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THE BLUE VEINS OF TEHRAN:

TOWARDS A SPATIO-SOCIAL CLASSIFICATION OF THE URBAN RIVERS

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ABSTRACT

In the urban studies, there has been less focus on the small rivers and the part can play in forming the city's configuration and the movement of people in the city. The aim of this paper is to discover new approaches that could lead to a spatio-social classification system to fill the void in understanding the rivers as social interfaces in the city rather than mere natural landmarks. Due to the broad range of natural types and sizes of the urban rivers, this exploratory research exclusively focuses on the small 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 endeavours to devise a new method to capture a holistic view of the small urban rivers that could unfold how a multi-river city structurally evolves around its natural features and how it socially responds to them.

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. It also shows that although the topological levels of the city do not have a direct correlation with the urban network, it can evoke a pattern in the system that could influence the social movement. Studying such patterns could potentially 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 around the intra-city rivers.

KEYWORDS

Small urban rivers, space syntax, multi-river city, urban accessibility, Tehran

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 structure of the river and the city indicates the lack of an in-depth understanding of the spatio-social layers of the urban rivers. Therefore, this piece of work tries to highlight the social value of urban rivers by studying the movements and morphological evolutions of the city adjacent to these streams and experiments geospatial methodologies for classifying the rivers as a part of a city structure rather than a detached natural body. This study aims to set the foundations for future developments in measuring the spatio-social dimensions of urban rivers in all civic contexts starting from Tehran.

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 characteristics 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 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 studied as an urban structure? And how can this method lead to a new approach to studying and classifying the urban rivers?
3. How can the small urban rivers affect the movements in the city and on what scale?

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 analysing 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

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). All these rivers have certain commonalities and distinctions which can be instrumental in comparing and sorting the river areas in the city.

