0.53	1.08	1.07	1.07	1679.89
Zone 2	1.12	0.91	0.84	1.03	1.06	1.04	1572.82
Zone 3	1.09	0.96	0.91	1.08	1.09	1.07	1502.27
Zone 4	1.2	1.06	1	1.05	1.08	1.18	1472.68
Zone 5	1.31	0.95	0.73	1.06	1	1.02	1381.84
Zone 6	1.32	1.23	1.04	1.07	1.09	1.09	1317.81

Table 3. Summary of the **Mean Integration** and **Choice** for three radii of **400**, **800** and **1600** along with **Mean Altitude** of zone segments of **Darakeh** river. Author

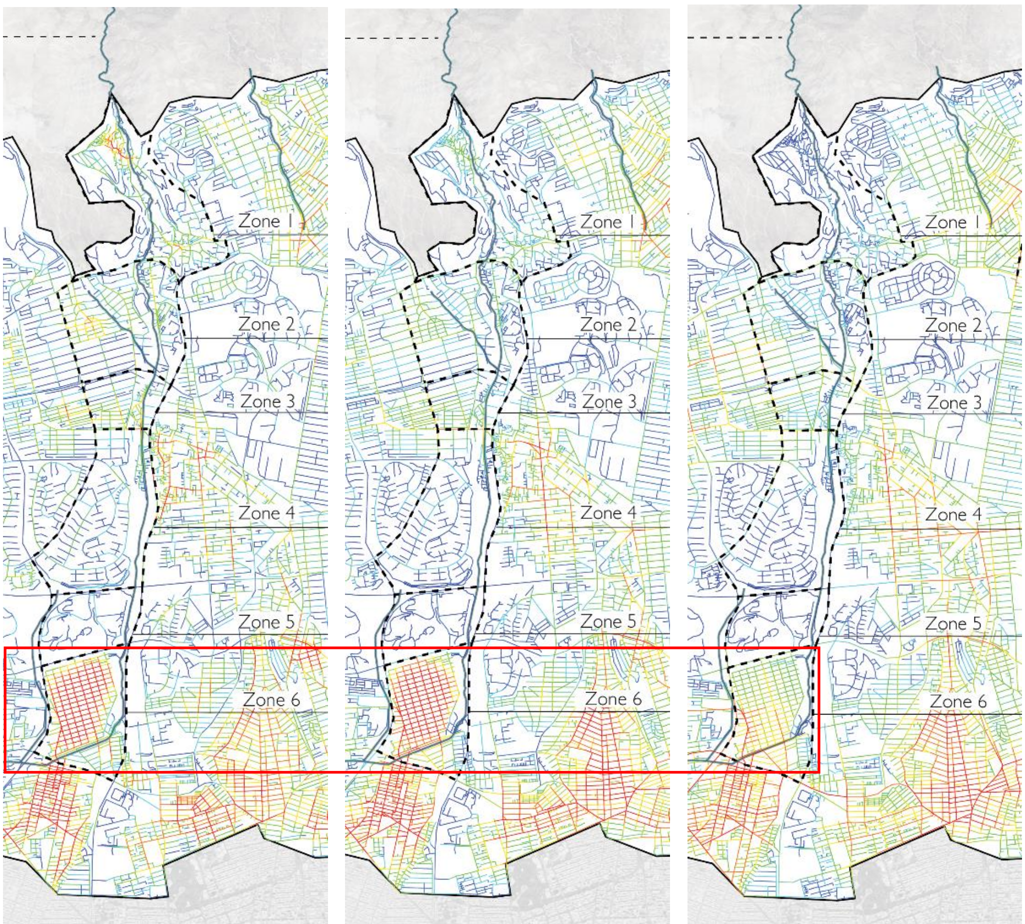


Figure 5.2 Integration Analysis for three radii of 400 (Left), 800 (Middle) and 1600 (Right) with zone divisions of Darakeh river. Author

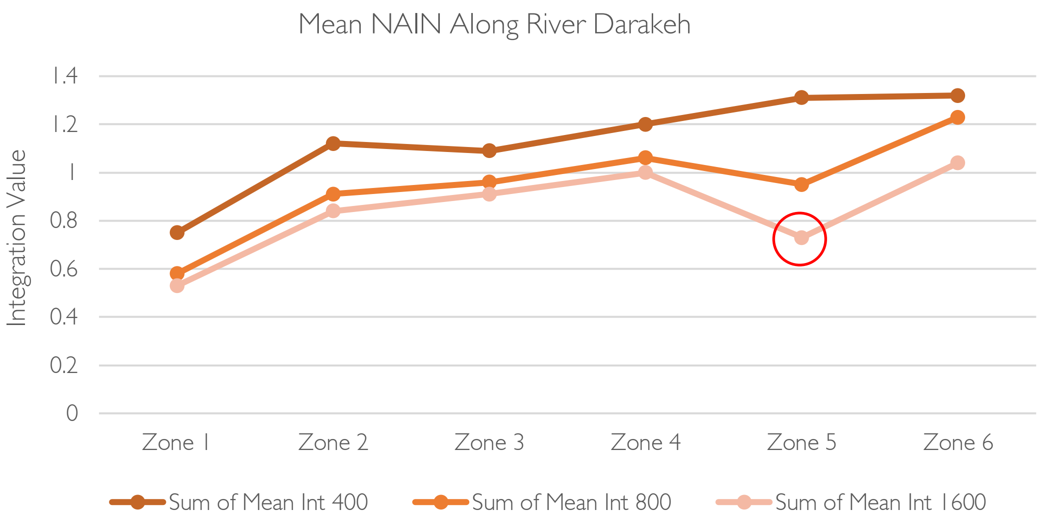


Chart 2. Mean Normalized Integration for three radii of 400, 800 and 1600 of the segment networks in 5min walking distance of Darakeh river. Author

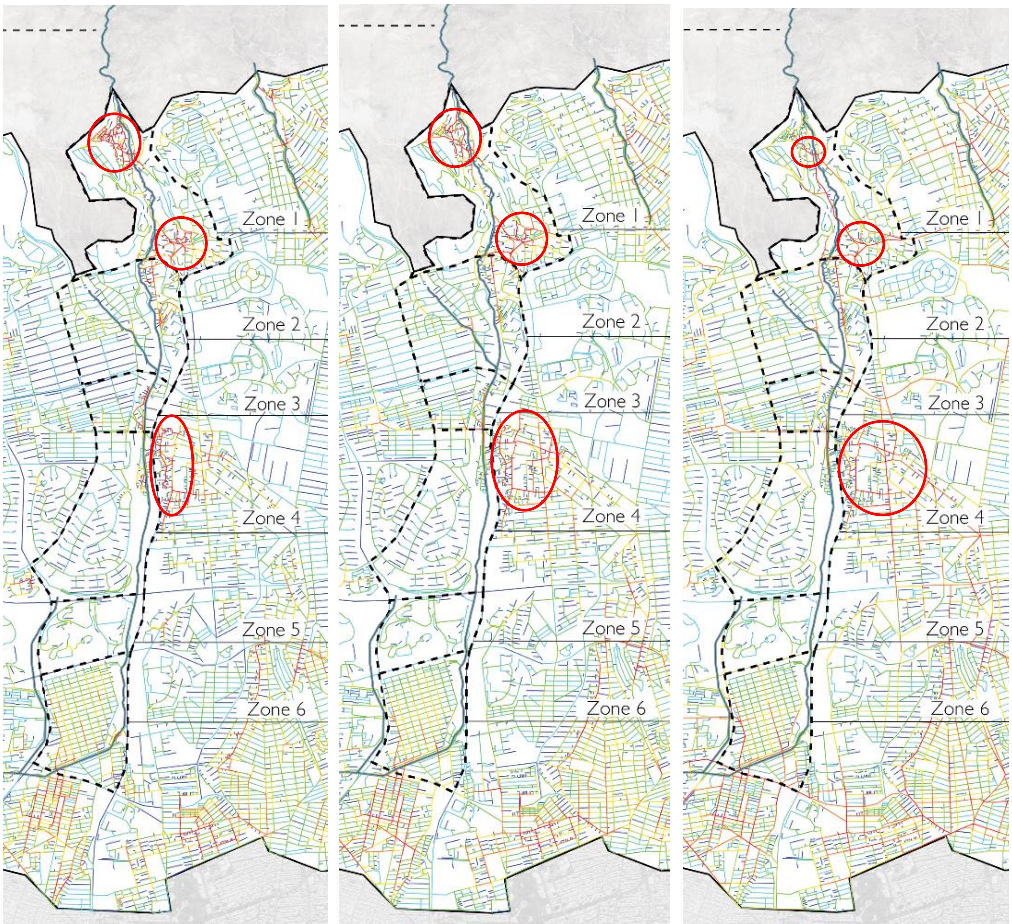


Figure 5.3 Choice Analysis for three radii of 400 (Left), 800 (Middle) and 1600 (Right) with zone divisions of Darakeh river. Author

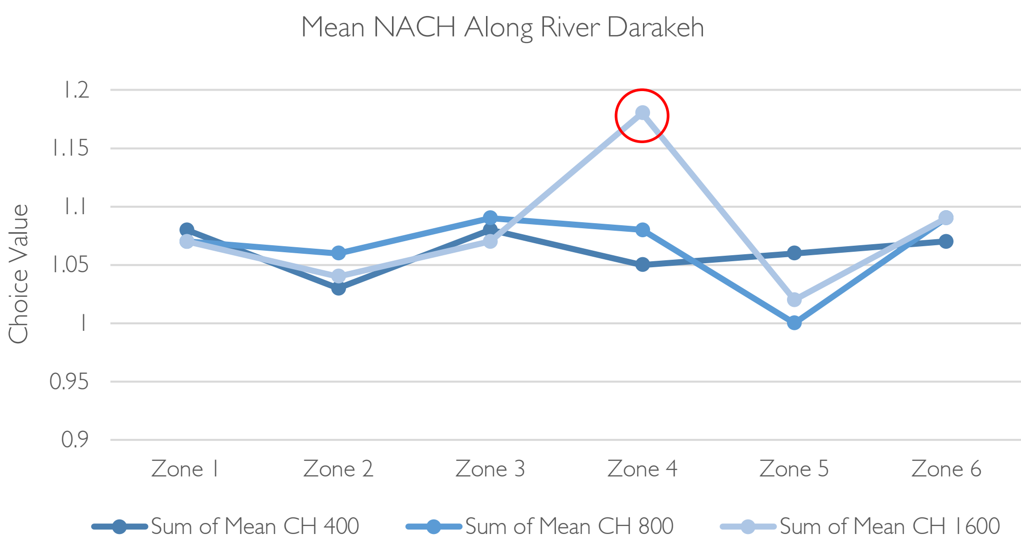


Chart 3. Mean Normalized Choice for three radii of 400, 800 and 1600 of the segment networks in 5min walking distance of Darakeh river. Author

The land use pattern of the riverbank is also analyzed regarding their type and proportions. This analysis considers the plots that are in the riparian area of the river to evaluate the impact of this intermediary space on the land use pattern of the city. The following chart indicates the percentages of each land use in the catchment 400 of the river. To reach a more concise result, the residential land uses are excluded from the chart (Chart. 4). This will facilitate the land use comparisons between the zones merely using green land use occupancies of the riparian area.

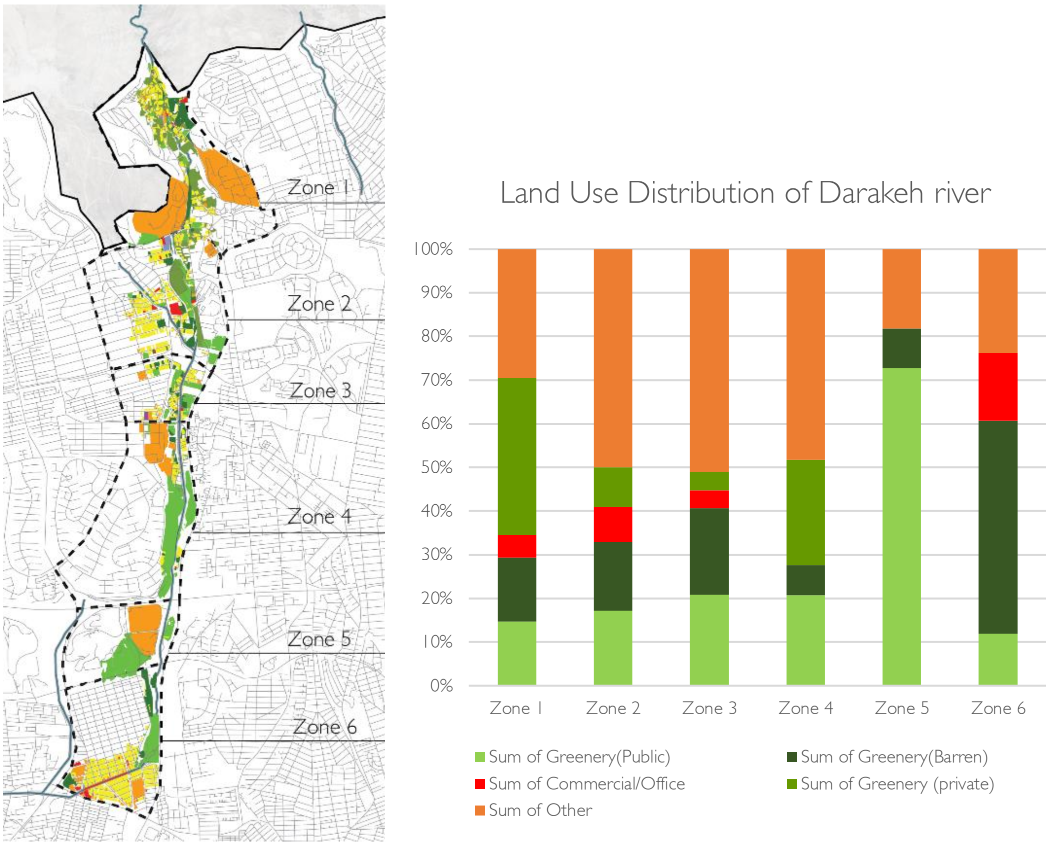


Chart 4. The **Land Use Pattern** of the plots within **catchment 400m** of the river **Darband** with zone divisions. Author

It can be understood from analyzing the patterns along the Darakeh river that most of the green areas in zone 1 are occupied by private gardens rather than public parks. This is while in zones 4 and 5 this relation is reversed. Although there are multiple small parks in zones with dense urban structures, the spacious public parks in these zones could hint that such areas are more likely to encourage global movements from across the city.

5.3 Darakeh river-valley stage 3: Combined analysis

The last stage of the analysis combines both systems of the river and the city and regards them as one single system. In this stage all the values are transferred to river length and the zones are compared based on a combined spatio-social unit. The following figures show the calculated Mean Integration per meter (Fig. 5.4) and Mean Choice per meter (Fig. 5.6) of each side of the river compared to the others. Subsequently, the differences between the sides are calculated and trajected onto the river itself (Fig. 5.5, 5.7)[6].

By looking at the mean integration discrepancies between sides along the Darakeh river, it could be understood that zone 1 varies much more than the other zones in different scales of 400 to 1600. This can be justified by the fact that there are two local centers on each side of the river[7], therefore, in lower radiuses integration value increases. This is while the level of contrast between two sides of zone 1 also escalates indicating that the sides are not working as a unified whole. Conversely, integration in zone 2 is almost invariable in different scales and maintains a steady value. The level of contrast between the sides in this zone (and zone 3) is also low which could be a sign that in this zone the river is not acting as a divider, and, although the integration is low on both sides but the whole zone is more unified in structure. On the other hand, in zone 6, which is comprised of firmly structured grids on the west side, the higher contrast between sides have portrayed the river as a barrier.

Comparing the Mean Choice values of Darakeh riversides, it can be concluded that generally the through movement quality of the urban network along this river is more susceptive to scale change. In the local scale of radius 400, the contrast between riversides decreases from north to south. In the higher scale of 1600, zone 1 and 3 are the most unified zones although their choice values are relatively low.

6 It must be noted that in all analysis, only the segments that are in catchment 400m of the river are included and not the whole zone.

7 These local centers are the remaining structures of the old villages of Darakeh and Evin

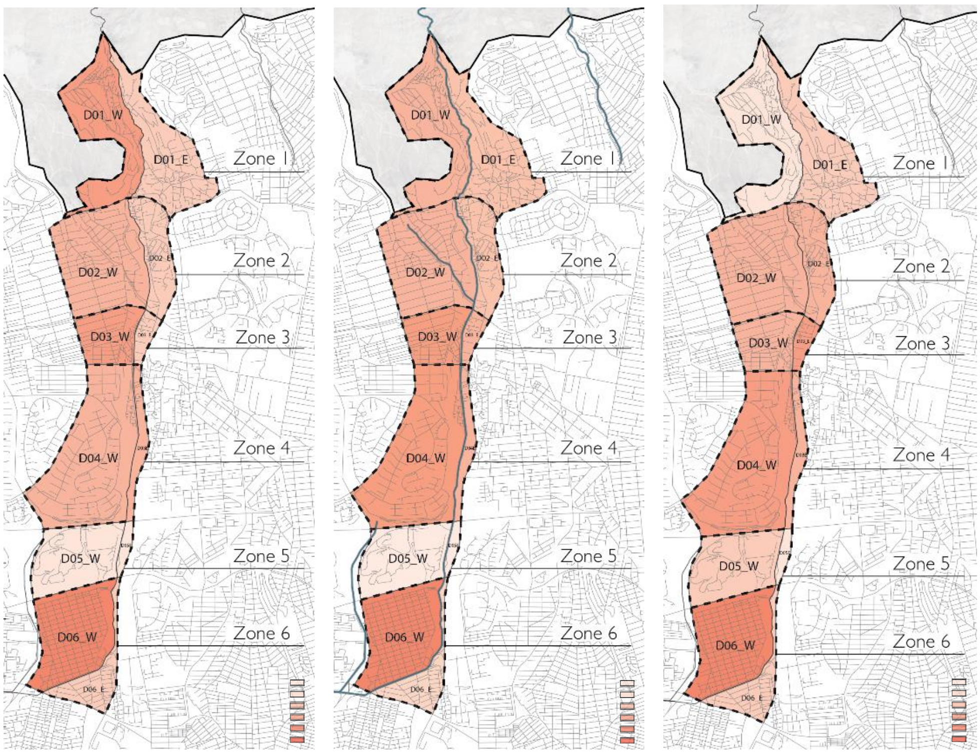


Figure 5.4 Comparing Mean Integration per Meter of river sides of Darakeh river zones for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

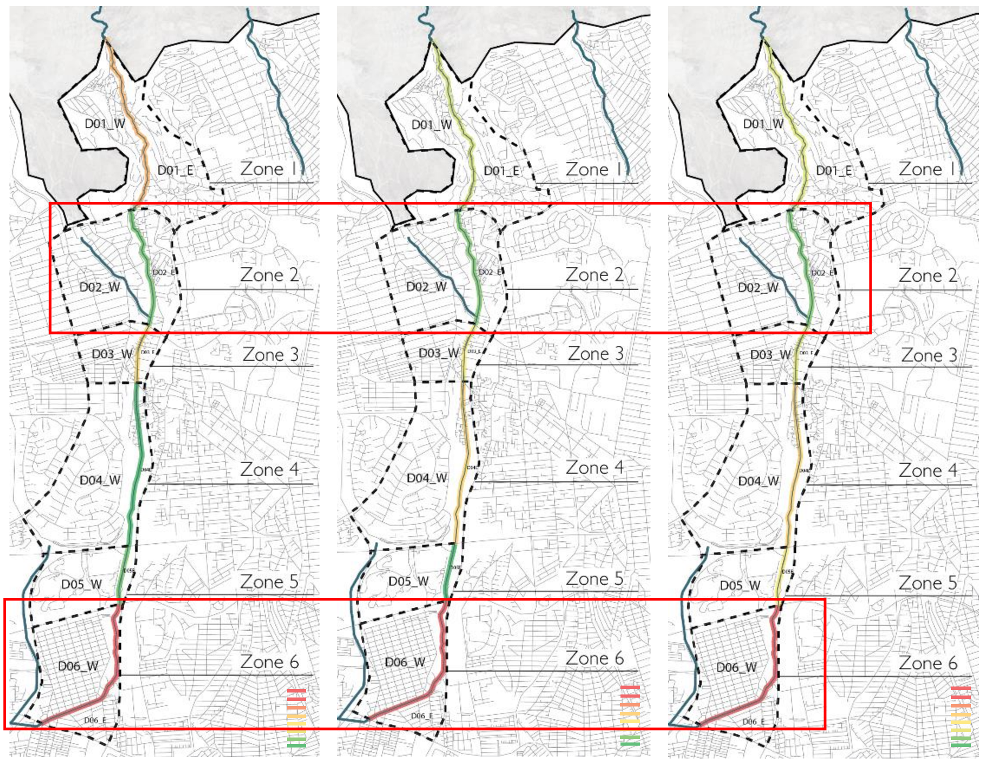


Figure 5.5 Level of Contrast between sides of the Darakeh river according to Mean Integration per River Length for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

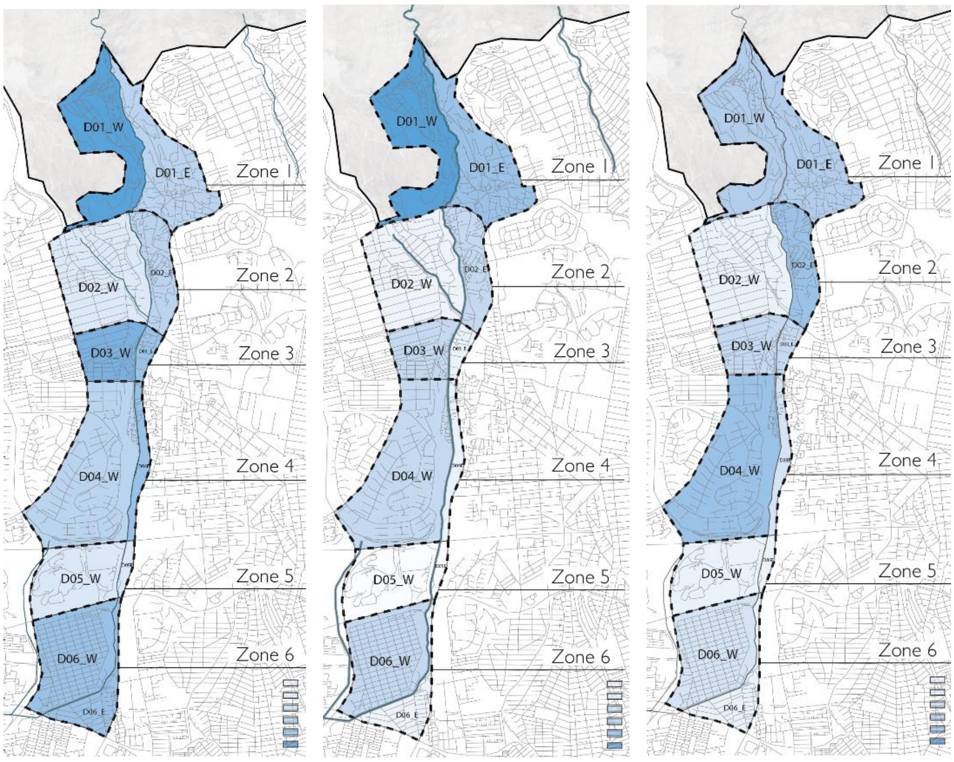


Figure 5.6 Comparing Mean Choice of river sides of Darakeh river zones for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

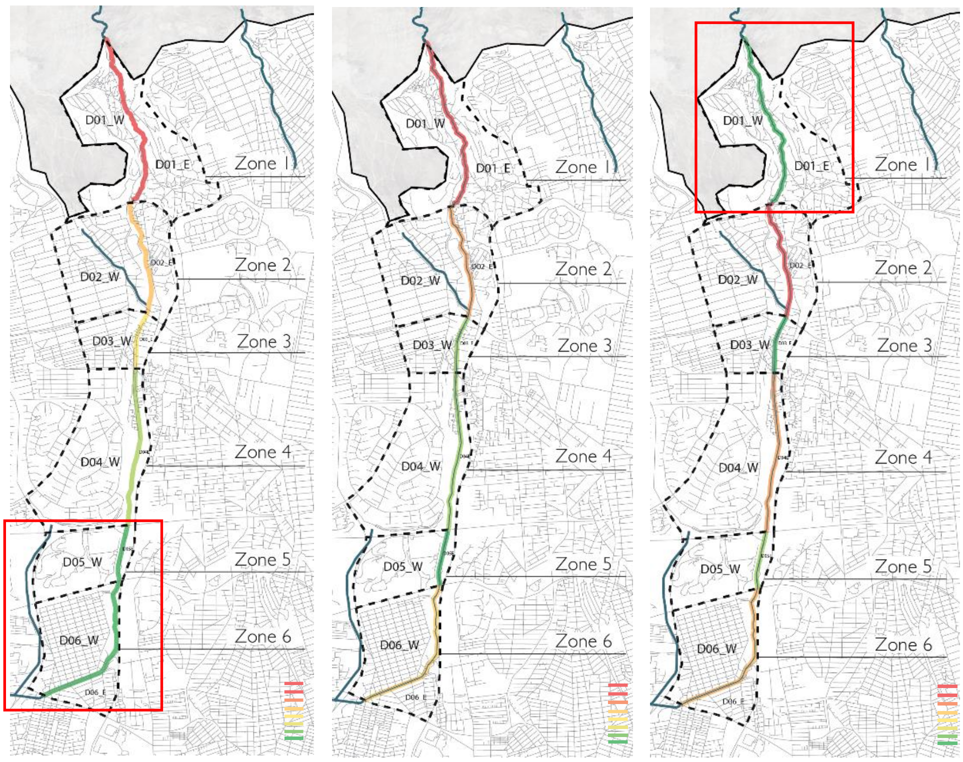


Figure 5.7 Level of Contrast between sides of the Darakeh river according to Mean Choice per River Length for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

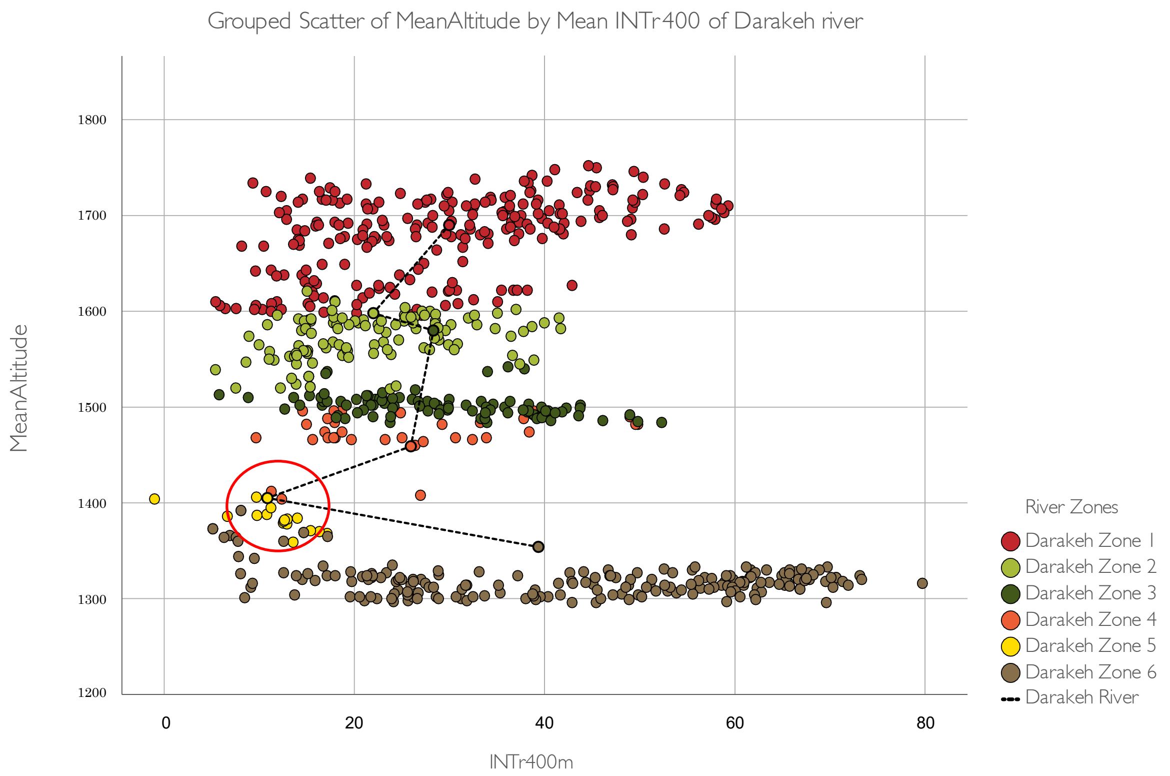


Chart 5. **Combined Scatter Gram** of **Darakeh** river zones with respect to the segments' **Mean Altitude** and **Integration** value. The dashed line represents the river itself. Author

The scatter gram of Altitude-Integration of the riverside networks provides several useful information about the Darakeh river area in terms of both topological and urban transformation (Chart 5). It explicitly shows the decreasing levels of the street segments from north to south along with their integration range in each zone. This graph suggests that zone 1 has the most erratic altitude range within its structure while zone 3 is comparably flat in close vicinity to the river. Furthermore, zone 6 is the most diverged in terms of integration value and zone 5 with the least urban networks consequently has the least integration range.

The dashed line represents the river with its corresponding mean altitude and integration in each zone. comparing the river's mean altitude with the street segments' altitudes, can indicate that contrary to what it seems, in some zones the altitude of the street segments are less than the average altitude of the river segment in the same zone. This implies that in zones like zone 3 and 6, topography changes from a V-shaped valley to a plain field, and therefore, the urban network has the same altitude level.

5.4 Farahzad river-valley stage 1: River attributes

In the second phase of the study, Farahzad river-valley is analyzed and processed based on the methodological framework of the study. The initial study of the Farahzad river involves the river attributes. Table 4 reveals that the river section in zone 3 is the lengthiest with the most expansive riparian zone. However, the widest part of the river is in the lower zones of 6 and 7. The density of the crossings per river length in each zone also signifies that zone 7 has the highest bridge density and zone 2 – with only one bridge – has the lowest density per river length (Chart. 6).