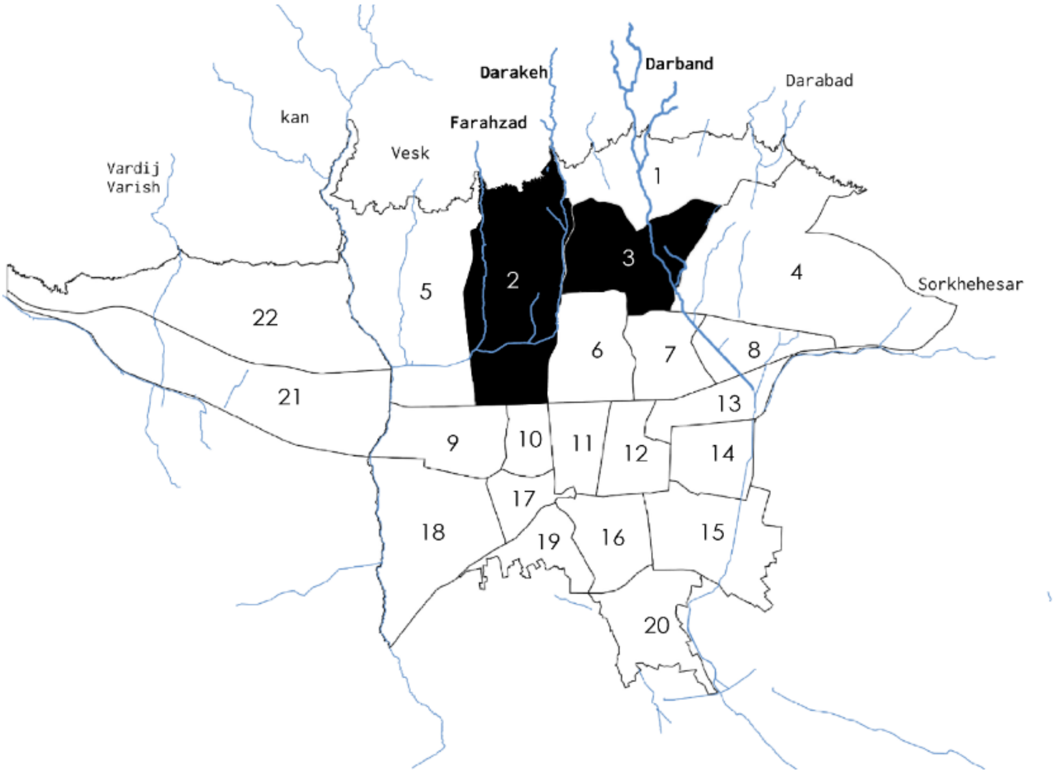

Figure 1. The map of Tehran district divisions along with its main river-valleys. The rivers of Darband, Darakeh and Farahzad in the black districts are the focus of this research study. Author

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. 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.

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. 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).

1.5 Research background and prospects

This paper can be considered as a continuation of a series of studies on the small urban rivers in Tehran which was done by the author as part of an educational university program. 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. Analytical evaluations of the Darband river were 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 emerged occasionally along the rivers' edge.

The outcome of the previous research project can be useful 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 paper'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.

2 LITERETURE 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). This can also describe the nature of the river-city relation with a third separate instance that works as a medium between both. Therefore, discovering the extent of this threshold and its characteristics may give insights on how the city and the river evolved over time.

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 and the problem of terminology and taxonomy

In classifying the rivers 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 a 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.

3 METHODOLOGY

3.1 Methodology Overview

The methodology rationale is to breakdown the study 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 (Fig 2). 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.

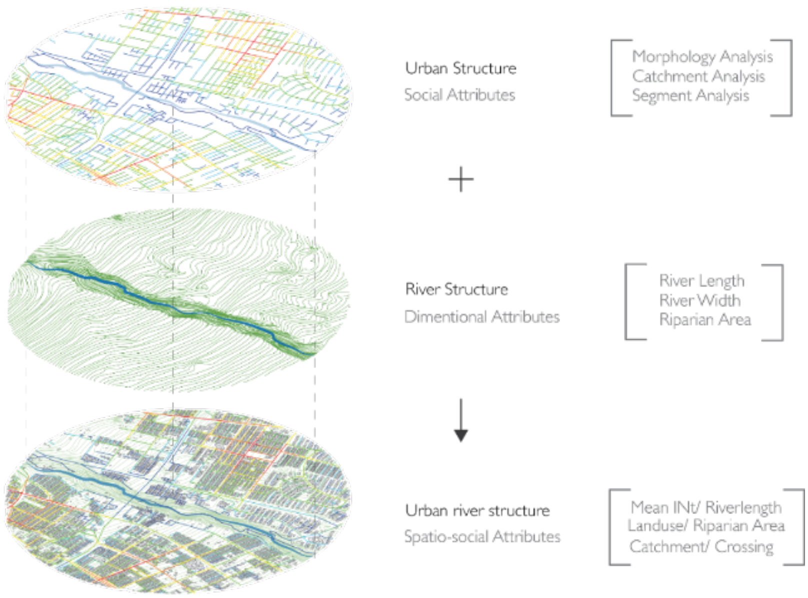

Figure 2. Summary of the methodology rationale. Author

3.2 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 3).