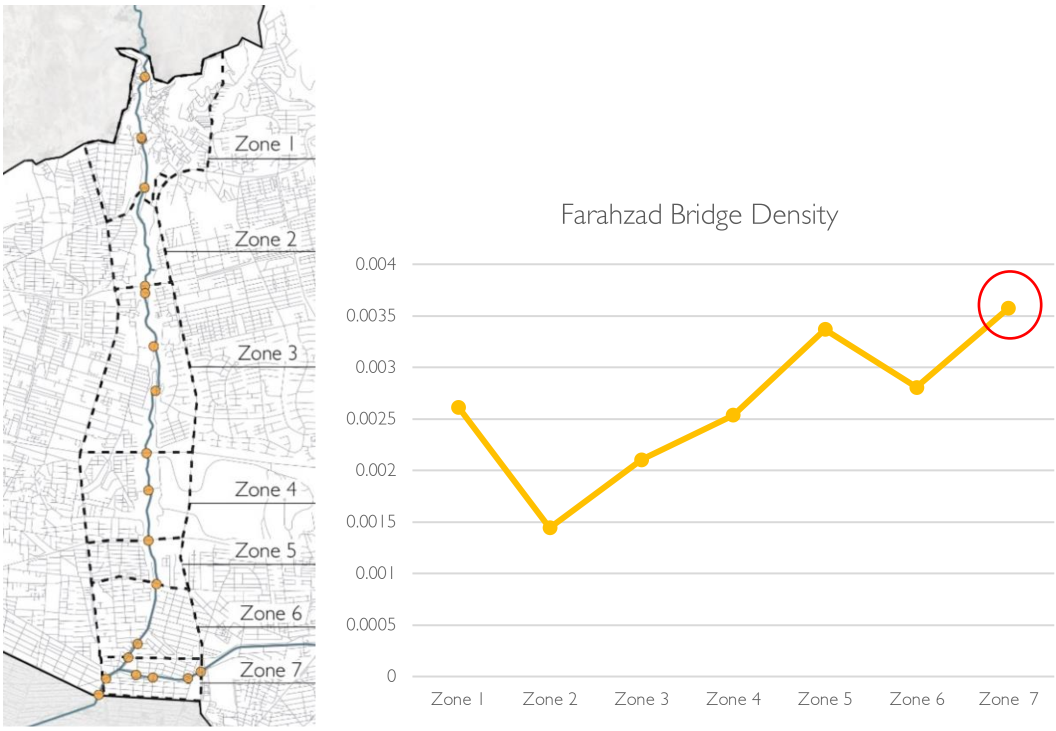


Chart 6. **Farahzad** River **Bridge Density**. The vertical bar indicates the density of the **Crossings per River Length** in each zone (n/m). Author

River Zones	River Length	Mean Width	Riparian Area	Mean Altitude
Zone 1	1531	6.5	227722	1599.52
Zone 2	1387	4.5	148658	1525.29
Zone 3	2377	5.5	469638	1443
Zone 4	1183	4.1	300344	1374.43
Zone 5	594	4.4	80967	1331.76
Zone 6	1069	7.5	51106	1299.31
Zone 7	1679	7	89770	1271

Table 4. **Farahzad** river's **Dimensional** and **Topological** attributes summary

5.5 Farahzad river-valley stage 2: Urban analysis

In the next step, the Farahzad river-valley is analyzed according to its urban attributes. Table 5 summarizes the segment counts in each zone along with the number of segments within the river's 5-minute walking distance. The results indicate that although zone 1 has the highest number of street segments among the zones, only 13% of its segments are in close vicinity to the river. Conversely, in zone 7 most of the segments are in catchment 400m of the river, though this zone consists of much fewer segments.

Farahzad River Zones	Total Segment Length	Total Segment count	Catchment 400 Segment count	Catchment/Total
Zone 1	4885	898	115	13%
Zone 2	1630	148	16	11%
Zone 3	2958	454	42	9%
Zone 4	2938	295	40	14%
Zone 5	5517	167	54	32%
Zone 6	5321	287	67	23%
Zone 7	14836	175	154	88%

Table 5. The summary of urban **Segment Count** and **Segment Length** for each zone of **Farahzad** river area. Author

By analyzing the accessibility of the street segments in catchment 400m of Farahzad river zones (Table 6) it can be understood that close to the river, in zone 3, the mean integration drops in higher radiuses of 800 and 1600 (Chart 7). This is while, zone 5 is generally more integrated than other zones of Farahzad river. By looking at the choice values, it is evident that the disparities between the zones are far greater in radius 400 than in other radiuses (Chart 8). Although, in the maps (Fig. 5.8, 5.9), zone 1 is illuminated in the Farahzad village area, in the Charts – which only include segments within catchment 400 – the village is excluded because it is mostly not accessible (within 5 minutes) from the river.

River Zones	M_INT 400	M_INT 800	M_INT 1600	M_CH 400	M_CH 800	M_CH 1600	M_Altitude 400
Zone 1	0.84	0.67	0.61	1.08	1.09	1.09	1623.99
Zone 2	1.2	0.87	0.77	1.17	1.11	1.09	1550.66
Zone 3	1.26	0.79	0.52	1.15	1.12	1.06	1451.27
Zone 4	1.14	0.94	0.74	1.11	1.09	1.06	1379.96
Zone 5	1.34	1.22	1.05	1.01	1.06	1.03	1332
Zone 6	1.38	1.12	1.07	1.06	1.11	1.14	1286.38
Zone 7	1.34	1.1	0.99	1.01	1.04	1.02	1268.27

Table 6. Summary of the **Mean Integration** and **Choice** for three radii of **400**, **800** and **1600** along with **Mean Altitude** of zone segments of **Farahzad** river. Author

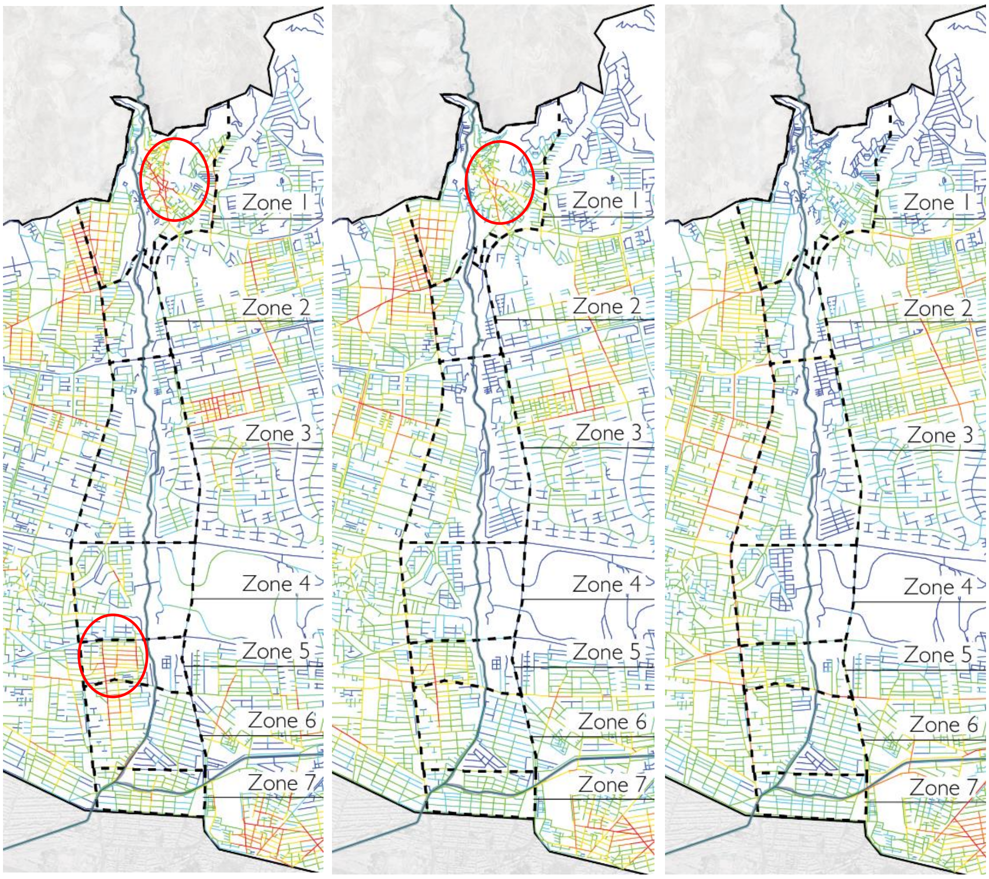


Figure 5.8 Integration Analysis for three radii of 400 (Left), 800 (Middle) and 1600 (Right) with zone divisions of Farahzad river. Author

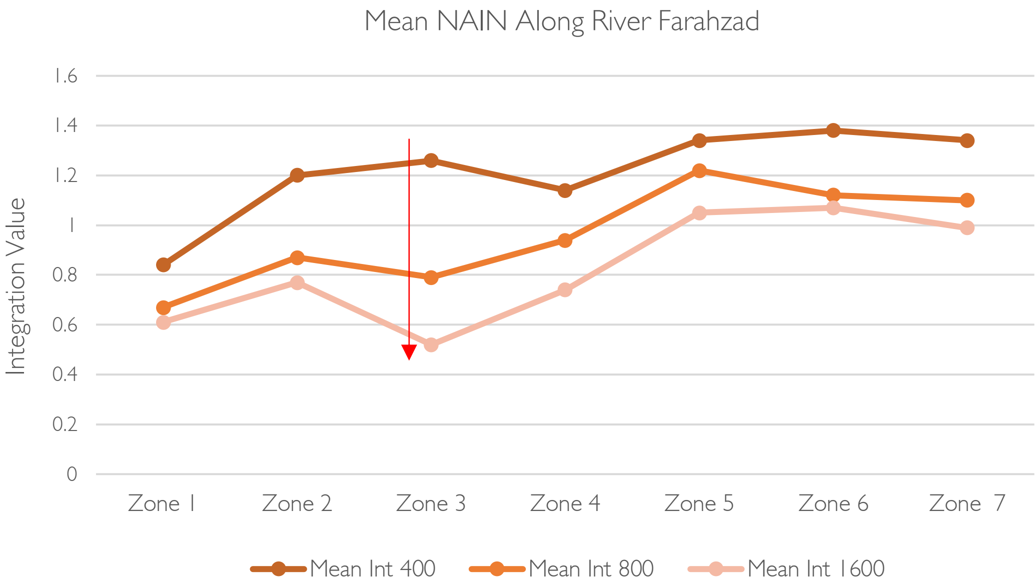


Chart 7. Mean Normalized Integration for three radii of 400, 800 and 1600 of the segment networks in 5min walking distance of Farahzad river. Author

Figure 5.9 Choice Analysis for three radii of 400 (Left), 800 (Middle) and 1600 (Right) with zone divisions of Farahzad river. Author

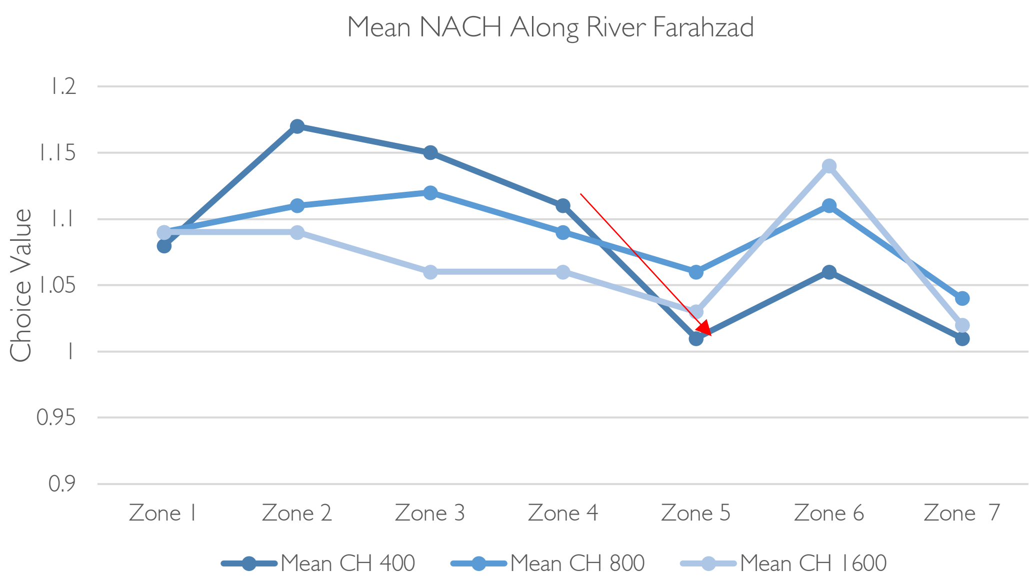


Chart 8. Mean Normalized Choice for three radii of 400, 800 and 1600 of the segment networks in 5min walking distance of Farahzad river. Author

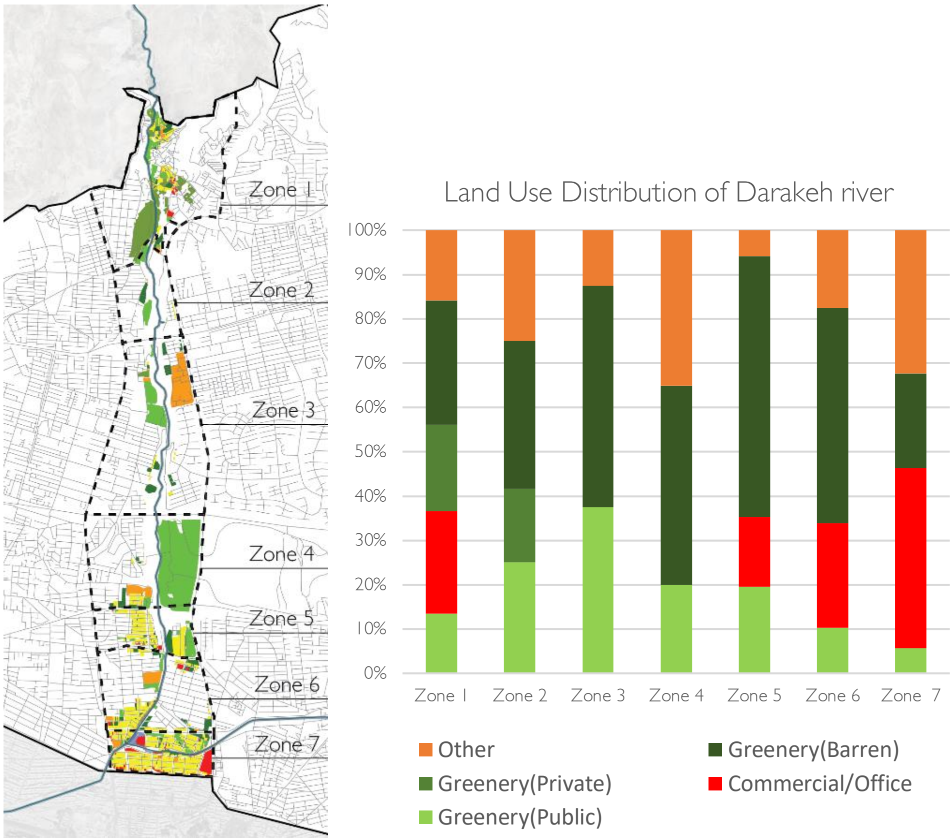


Chart 9. The Land use pattern of the plots within catchment 400m of the river Farahzad with zone divisions. Author

Finally, the land use pattern of the urban areas surrounding the Farahzad river is analyzed (Chart 9). The outcome of the analysis shows that comparing to the Darakeh river, Farahzad river has fewer private gardens – exclusively in zones 1 and 2. It also indicates that the middle zones (2,3,4) proportionally own more green land uses than others and zone 7 possesses the least green land uses. The Nahjol-Balagheh park which has lately been constructed in the middle zones of Farahzad river-valley like the riverine parks along the Darakeh river-valley could point to this fact that these areas could alternatively be a destination for recreational activities rather than local mediators of everyday urban functionalities.

5.6 Farahzad river-valley stage 3: Combined analysis

In the last stage of the analysis all the topographical and socio-spatial attributes are transferred onto the river length and compared for each side of each zone. Farahzad riverside mean integration analysis shows that the middle riversides are the less integrated sides of the river (Fig. 5.10), however, according to the level of contrast analysis, the riversides of zone 3 are more homogenous in terms of integration, thus, more unified (Fig. 5.11). This zone is also the zone with the least integration variation across different scales of analysis.

Studying the choice analysis of the riversides along with their level of contrast (Fig. 5.12, 5.13), it is revealed that once more, zone 3 obtains the lowest value with the highest conformity of East-West sides across all scales of analysis. Zone 1 has the highest value of choice among the zones in all scales, while the difference between the choice values of East and West sides of this zone have mismatching values in lower scales but completely matched in radius 1600. Overall, it can be argued that contrary to what it seems, Farahzad river can be regarded as a means of connection in the middle zones, by dividing these zones into two equally integrated and accessible networks. However, the disparities between sectors of the river along its length, depicts it as an inconsistent string within the city.

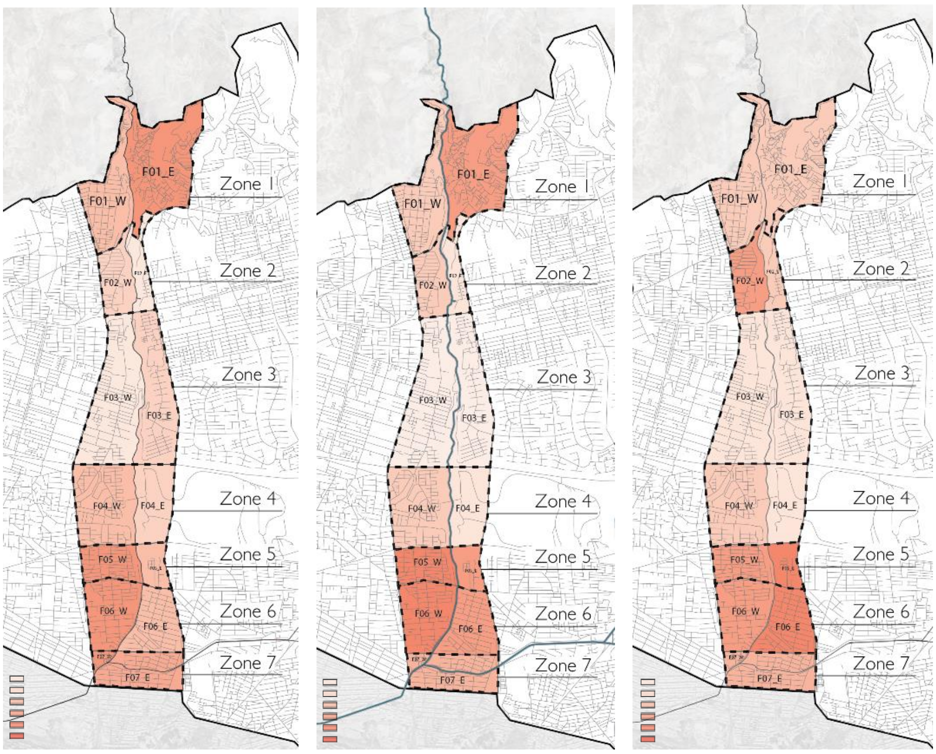


Figure 5.10 Comparing Mean Integration of Farahzad river side networks in each zone for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

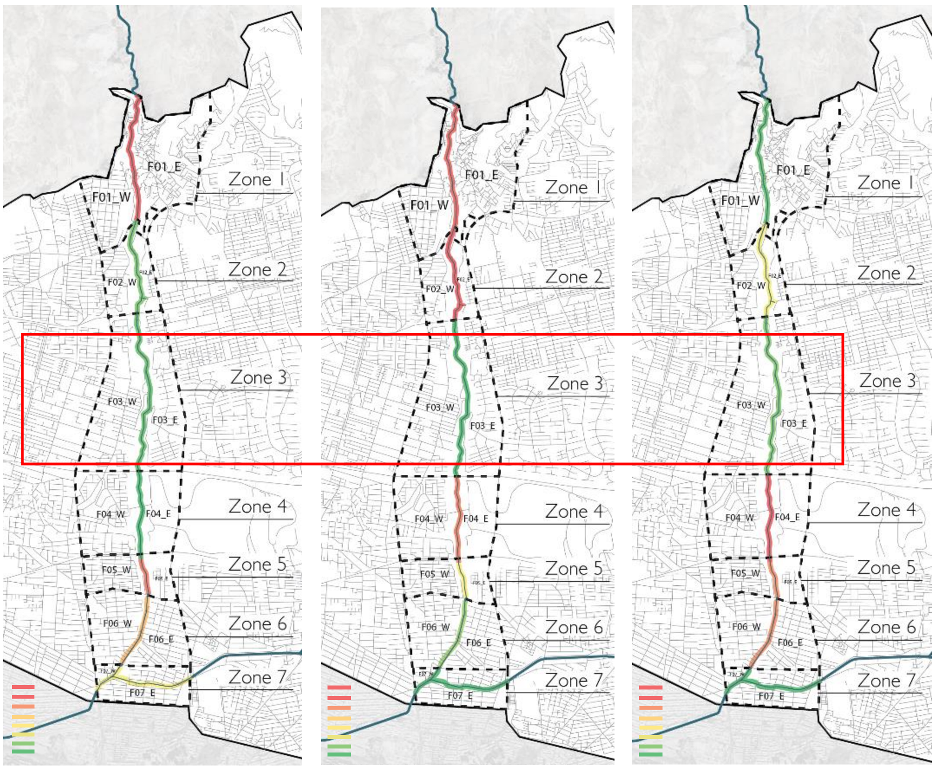


Figure 5.11 Level of Contrast between sides of the Farahzad river according to Mean Integration per River Length for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

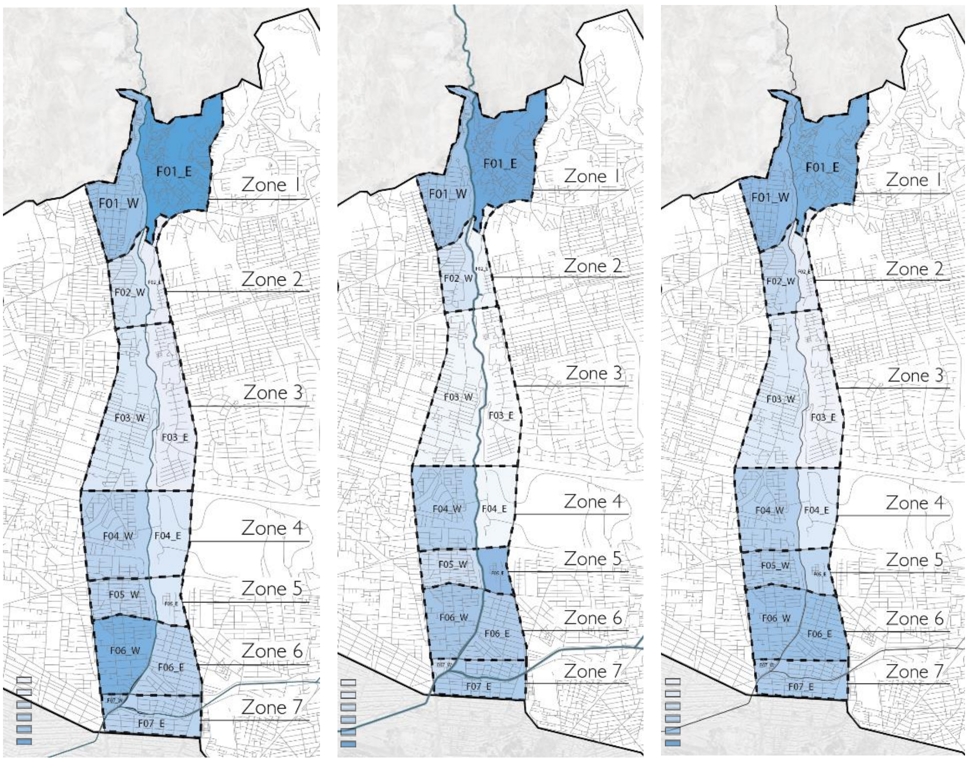


Figure 5.12 Comparing **Mean Choice** of river sides of **Farahzad** river zones for three radii of **400** (Left), **800** (Middle) and **1600** (Right). Author

Figure 5.13 **Level of Contrast** between sides of the **Farahzad** river according to **Mean Choice per River Length** for three radii of **400** (Left), **800** (Middle) and **1600** (Right). Author

Chart 10. **Combined Scatter Gram** of **Farahzad** river zones with respect to the segments' **Mean Altitude** and **Integration** value. The dashed line represents the river itself. Author

The combined scatter gram of Farahzad river also captures the descending topographical levels of the zones from north to south (Chart 10). Like Darakeh river, the zones with the highest and lowest altitude levels have the widest range of integration values. It can be concluded from comparing the urban network to the river, that the mean altitude of the river is lower than the street segments in higher altitudes, but it gradually merges with street segments in lower levels. Essentially, this graph can summarize the socio-spatial performance of the system at the interface of the river and the city.

6. Discussion

6.1 General Interpretations

By analysing the city's street network with respect to its through-movement on the local level, the old village structures are illuminated in organic forms along the rivers (Fig. 6.1), which suggests that these organic structures still work as the local centres within the city. A more global Choice analysis, highlights the general division of the neighbourhoods and by overlaying the river zone divisions, it can be observed that some of these old structures – specifically in the case of Vanak village – are not included in the river zones. This could be a sign that in some parts the connections between the village and the river is interrupted or completely broken by the city's protracted highways and that the city's new infrastructure, however efficient as the global connectors, could have a negative effect on a local city-river relationship. Nevertheless, these networks can play a vital role in transitioning the global movement to the riverine local areas. Among the case studies, only Darband river seem to be both locally and globally accessible, but for the other two this transition from global to local appears to be missing or at least, not as smooth along the river.

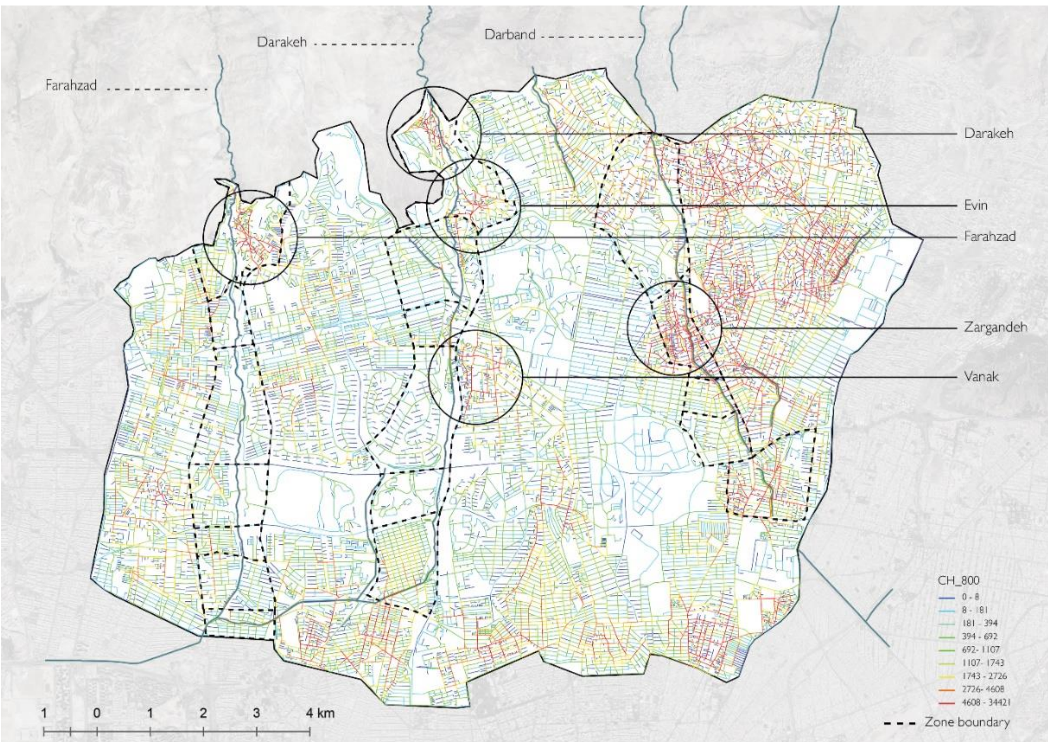


Figure 6.1 Choice analysis radius 400 of the three river areas of Darband, Darakeh and Farahzad with the overlay of the zone divisions. The identified areas indicate the existing remainder of the old villages along the rivers. Author

6.2 Analytical interpretations: addressing the research questions

The results of the analysis of Darakeh and Farahzad river-valleys confirm that the topographical attributes of the rivers impact the way in which an urban area forms and functions in their adjacency. Although it does not indicate a direct correlation between those variables, they follow a certain pattern that is distinct for each zone. These clustered patterns of geospatial relations might be the cause of what is sensed as a threshold between the neighbourhoods along the rivers, with the river working as the connecting link. However, the strength of this link can vary due to the topological ruggedness of the city and the cause and effect of the historical adaptation. To elucidate, if we imagine Darakeh river as a string that connects each cluster of urban networks along its path, we can say that this string is severed in zone 5 (according to the combined analysis). But comparatively, this river is much more consistent than Farahzad river.

In this light, we can approach the first research question in two different manners. First, we can consider the whole river length and discuss that the river-valleys in Tehran generally work as a link between sides in a micro scale (r400) but a neighborhood divider in the meso and macro scales (>r800). This notion is beneficial in exploring whether the rivers promote or discourage the movement along the river and between zones and how these rivers sit in the context of the city. For the second interpretation, a sectional overview of the river and the city is presented that could identify where these connections are stronger or weaker between the sides and not merely between the zones.

Answering the second research question regarding the classification of the rivers would depend on how these rivers are engaged with the city structure and how they are socially utilized. Based on the findings of this study, it is suggested that the small urban rivers in Tehran be sectionally classified into three spatio-social types of:

1. **Recreational river sectors**: the sections where the river is a destination for recreational activities. These sectors usually have wider natural riparian areas and steeper valleys. Their poor connection to the urban network, consequently, result in low local integration and choice. However, these

sectors are globally accessed and can act as an attractor location within the city.

2. **Generator river sectors**: these river sectors are closely attached to a local organic structure and usually have generated a local center with high integration. These local areas are mostly the preserved old villages that have been integrated into the city structure.

3. **Synthesized river sectors**: the rivers in these sectors are incorporated into the structure of a defined urban network – usually a grid structure – in which the riverbanks work as part of the network contributing to the movement in the system. These river sectors are formed by the urban structure rather than the other way around and could contribute to the local movement economy.

It is worth mentioning that these classifications are solely based on the results of the studies on three rivers in Tehran and may require additional studies on other cases or qualitative observations to be validated as a general classification with stronger evidence.

The final question regarding city-river social interface requires an overall interpretation of all the analysis together. Generally, it can be argued that the presence of a river per se, do not ensure a social junction; but other factors like the synthetic structure of the urban network and topological variations might also take part in shaping a sustainable social interface. The findings of this study demonstrate that higher structural contrast between riversides can decrease the possibility of centralizing the river as a social interface. On the other hand, the rivers which are more leveled with the city network have more chances in becoming socially integrated across all scales of movement.

7. Conclusion

This dissertation along with its supplementary study on the Darband river can provide a further understanding of the way the urban rivers are integrated into the cities as social interfaces. As a general outcome, it reveals that the city of Tehran and its small rivers are not independent structures and interact with one another on many levels. To obtain a spatio-social understanding of the urban rivers, the study takes on an exploratory approach considering different layers of historical, morphological, and spatial analysis in three different stages.

Glancing through the study, an overall assumption can be made that the current form and condition of Tehran is the result of the structural coupling of the two dynamic systems of its small rivers and the urban network. The critical role of small rivers in shaping a multi-river city is an undeniable fact that can be traced in the historical timeline of the city's development. Nevertheless, the footprints of urbanization and modern infrastructure is also evident in the structure of the urban rivers in Tehran.

Furthermore, this study has shown that defining the rivers by one absolute term might not be possible due to their protracted nature, but it is possible to obtain a classification of the rivers by closely studying the parts. Although the river's attributes per se could not identify the river as a definite barrier or link within the city, the way that the city forms along the river – organically or planned – can be decisive in determining its role in each part.

This study can be considered as a part of the serial studies around the urban rivers. The significance of this study, however, lies in devising a framework for classifying the urban rivers based on their spatio-social dimensions. Accordingly, the methodology defined in this dissertation measures the urban attributes by accounting the natural features of the city's small rivers as a part of the urban tissue and introduces new measuring systems based on the river length and sectional divisions.

The limitations of the study include both direct and indirect constraints. Some of the direct restrictions of the study include difficulty of access to up-to-date land use data and Lack of relevant and processed data regarding the topological features of the city such as segment-based slope of the street network. The global COVID-19 pandemic and the restrictions upon observational methods indirectly impacted the process and added to the challenges of the study. The initial intension was to include the riverbanks width and study how the space appropriations are influenced by the spatial attributes on the edge of the rivers, but due to the unusual events of the time the study took on a different direction.

This dissertation on Tehran's urban rivers highlights the importance of the small urban rivers not only in shaping the formal structure of the city, but also as a medium for the social structure of the city. Future studies on diverse aspects of this social interface could inform the river related designs and restoration projects of the potentials that could benefit the city and augment the social life of its citizens.