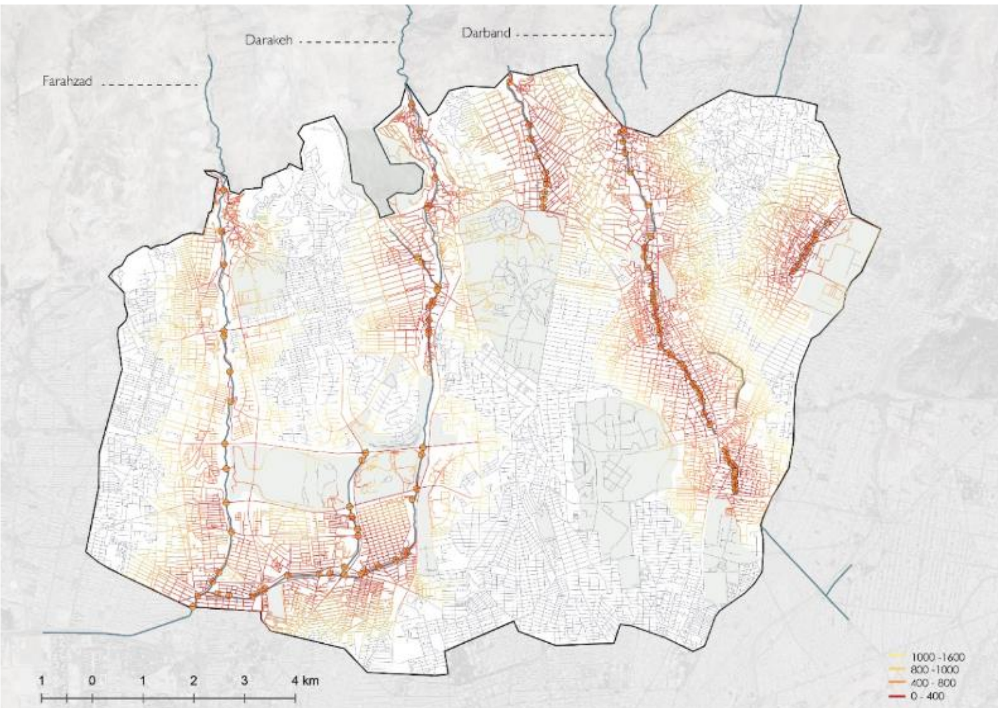

Figure 3. Rivers Catchment 1600m from the crossings. Author

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 (Fig 4) (Fig 5). 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).

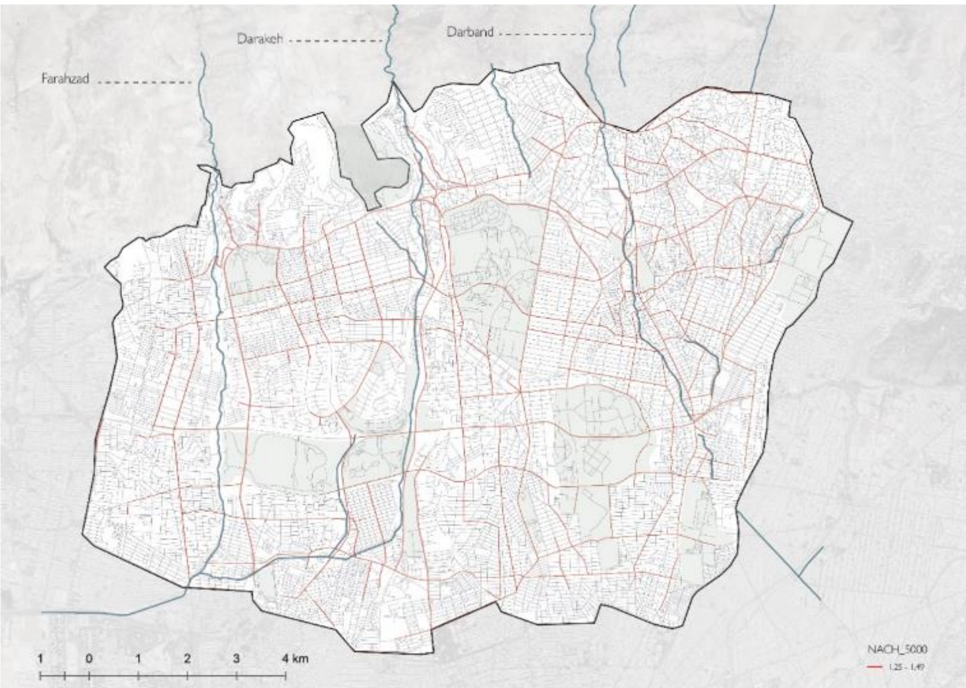

Figure 4. Coloured segments are the segments with **choice values** higher than **1.2**. These segments are used to subdivide the rivers. Author

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. The road segments with choice values above 1.25 are identified as the dividing threshold of the zones. The following figure outlines the river zone divisions based on the catchment 1600m and choice 5000m (Fig. 3.4).

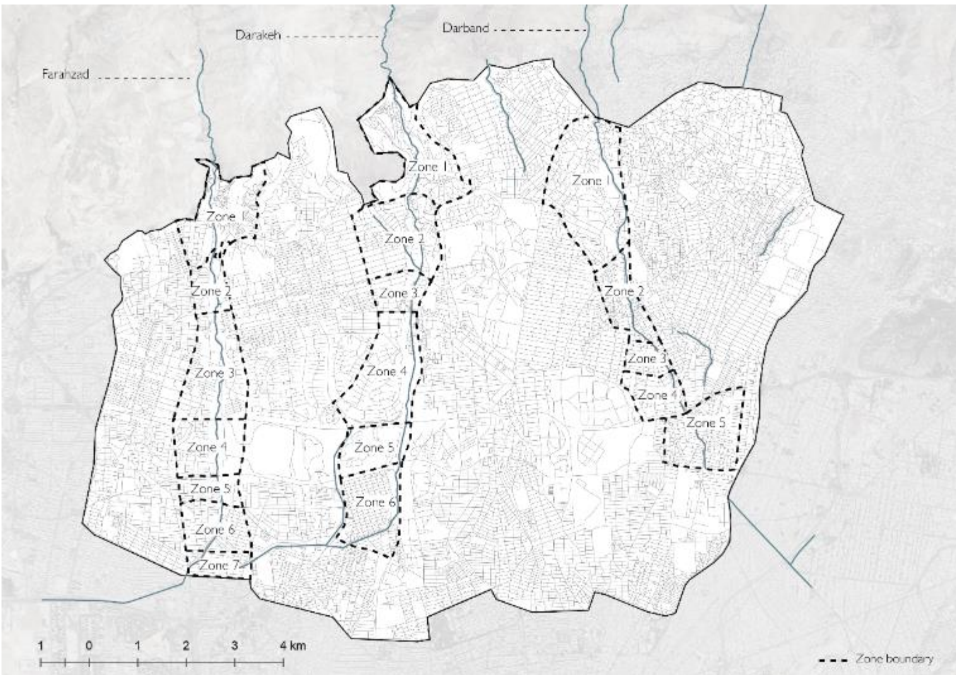

Figure 5. Defined rivers' zone borders resulting from superimposing Catchment 1600 and NACH 5000.Author

3.3 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.

3.4 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.

3.5 Formulating the combined system

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 paper, 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, Riparian areas, and Mean Altitude.

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.

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.

4 RESULTS

4.1 Stage 1: River attributes

Following the methodology steps in the last chapter, natural dimensions of the rivers and their riparian areas are measured along with their mean altitude in each zone (Fig 6). In Darakeh river, the summary of these dimensional attributes indicates that zone 4 is the largest in terms of river length, width, and riparian area (Table 1). On the other hand, in the Farahzad river, 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 (Table 2) In general, the riparian zone of the Farahzad river is vaster than Darakeh river.

Figure 6. Riparian areas identified by tracking the turning points of the contour lines onto where it meets the street segment network. Author

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

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	6.7a	190962	1354

Table 2. Farahzad river's Dimensional and Topological attributes summary

Farahzad River Zones	River Length	Mean Width	Riparian Area	Mean Altitude
Zone 1	1.531	6.5	227722	1599.52
Zone 2	1.387	4.5	148658	1525.29
Zone 3	2.377	5.5	469638	1443
Zone 4	1.183	4.1	300344	1374.43
Zone 5	594	4.4	80967	1331.76
Zone 6	1.069	7.5	51106	1299.31
Zone 7	1.679	7	89770	1271

The number of the river's crossings are also counted per river length to identify the density of the bridges in each zone for each river (Fig 7). For Darband river, 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. The density of the crossings per river length in Farahzad river also signifies that zone 7 has the highest bridge density and zone 2 – with only one bridge – has the lowest density per river length. Comparing the density of the bridges on both rivers show that the density of the bridges on the Farahzad river has a more consistent rise from north to south. In general, the dispersion of the bridges can immediately show where the river has a weak or broken connection with the city structure. Zone 4 on Darakeh river, for example, has explicitly made the river a mere barrier between two sides of the city.