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Appendix A:

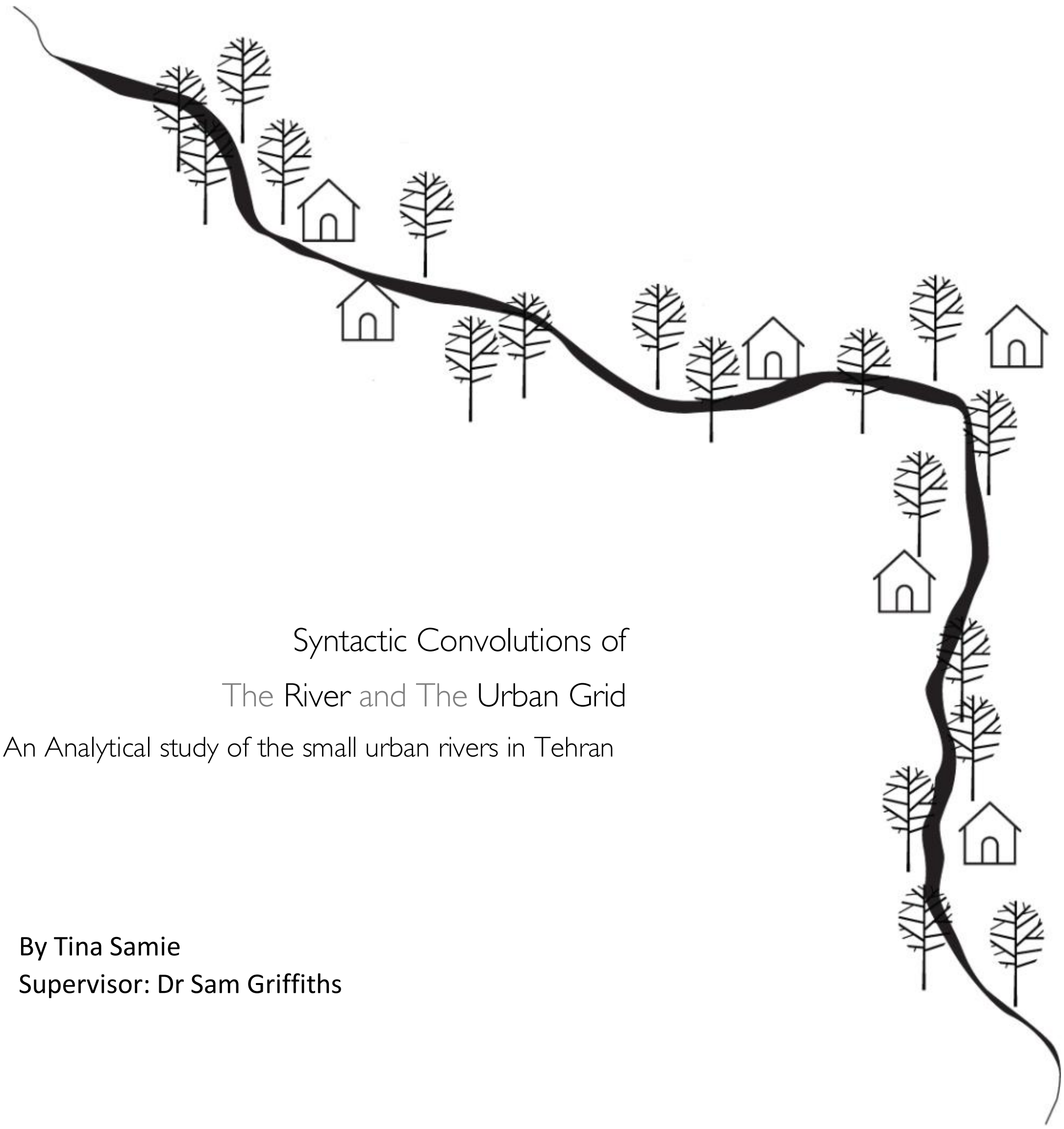
Zones	CH 1600	CH 400	CH 800	INT 1600	INT 400	INT 800
D01	234.19	878.93	2203.96	15.54	11.24	7.70
D02	11982.78	289.92	1408.09	0.93	2.41	5.89
D03	3.88	113.93	410.50	15.52	6.70	9.52
D04	8239.82	54.29	415.78	43.63	1.59	22.20
D05	2551.82	13.33	83.10	19.64	2.28	4.53
D06	7108.36	17.25	990.96	156.04	21.96	86.17

Table A.1 Level of contrast of the Mean Integration and Choice for three radii of 400, 800 and 1600 along with Mean Altitude of zone segments of Darakeh river. Author

Zones	CH 1600	CH 400	CH 800	INT 1600	INT 400	INT 800
F01	1488.558	787.2224	3582.785	8.541965	16.11954	29.93776
F02	9118.292	33.61905	702.4583	37.30716	4.147222	31.765
F03	2565.609	45.41688	211.7995	14.67491	3.678104	0.734028
F04	999.7926	112.32	288.263	84.32003	3.162096	26.12823
F05	15246.14	81.58527	386.6667	67.58388	14.04842	10.80532
F06	9396.661	101.1587	88.55	68.87879	9.831762	5.272834
F07	3827.457	68.99145	325.3007	4.059728	6.482489	0.334711

Table A.1 Level of contrast of the Mean Integration and Choice for three radii of 400, 800 and 1600 along with Mean Altitude of zone segments of Farahzad river. Author

Appendix B:



Syntactic Convolutions of

The River and The Urban Grid

An Analytical study of the small urban rivers in Tehran

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Abstract

This paper analytically narrates the structural coevolution of the natural organic rivers and the urban grid and explores the grounds on which each has transformed the other through coexistence. The aim of this research study is to explore the spatio-social impacts that small urban rivers have on their local urban tissue and rediscover their invisible potentials which have been buried under the planning policies in the context of a mountainside city, the research takes on studying Tehran's small streams and rivers running quietly under the cities skin. Taking on an evidence-based approach, this paper proves that although these rivers seem to be undermined by the city and urbanization process, they have had a significant role in shaping the city.

Table of Contents

1. Introduction

As geographical features, urban rivers are the natural elements of an urban system which is constantly reformed and redefined by the city's structure in time. Regardless of the scale and size, the river and the city dynamically collide, and therefore, mutually shape their territorial boundaries and the urban space. Nevertheless, the range of the impact depends highly on the scale and intensity of the river and the typological structure of the city (Kondolf and Pinto, 2017). Contrary to the large-scale rivers, which characterize cities on the global level, the smaller urban rivers, or streams interact with the more local areas and neighborhoods within their effective distance. The research conducted in this paper is focusing on the small urban rivers/streams transformed by the urban interventions in the context of a mountainside city.

While there have been many groundbreaking studies on restoration, ecological sustainability (Paul and Meyer, 2001) and landscape issues of urban streams (Rackham, 1991), the importance of the configurational attributes of these rivers and how they interact with their surrounding network rarely appeared as a subject in the scholar investigations. Today, issues like water contamination and smell, or the flood threats have been resolved with innovative technical solutions (Chen, 2017). However, these improvements do not necessarily upgrade the social interaction, nor do they fundamentally change the configuration of space as an abstract principle of social phenomenon (Hillier, 1996). Understanding the spatial structure of the riverside is the first step to demystifying these social and behavioral complications arising from integrating a linear organic system into the grid structure of the city. Hence, this research paper aims to narrow down the gap between technical and social by focusing on the spatial attributes of these small rivers as part of the urban tissue to explore their effective distance and boundaries and consequently decode the social implications of their continuous and repetitive patterns.

1.1 Defining urban rivers

The linearity of the urban rivers is an important feature of these natural elements which could create unintended spatial continuities within the city. Studying linear structures such as rivers and railways, might be even more revealing than studying static or radial phenomenon since the sense of side and positioning becomes a decisive factor (Bolton, 2018). This research study tends to explore how different structures of the city respond to such occasional linearities in the system.

Scale is another important variable in studying the urban rivers since it defines the proportional relations between the elements of the city and the range of effect it can have within the system. In studying the small urban rivers, it is important to notice the proportional size of the river with respect to its surrounding city elements (Kondolf and Pinto, 2016). Considering such elements in studying the rivers would shed light on the probable similarities and differences in their roles. For instance, the linearity of small urban rivers and their proportional width can be analogous to main streets and roads connecting different areas in the city. This resemblance in appearance can account for possible overlaps in how they function in the system and might also explain why in some cases they are treated in the same way.

The term "urban river" often associates with the thought of cities such as London, Paris and Istanbul with prominent rivers that characterizes the city on a global level. However, it often eludes the mind that urban rivers can also be relatively small and narrow and still appropriate the term. In this context what the research refers to as an urban river is a stream-like river running through the city sourced from a main river valley and enclaved with flood defensed walls as a process of urbanization.

1.2 Introducing Case Studies

Tehran as a mountainside city has a great number of small urban rivers or streams all of which are branches sourcing from 7 main River-valleys known as: Darband, Velenjak, Darakeh, Golabdareh, Farahzad, Kan and Darabad (Tali, 2011). With their roots on the foothills of Alborz Mountains, these small rivers introduce green corridors in their surrounding area as public lands that are often left unplanned (Khorshidfard, 2014). Since the mid-twentieth century, due to urban growth and the expansion of constructions, Tehran's river-valleys were partially buried under the city fabric or covered with concrete slabs. The remaining uncovered waterways face the same threat while running through an already strongly confined structure. The top down policies have also compelled construction growth along the river which has pushed the small rivers to the sideway. The supper-imposition of the urban grid on the organic river corridors has a physical and social implication in different scales which can define the binary role of the river: working as a barrier dividing the two sides, or acting as a Linear Link between the settlements alongside the river. In both cases, studying the underlying spatial and social products of this collision will pave the way for further understanding of how this juxtaposition can potentially lead to a sustainable urban space. To this end, the research is aimed to pursue case studies on the Darband river extension in district 3 (Fig.1).

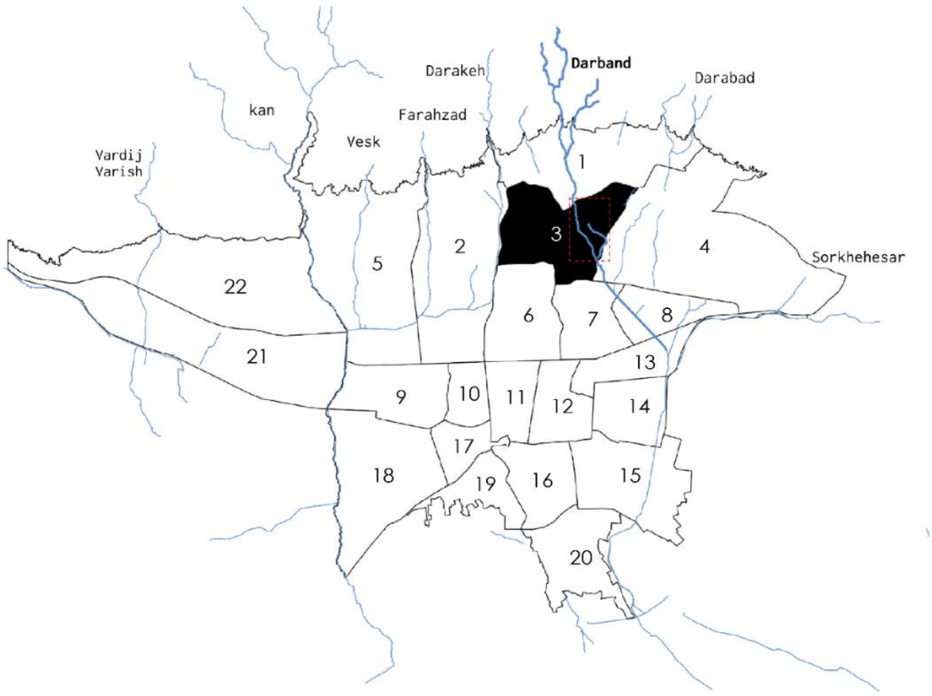


Figure 1. Tehran River-valleys and the districts they run through (The red rectangle identifies the research area). Author

Zargandeh river with the mean width of 10 meters is a part of the Darband river which crosses the old neighborhood of Zargandeh , hence the name, and Pasdaran river with the mean width of 5 meters is a branch of the same main river, which is connected to its source from under the ground, thus, it is only partly visible (Fig. 2).

Figure 2. Two rivers of Zargandeh and Pasdaran are chosen as the case studies in Tehran. Author

1.3 Research questions

In studying Tehran's rivers, the research takes on three different propositions to understand how rivers are integrated into the grid system of the city and what are the effects of this association:

- How do the small rivers contribute to the movement and connectivity of the local network in a structurally diverse urban tissue?
- How does the morphological aspects of the surrounding settlements account for the movement economy in the river's area of effect?
- How does the local context of the neighborhood define the role of the river as a bifunctional system (a barrier or a link)?

2. Literature Review

This study draws upon diverse literature sources in three main categories. The first category is focusing on the urban evolution along the small rivers through history which can then be compared to the history of evolution of cases in Tehran. In the second category the research scrutinizes the general policies and planning decisions imposed by the government and the local municipality to acquire a better understanding of the situation from the top-down perspective. Lastly, the previous studies and literatures on the subject are included as a base and foundation for the research to thrive upon.

2.1 History of the urban evolution along the rivers

The significance of rivers as the indispensable part of the history of urban settlements is repeatedly emphasized through many scholarly articles and books. The diverse nature of the urban rivers allowed human exploitation for different purposes which in turn transformed and shaped the rivers in time. Depending on the scale, type and their environmental conditions, the rivers endowed towns with fresh water, food, energy and means of transportation. These watercourses provided the main resources and a sustainable base for generating future growth and urban development (Francis, 2012). However, just like other ecological features, rivers were not completely immune to the impact of urbanization (Baron et al. 2002). By the beginning of the nineteenth century and accumulation of population in the cities, small rivers and streams disappeared gradually. Most small rivers became part of the subterranean sewage and drainage networks and Larger streams were enclaved in artificial beds and flood protection walls (Winivarter, 2016).

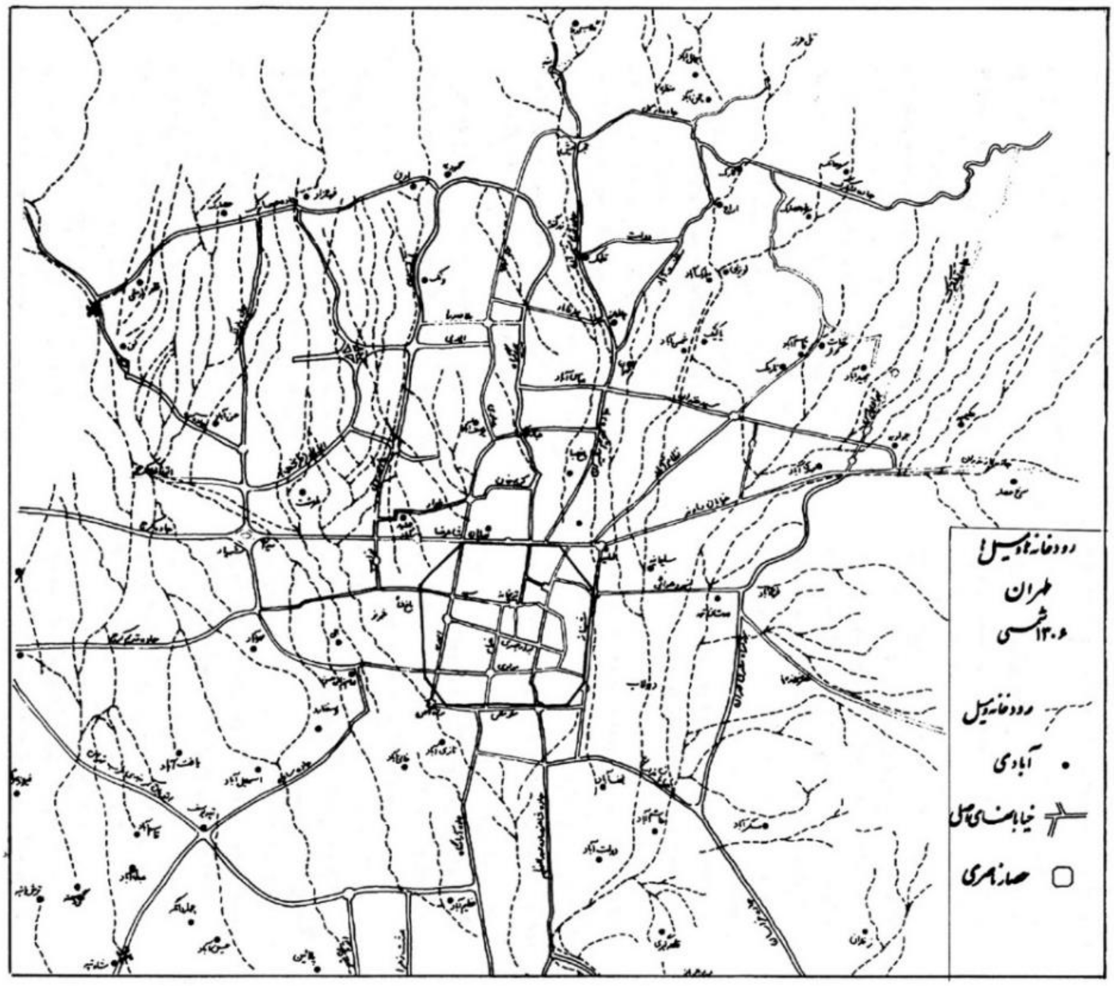


Figure 3. All of Tehran's rivers and streams in 1927 (The rivers are illustrated with dashed lines)
Image Source: Motamedi, 2002

Particularly in Tehran, the streams also faced a similar fate. The map of Tehran's Streams and river valleys, reveals the abundance of rivers at the brink of urban development in 1927 (Fig. 3) Chronological mappings of the northern parts of Tehran explicitly illustrates how the city has evolved with the rivers and how it transformed morphologically around the sides through time. Zooming to the study area in the maps of 1941, dispersed settlements can be identified forming along the Darband river extensions in five main areas known as Tajrish, Zargandeh, Daroos, Gholhak and Davoodieh, all of which have maintained their names as the main neighborhood areas until today (Fig. 4).