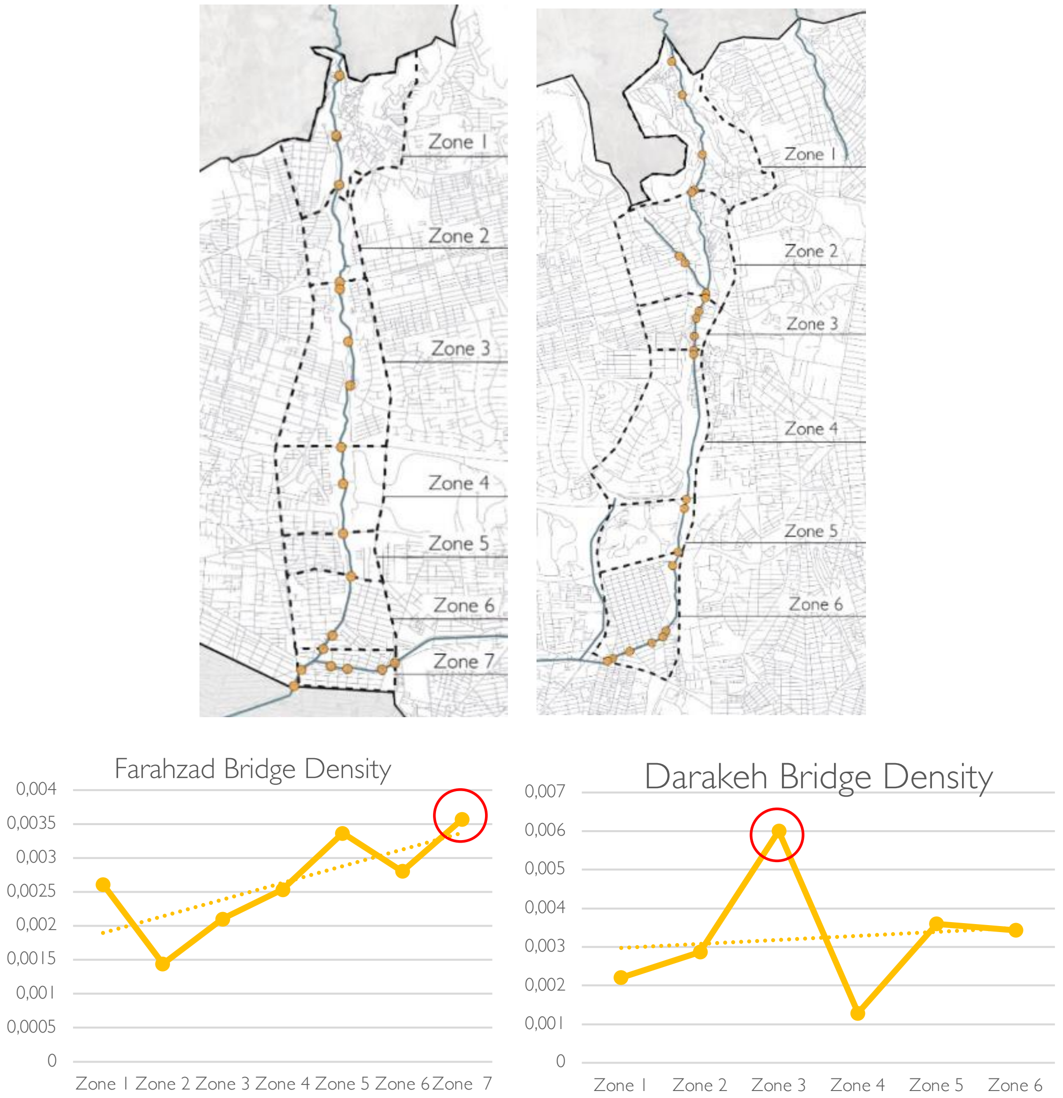

Figure 7. Right: Darakeh river Bridge Density; Left: Farahzad River Bridge Density. The vertical bar in the charts indicate the density of the Crossings per River Length in each zone (n/m). Author

4.2 Stage 2: Urban analysis

In the next step the attributes of the city are measured using space syntax methodologies. Table 3 shows that in most zones – apart from zone 3 – less than half of the segments are within 5 minutes walking distance of the Darband river (Table 3). On the other hand, in Farahzad river sections zone 7 almost all of the street segments are within 5-minute walking distance of the river (Table 4).

Table 3. The summary of urban Segment Count and Segment Length for each zone of Darakeh river area. Author

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

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%

Subsequently, the Integration (Fig 8) (Fig 9) and Choice (Fig 10) (Fig 11) 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 rivers to evaluate the performance of the urban system on local areas within the catchment of the river in each zone. Zone 6 in Darakeh river is the only part where the integration value remains high along the river (Fig 8). In other parts the centers are only connected by an anchor point and not on the length of the river. The choice analysis of Darakeh river brings to front two old village structures in zone 1 (Fig 10). The analysis on Farahzad river illuminates a local center in the vicinity of the river in zone 1 which is a very old village (Fig 11). This could indicate the role of the small rivers in generating such villages in their vicinity. Also, in zone 4 there is an old village close to the zone borders, however, the main highway of Chamran has broken the link of this center with Farahzad river.

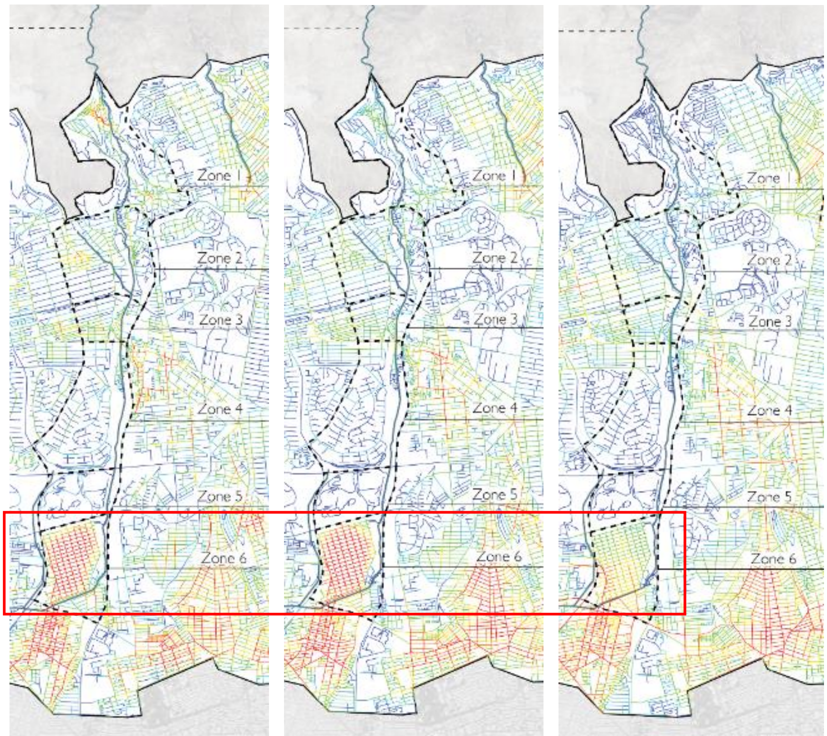

Figure 8. Integration Analysis for three radii of 400 (Left), 800 (Middle) and 1600 (Right) with zone divisions of Darakeh river. Author