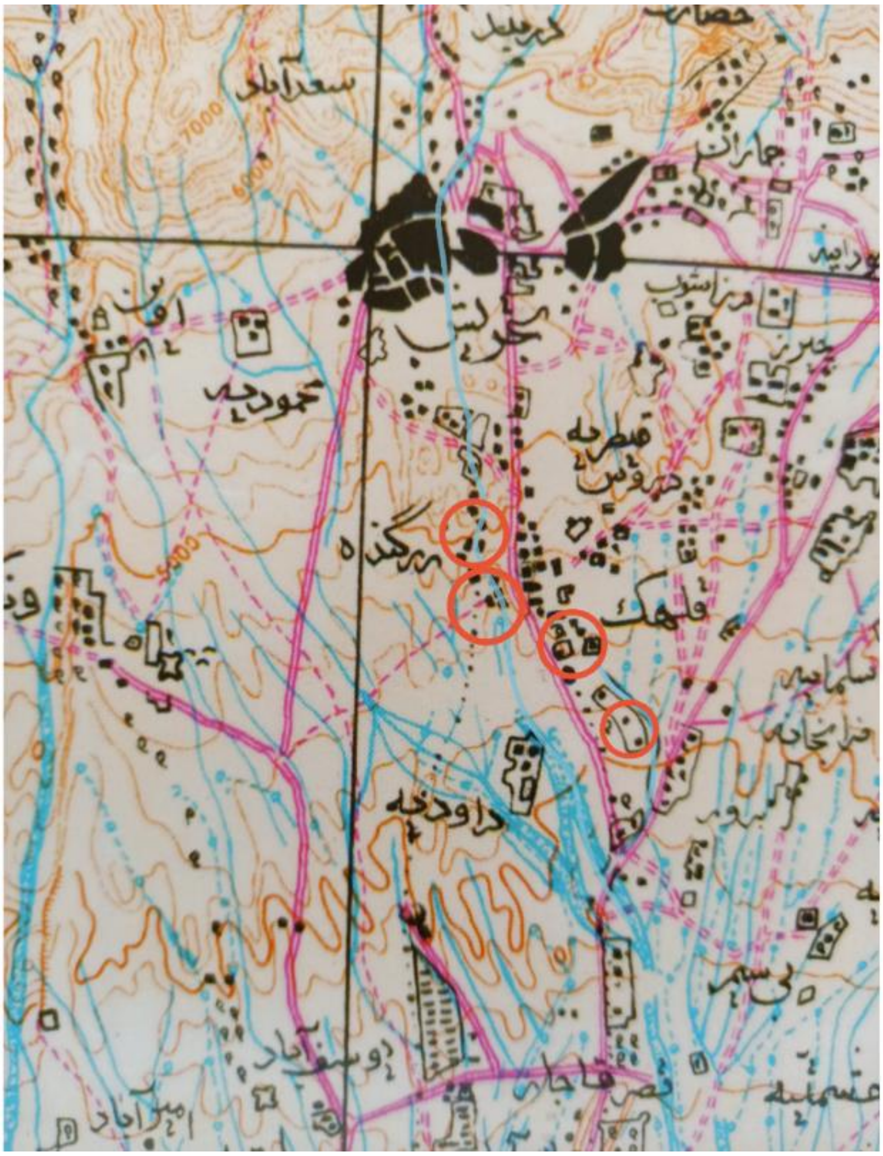


Figure 4. Dispersed settlements forming along the rivers in 1941
Image Source: Shirazian, R. 2018. Tehran Negari.

In 1958, the settlements were gradually surrounded by the grid-like networks planned to accommodate the growing population of the capital (Fig. 5). Finally, the map of the area in 1972, depicts a consistent urban tissue with the river working as a string within the fabric (Fig. 6). With the city expanding quickly and the constructions overloading the tolerance of the riversides, flooding management became necessary for the steep slopes in the northern part of Tehran. After the destructive flooding in Tajrish, in 1987, the whole river basin was equipt with flood prevention walls drawing a strict line between the river and the city's interface by prohibiting direct contact with water (Tali and Nezammahalleh, 2013).

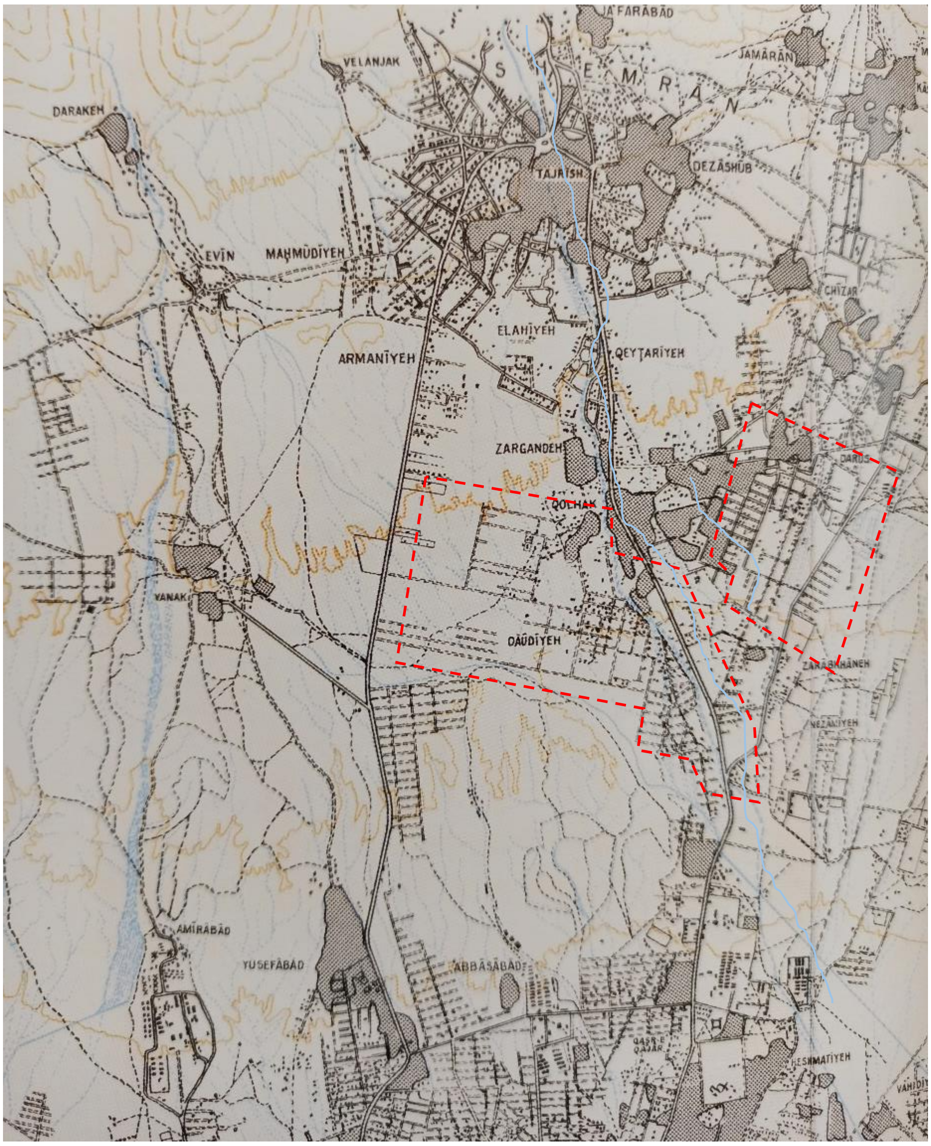


Figure 5. The urban grid starting to emerge along the rivers in 1958
Image Source: Shirazian, R. 2018. Tehran Negari.

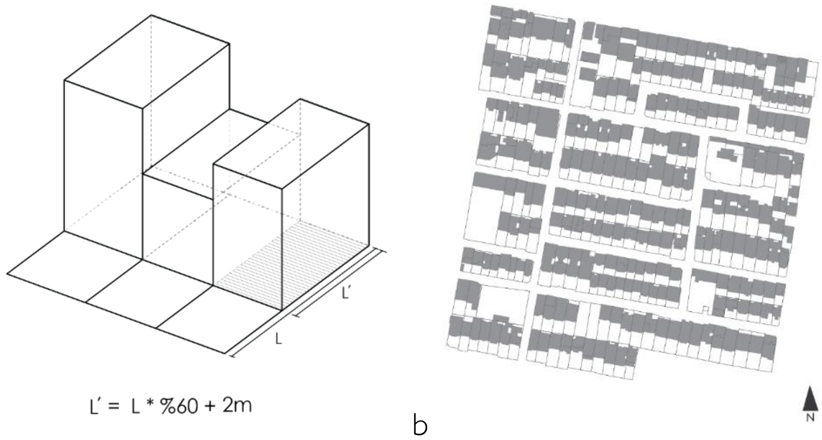
Thereafter, the rivers were partly covered and connected to the underground sewage system which contaminated the river's water and consequently produced an unpleasant smell. Thus, to avoid such scenery and smell, the buildings near the river were mostly built in a way to minimize any direct view or opening to the rivers. Although in the last decades, with the restoration projects, the condition of the rivers has improved ecologically, the top-down policies are now preventing fundamental morphological changes in the system.

Figure 6. The rivers connecting the old fabric (The identified area) of the neighborhood with the new built grid system 1972
Image Source: Shirazian, R. 2018. Tehran Negari.

2.2 Tehran's planning and construction policies

Tehran is one of the most populated cities in the world. According to statistical data until 2016, the total population of Tehran exceeded 13 million (Statistical Center of Iran, 2016). Evidently, the city possesses a very dense urban fabric. Therefore, maintaining an urban quality life in such cities requires explicit planning provisions and regulations.

Two instrumental construction regulations are briefly pointed out in this paper, as they have the most decisive role in defining the current form of the city around the rivers. First, is the general policy regarding the land occupancy. According to this policy, the maximum occupation of a plot permitted for construction is calculated by the length of the plot, that is, 60% of the length plus two meters multiplied by the total width of the plot (Tehran General policy, 2007)(Fig. 7.a). Another derivation of this policy requires the buildings to be placed in the most northern part of the land (Tehran General policy, 2007). Thereby, every building can benefit the desirable sunlight from the south (Fig. 7.b).



a b

Figure 7. a. Occupation policy of construction in Tehran b. The planning policy requires the buildings to align to the north
Image Source: Shirazian, R. 2018. Tehran Negari.

The zoning plan of the city is another top-down policy contributing to the formation of the city on a general level. Therein, defined general functions are allocated to specific zones to control the distribution of the desired land uses in each district. There are four main zoning categories in Tehran planning maps (Tehran General Policy-Revised, 2019):

1. (R): The residential land uses and their supporting activities and services
2. (S): The activity zones permitted for mostly commercial and retail land uses and related activities.
3. (M): Mixed used marginal zones where dispersed commercial land uses, and offices emerge within the residential areas.
4. (G): The public open spaces, parks, and conservation areas

Figure 8 is the zoning plan of district 3 with the focus on the study area and the rivers of Pasdaran and Zargandeh (Fig. 8).

Figure 8. The zoning map of the study area in district 3 (Left) The Land use map of the study area in district 3 (Right)
Image Source: Tehran General Policy, 2007

In this map, the riverside areas are identified as the (M) zones which allow mixed land uses and activities in vicinity of the residential zones. This is while the actual land use map reveals that the settlements around the rivers have remained mostly residential.

2.3 The rivers in the urban contexts

There are fundamental differences between urban rivers and natural ones on certain levels. The first and most evident distinction is hinted by severe human interventions (May, 2006). The urban rivers are in direct contact with human habitat, as parts of a complex system that work and change with the whole system in time. In other words, the rivers are tamed for the human activity and life (Hermida et al. 2019). The significance of the human being relationship with water throughout the history has preserved a symbolic value for the urban rivers as a vital element for urban life. Many attempts of restoration and rehabilitation projects around urban rivers was to restore this connection with the water (Everard and Moggridge 2012). But the rivers in the contemporary world have a different value and meaning for their urban context. Today, the decisive yet invisible role of the urban rivers lies within their spatial and formal features which directly influences the city on a structural level.

According to the Space Syntax fundamental theories, societies as spatial systems respond to the logic of space complying with the underlying laws of the material and spatial form of the city (Hillier, 1989).The presence of an elongated river as a natural barrier that splits the city and creates possible spatial divisions or connections, lays the foundation for the potential social and individual activities and behaviors.

Recently, there have been several studies focusing on the urban rivers using the space syntax methodologies and similar interdisciplinary approaches with different perspectives. Reviewing the studies previously done on the subject can provide an all-encompassing perspective required to build new knowledge about the rivers and their relationship with their urban context. Studying on a collection of river-cities, Abshirini & Koch (2016) have explored how the urban rivers as the geographical features have contributed to the formation of the cities at a larger scale. At a similar scale, examining different positional types of the rivers in Portugal, the relationship between the city's integration values and its river has been studied by Silvia et al. (2006). A More recent research on the small urban rivers in London has been conducted by Vandegas (2019) to evaluate the social and economic implications of the rivers within their local community. Building up on the hitherto researched subjects, this paper aims to tackle the recurrent subject on the rivers with a more methodological depth and a wider perspective.

3. Methodology

A scientific inquiry into an interdisciplinary concept of a spatial and social complexity as such, demands a variety of methods and diverse creative approaches. Using space syntax, an analytical methodology bridging the society with the spatial concepts (Hillier and Hanson, 1998) along with quantifiable data, which is backed up by observational methods, could provide the research with ample information to address the defined research questions. Particularly for this research, the methodology is generally divided into two main parts of analytical and observational methods (Fig .9). In the analytical section, the report is fundamentally using the basic space syntax integration and choice to explore the spatial structure of the river in the urban context. Catchment analysis is also another informative general method to define the scope and relational aspects of the project with a sensible logic. Furthermore, the research uses morphological analysis to discover the orientational state of the settlements along the river and land use data to interpret the local differences on top of the morphological results. For the observation sections, the research constructs a comprehensible method to understand the reality of life around the river through a series of snapshots from the area, carving out the underlying social structures formed along the riversides. Mapping the varied conditions of the footways and streets as another observational method can uncover the obscured factors that might contribute to the way people use and view the urban rivers in the area.

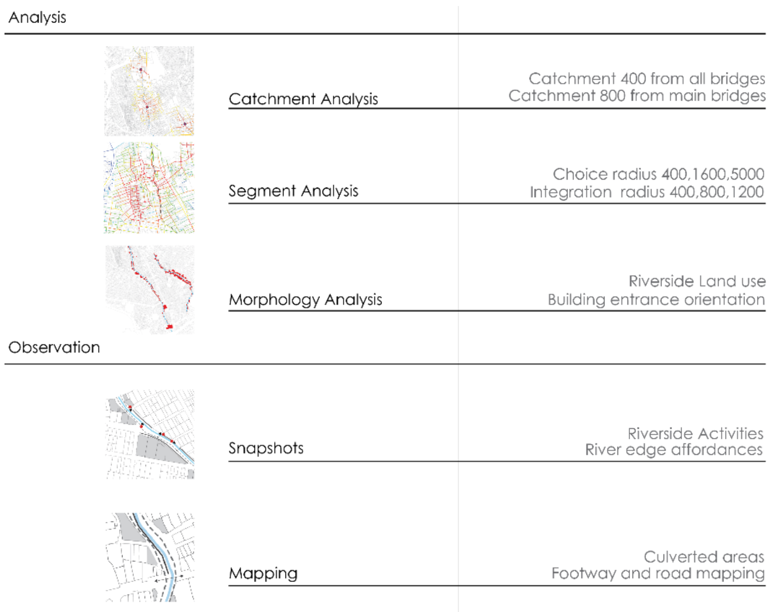


Figure 9. The methodological steps of the project. Author

3.1 Catchment Analysis

This method has many applications in different fields and is generally used to define the area of effect of a certain store, place, or a venue from which it is expected to draw potential customers or identify existing competitors etc. In the space syntax context, the metric catchment analysis (Metric Step Depth) also integrates the street segment length into the distance calculation. Using this tool, the research defines the catchment from the river for two radii of 400 and 800 which is equivalent to 5 to 10 minutes walking to study the local effective area of the river within its walking distance. Initially the catchment is run from all the crossing bridges on the river which link two sides of the river for pedestrian access (Fig .10).

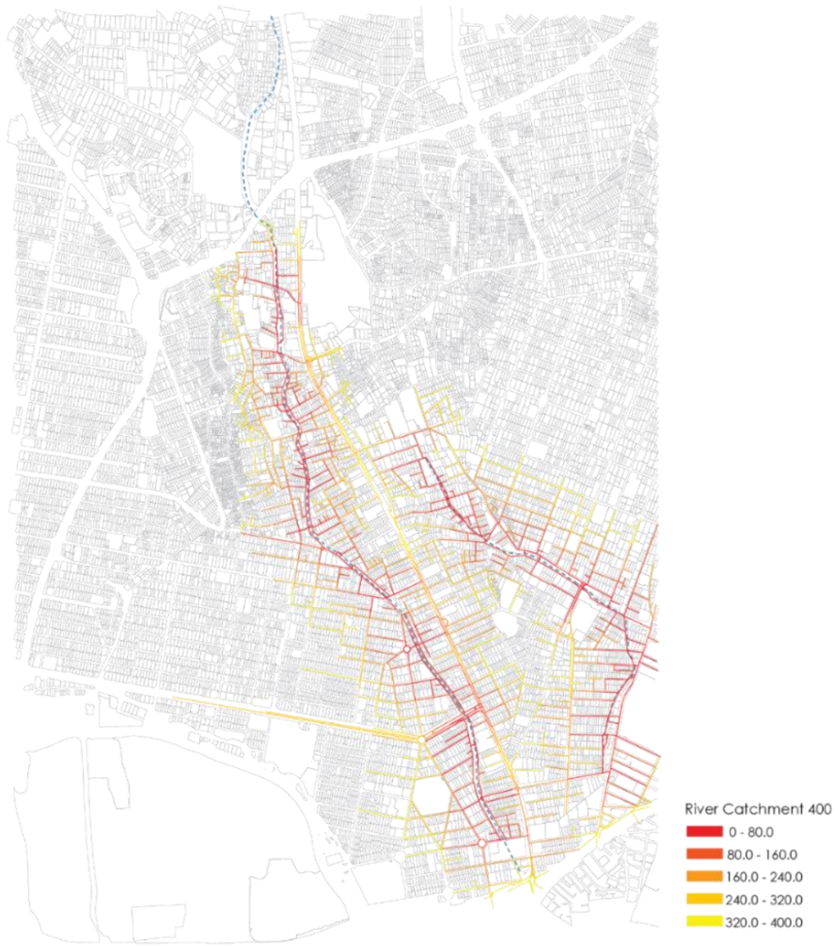


Figure 10. The Catchment 400m from all the pedestrian accessible bridges of the rivers. Author

The primitive interpretation of the analysis would give a spatial boundary that identifies the accessible spaces within the proximity of the river. This will effectively show the connectivity of the surrounding area from the walkable and accessible river junctions. In the next stage the analysis is run from the main bridges, where the network of the road system is converged on the river (Fig. 11). This catchment will divide the river into separate zones with the river as a central spine. A secondary interpretation of such analysis might explain how consistently the river interlaces the walkable routes to the main network of the city.

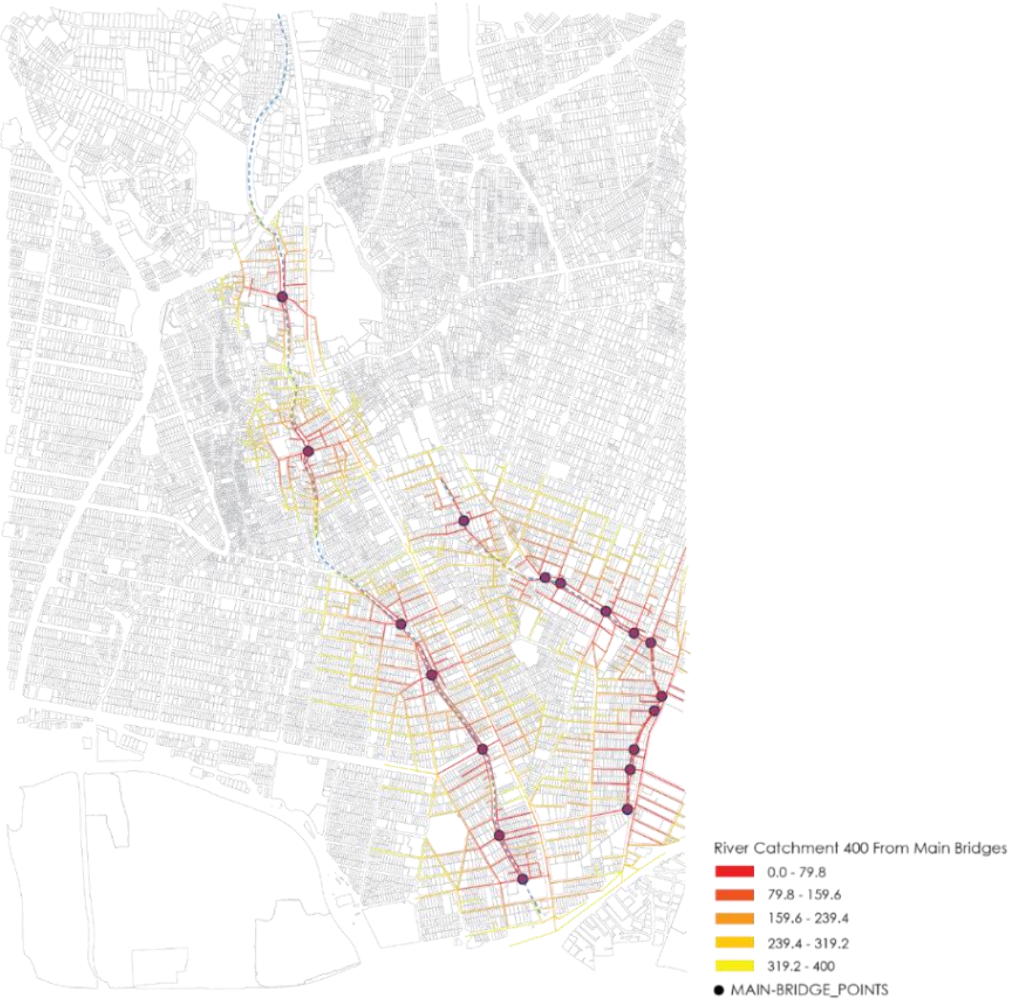


Figure 11. The Catchment 400m from main Vehicular bridges of the rivers. Author

3.2 Segment Integration and Choice Analysis

To analyze the syntactic qualities and the accessibility of the system, the research deploys two measurements of Integration and choice. In space syntax terminology, integration is equivalent to the mathematical closeness, and choice is the syntactic term for betweenness (Hillier, 2009). For this research, the Integration analysis was run on radii 400, 800, 1200 (5, 10, 15 min walking distance) to capture the relationship between the urban system and the rivers' structure on different levels. To be more accurate, in the model of the network system, the river is represented by the paths along its both sides since the river itself is a barrier and not a walkable route. In the preliminary outcome of the integration analysis the river area becomes red, which indicates that on a meso scale, the river has a high value of integration possessing a to-movement potential as a destination (Hillier, 2009) (Fig .12).

Figure 12. Integration analysis r1200 of the river area indicates that the rivers have increased integration in the urban network

As for the Choice analysis, the model was run on mixed radii of 400, 1600, 5000 to evaluate the relationship between the river and the network in terms of through-movement. The firsthand results reveal that on the wider network, the river fails to be a means for through-movement while on the neighborhood scale it improves local accessibility (Fig .13).

Figure 13. On the left - Choice analysis r5000 of the river area; On the right – Choice analysis r400 of the river area. Author

3.3 Morphological Analysis

The last set of analysis looks deeper into the morphology of the settlements around the river within the catchment boundaries. This analysis is conducted to evaluate the orientation of the entrances towards the river. Four distinct orientations are defined by color coded steps of 90 degrees referring to the angle that the entrance surface of the building makes with the river's tangent line. Red being one step away from the river (zero degree) to green assigned to the building's that are four steps away from the river (270 degrees) (Fig .14). The orientations of the entrances are particularly important for understanding the morphological aspects that might contribute to the movement economy of the riverside. Therefore, all the land uses of the settlements of one step away from the river are mapped to see how they correspondent to the orientation they have towards the river. In the next step, both rivers are divided into 5 sub zones in each river's catchment area, according to their value of integration, structure of the urban context and the main roads that divide the river. These 10 zones are then evaluated for their proportion and diversity of the land use to discover the relationship with the land use pattern and the spatial attributes of the river area in each zone.

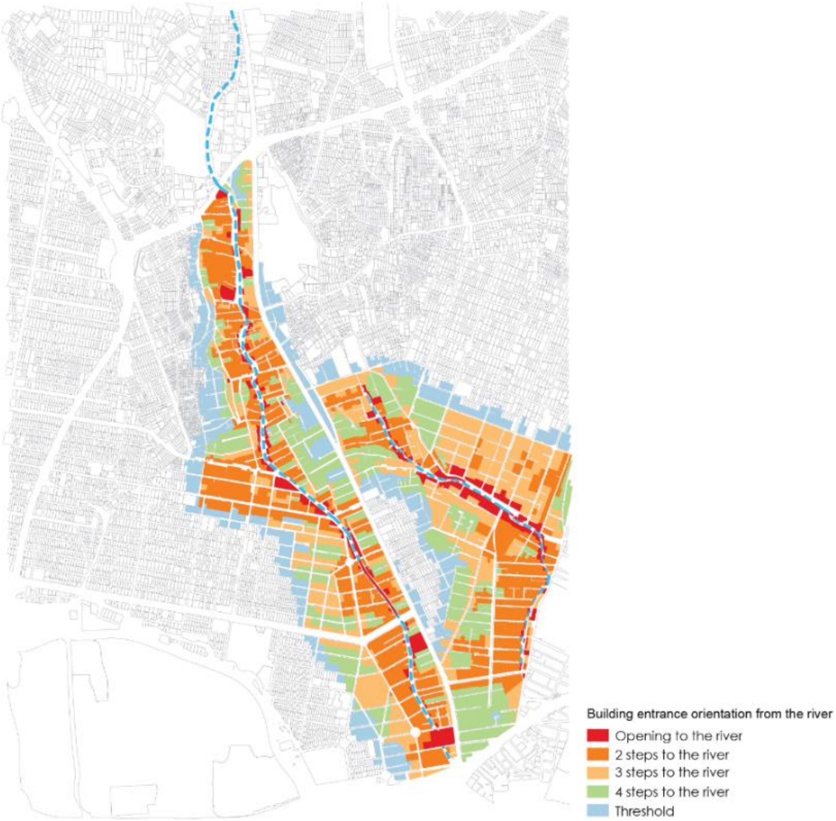


Figure 14. The step orientation of the building plots from the river (Right). Author

3.4 Snapshots and Mappings

Observational methods in this research project has been deployed to reveal the nature of the small urban rivers in Tehran through visual sequences and footway mappings. The snapshots from the river and the surrounding space identify certain activities taking place along the rivers and help explore the spatial appropriation potentials of the river and its character in each specified zone.

On the other hand, mapping the footways and roads along with the bridges gives a sense of where these details of the riverside paths are promoting continuity and connectivity and where they are discouraging and disrupting the movement.

4. Discussion and Findings

Putting together all the analytical and observational results, the narrative of the small urban rivers in Tehran is presented through an evidence-based research. In this section a conclusive image of the rivers is depicted by answering the research questions while unfolding the story.

4.1 Small urban rivers through time

Glancing through the previous studies and literature we can prove that these small rivers in the cities can act as double-edged swords. The rivers can be a source of contamination and a hotbed for vermin, meanwhile, they can also benefit the city spatially as well as environmentally. The role of the rivers of Tehran through their history of encounters with urbanization was more complex than what it appeared to be. According to the historical maps of Tehran dispersed small settlements had organically formed along the rivers before the urban developments. This indicates the rivers were first a common integration line for the human settlements. During the urbanization process, the top-down policies have devised plans overlooking the small rivers that could have been beneficial for the city as natural elements and spatial opportunities. Thus, most of the smaller rivers was buried under the ground becoming part of the sewage system. The remaining rivers, however, have secured their position in the structure of the urban grid creating linear informal barriers and streets that could separate sides while fundamentally connecting the old structure of the city. This study shows that to understand the true mechanism of the small rivers in the urban fabric, their evolutionary role in the length of time and in different parts of their own length should be studied.

4.2 The loose strings within the grid

The choice analysis 5000 shows that the riverside roads acquire a relatively low value in the global network. However, by overlaying the catchment analysis 400, it could be understood that the main roads and global connectors with high choice values are within the river's catchment (Fig .15). This means that the rivers, just like a loose string within a net, are not strong enough to be accounted as a part of the foreground network in the urban system (Hillier, 2001), but they can provide a quick access to the main roads from the more segregated areas, thus, they can sew the foreground to the background through a locally accessible path. In other words, they are working as mediators between the two global and local scales.

Figure 15. Comparing the choice analysis 5000 (Left) Catchment analysis 400 (Right): Most of the main roads are in the catchment of the river. Author

In choice and integration analysis 400, the old structures of the city which has organically formed along the rivers are highlighted with higher values (Fig. 17) (a-1, a-2, a-3). This implies that these structures are using the river as a center as well as a main connector.