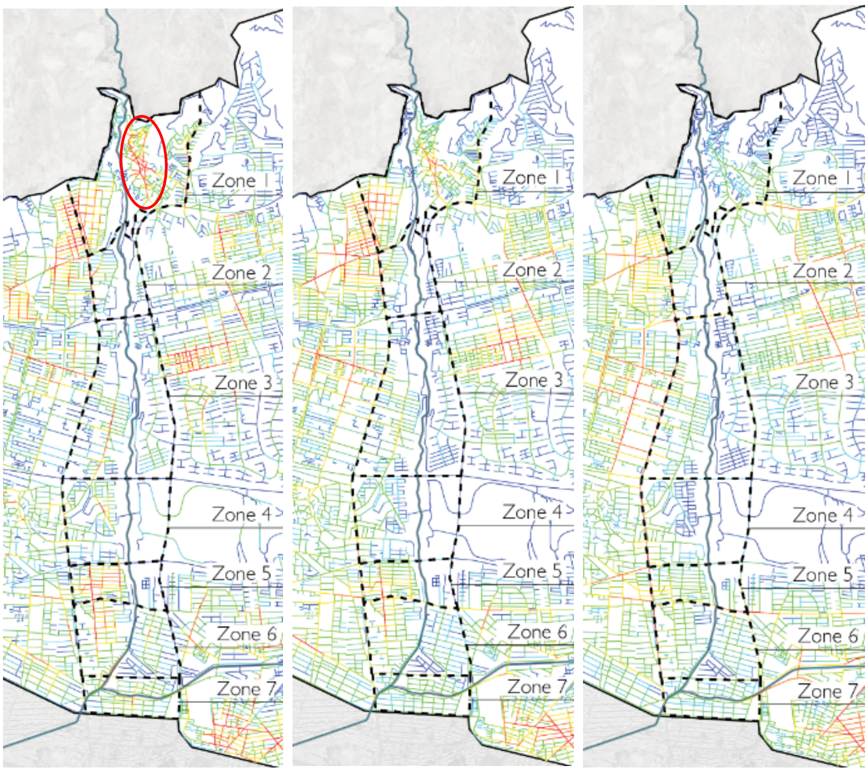

Figure 9. Integration Analysis for three radii of 400 (Left), 800 (Middle) and 1600 (Right) with zone divisions of Farahzad river. Author

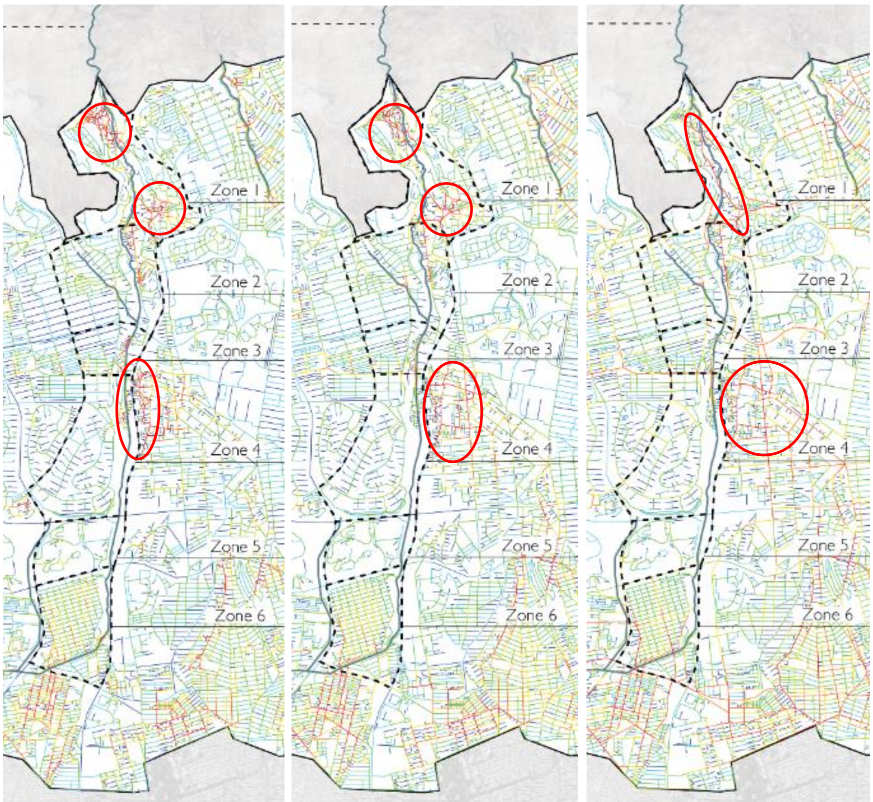

Figure 10. Choice Analysis for three radii of 400 (Left), 800 (Middle) and 1600 (Right) with zone divisions of Darakeh river. Author