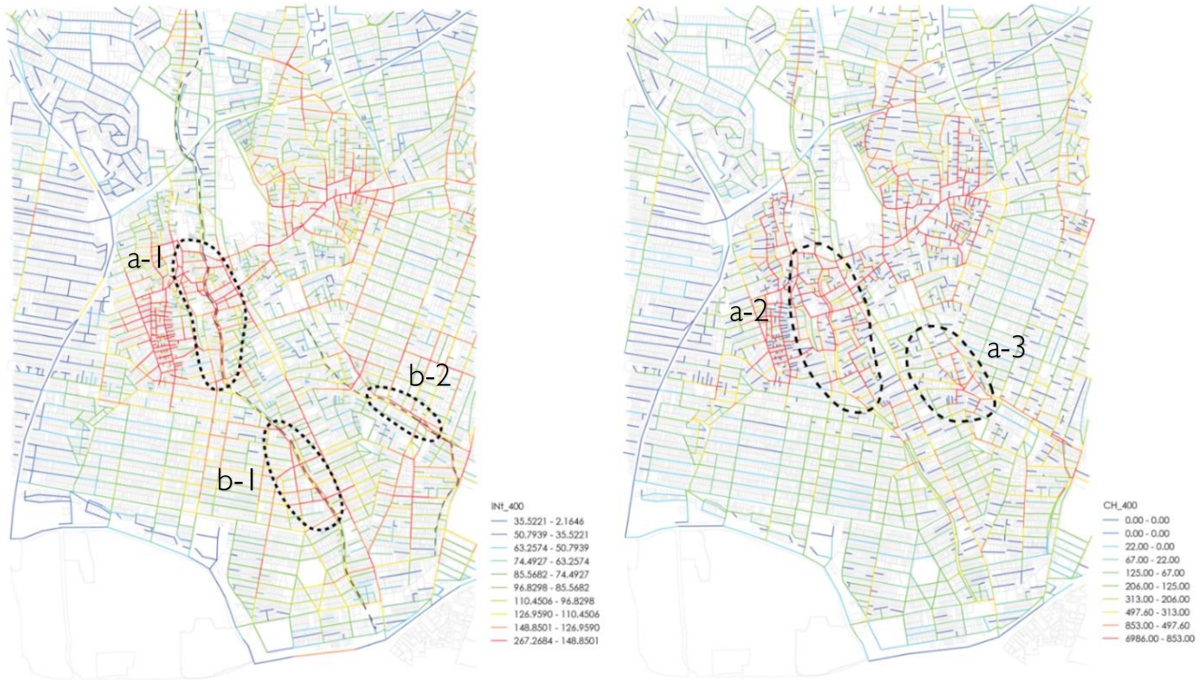


Figure 16. The effects of the rivers on the local integration (Left) and accessibility (Right). Author

The rivers oriental positioning is also worth noticing in comparing the two rivers integration analysis 400 (Fig .16) (b-1, b-2). What can be understood from comparing the two rivers positions against their grid system is that the diagonal crossing of the Zargandeh river (b-1) has increased the integration value in the grid, whereas, the aligned positioning of the Pasdaran river with the grid system (b-2) has barely influenced the grid's integration value along its length, although the riverside itself is integrated.

The river's role in dividing or connecting the two sides across its length is another important factor in studying how they define neighborhood boundaries in the city. It can be conferred that parts of the river where the integration value drops, the river is acting as a barrier between the sides. This can be confirmed by interpreting the neighborhood boundaries of the area (Fig .17). Where the river acts as a barrier, the boundaries of the neighborhoods correspond to the river line and where the river integrates the two sides with a high value the river remains inside the boundaries of the neighborhood.

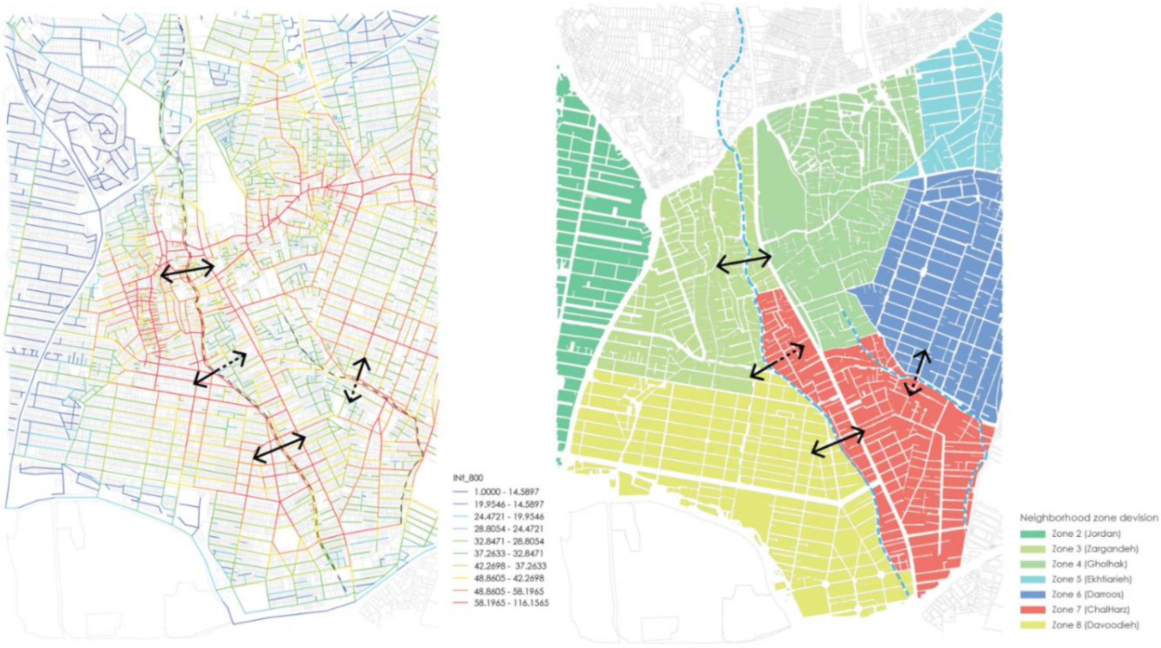


Figure 17. The integration analysis r800 (Left) corresponding to neighborhood zone divisions (Right). Author

4.3 Small urban rivers and socio-economic effects

The zoning map of district 3 identifies the river areas as mixed-use zones in the general planning of Tehran. The current land use map of the riverside, nonetheless, reveals that there is less land use diversity than what was planned in the urban planning of 2007, and the river zones are still 68% occupied with residential land uses. This implies that the value of the small rivers in Tehran, as potential socio-economic generators, are recognized in planning, however, implementing some construction policies as mentioned, has led the city to fail in ceasing the opportunity to fulfil the rivers' true potentials.

On the other hand, the orientation analysis of the plots shows that 53% of the riverside plots are oriented towards the river 75% of which are land uses other than residential (Fig .18) (Table. 1). It can be inferred that most of the riverside settlements which are facing the river has encouraged diverse land uses other than residential.

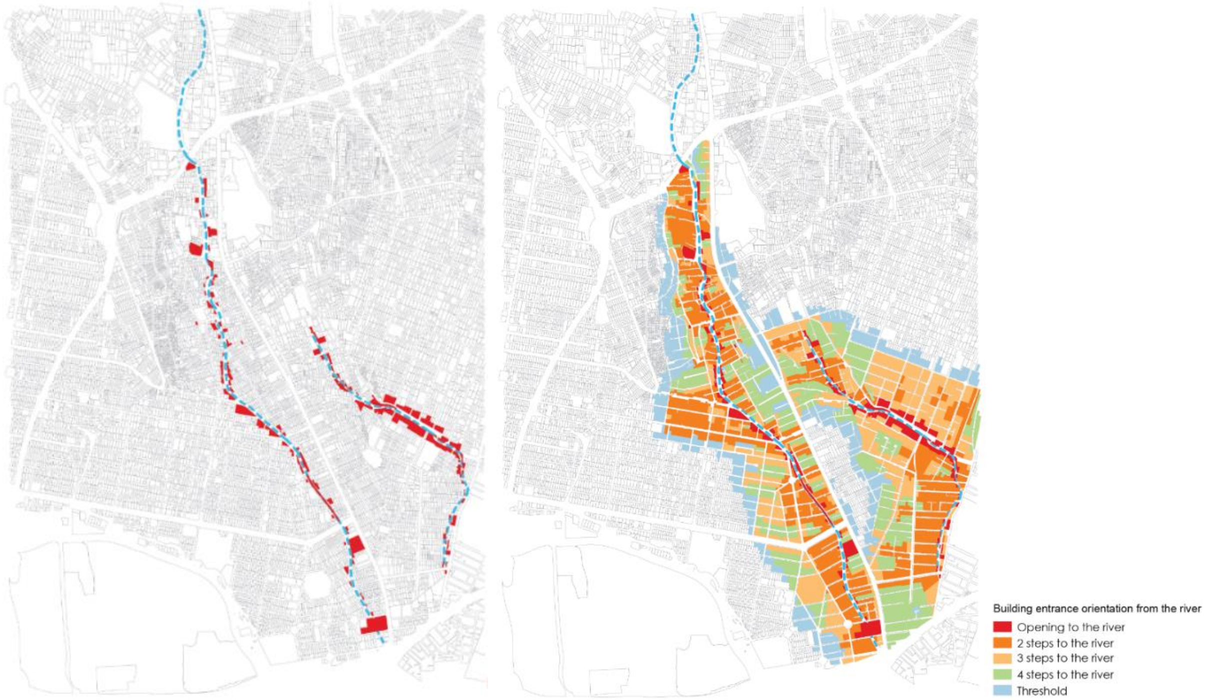


Figure 18. The building plots one step away from the river (Left) The step orientation of the building plots from the river (Right). Author

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	TOTAL
RIVER CATCHMENT	299	1827	1113	1437	69	4745
RIVER CATCHMENT precentage	6.3	38.5	23.5	30.3	1.5	-
IMMEDIATE PROXIMITY	290	194	40	17	0	541
IMMEDIATE PROXIMITY precentage	53.6	35.9	7.4	3.1	0	-

Table 1. Building entrance orientation count based on steps within the catchment area and the immediate proximity of the river. Author

By categorizing the land uses within 10 defined zones along the rivers, it can be understood that the zones with more plots facing the river are the zones with more diversity of land use along the river with the commercial land uses amplified when closer to main commercial axis (Fig .19).

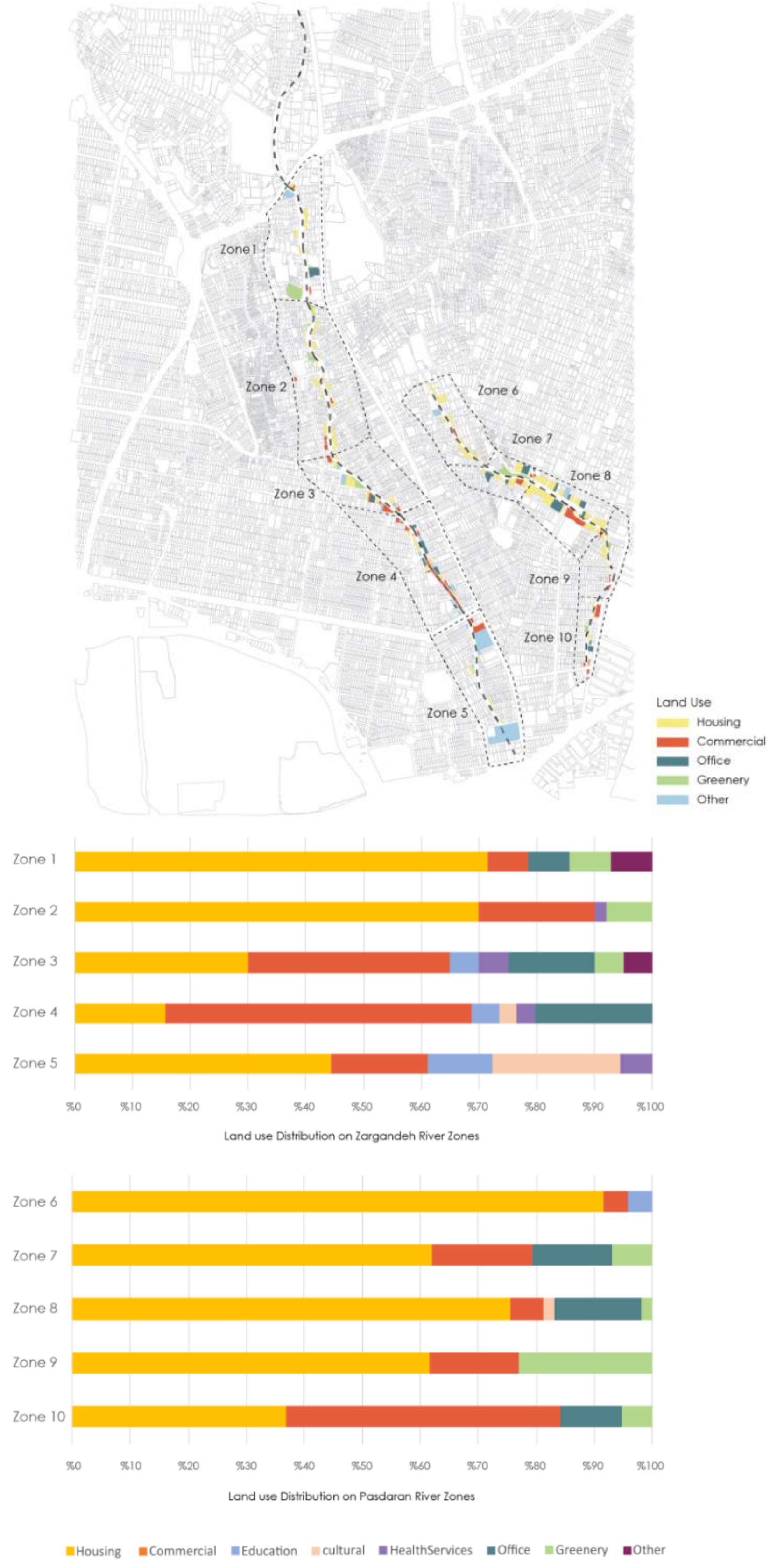


Figure 19. The land use map with zone divisions (Top) and land use distribution of zones for each river (Bottom). Author

4.4 Small urban rivers and space appropriation

As a public domain, the small urban rivers are elongated green open spaces resembling parks in specific features and characteristics. Therefore, they can provoke similar activities that mostly take place in a park such as walking, sitting, exercising etc. but the linear nature of the rivers distinguishes these unbounded organic paths from all other open spaces of the city in the way people appropriate them. Space appropriation is a term used to define 'the process by which each human constantly, whether consciously or unconsciously, lays claim to surrounding space' (Ostermann and Timpf, 2009). The structure of the urban river itself and its configurational position within the urban network create unplanned and informal spaces that could afford such appropriations. In the observations conducted for this research, the snapshots captured some of the most common and uncommon activities and space appropriations along the river. The river's flood protection walls, as the symbolic features specific to the urban rivers, define an edge for the river and the city. These edges are an important element for the local community as it exploits it potentials as a sitting area, a shelter for the homeless, or a shelf for presenting goods (Fig 20).

Figure 20. snapshots of the river showing different kinds of space appropriation along the river. Photo credit: Mana Sahebnasagh

4.5 Small urban rivers and disrupted paths

Since most of the space syntax analysis is based on spaces where people can see and go, studying the rivers can be a challenge for this methodology as it presents possible spaces that are visible but not accessible, whether it is in the case of crossing the river or walking along the river. In this research, the latter is briefly studied to discover the potential paths within each zone that were constantly disrupted leading to multiple dead ends and cul-de-sacs due to the discordances and incompatibilities of the urban grid and the organic structure of the river. The results of the study suggest that the footways along the river are more consistent in the zones with the old organic structure like zone 2 of Zargandeh river, where the initial settlements have had developed (Fig .21).

Figure 21. Mappings of the footways and roads along the river. Author

5. Conclusion

One of the main goals in this project was to uncover and study the complexities involved in different aspects of the small urban rivers in cities like Tehran. The structural coupling of the river and the city has many historical, morphological, and spatial facets that needs to be meticulously scrutinized to unfold the true story behind the scenes of this relationship. With the lack of up-to-date data and other limitations that has challenged the process in different grounds, the research has strived to remain consistent in facing these challenges and presenting a clear and comprehensible logic in interpreting the outcome. The results of this research study highlight some of the most important effects of the small urban rivers as part of the urban tissue and reiterates their undiscovered potentials, which can be exploited by the city to its advantage. Other important factors like visibility, vegetation and sense of belonging were excluded from the study due to time and information constraints. However, further research on these fields will pave the way for reaching a conclusive understanding of the small urban rivers. Before these natural sources fade into oblivion, it is worth reconsidering the ways in which they can be beneficial for our cities and seek to retrieve their long-lost value.

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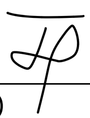

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