Figure 11. Choice Analysis for three radii of 400 (Left), 800 (Middle) and 1600 (Right) with zone divisions of Farahzad river. Autho

4.3 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 calculated Mean Integration per meter and Mean Choice per meter of each side of the river are compared to the same opposite side. Subsequently, the differences between the sides are calculated and trajected onto the river itself which indicates the level of contrast of the sides (Fig 13, 15) [1].

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 (Fig 12). This can be justified by the fact that there are two local centers on each side of the river[2], 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 both sides of Darakeh river, it can be concluded that generally the through movement quality of the urban network along this river is more susceptive to scale change (Fig 14). In the local scale of radius 400, the contrast between riversides decreases from north to south. In the higher scale of 1600, zones 1 and 3 are the most unified zones although their choice values are relatively low.

[1]It must be noted that in all analyses, only the segments that are in catchment 400m of the river are included and not the whole zone.
[2]These local centers are the remaining structures of the old villages of Darakeh and Evin

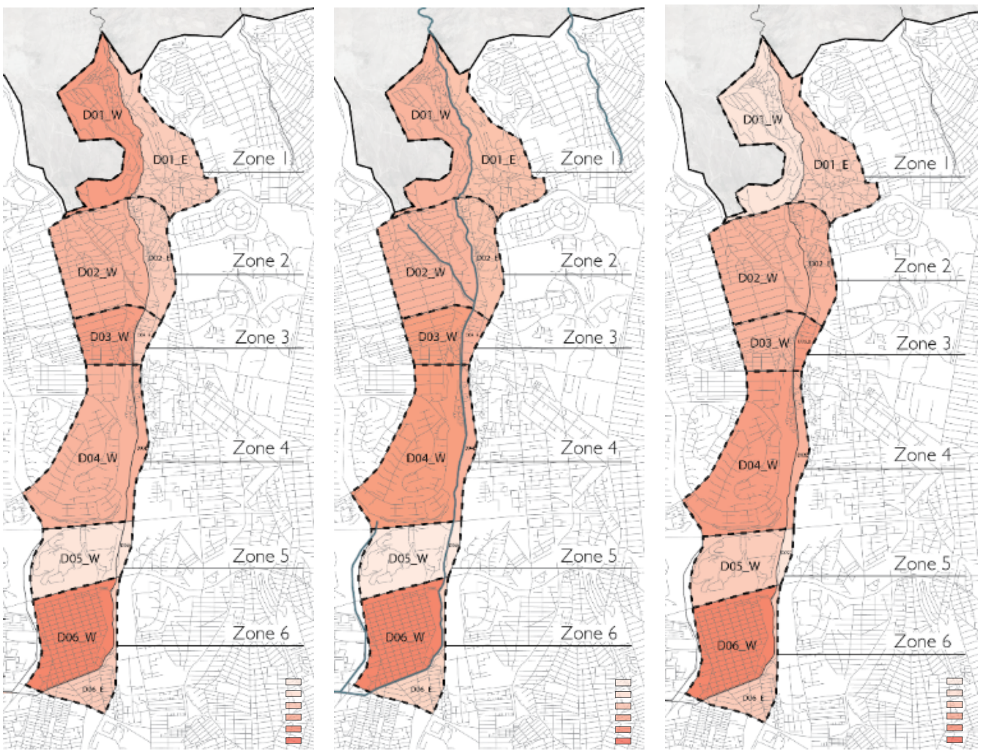

Figure 12. Comparing Mean Integration per Meter of river sides of Darakeh river zones for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

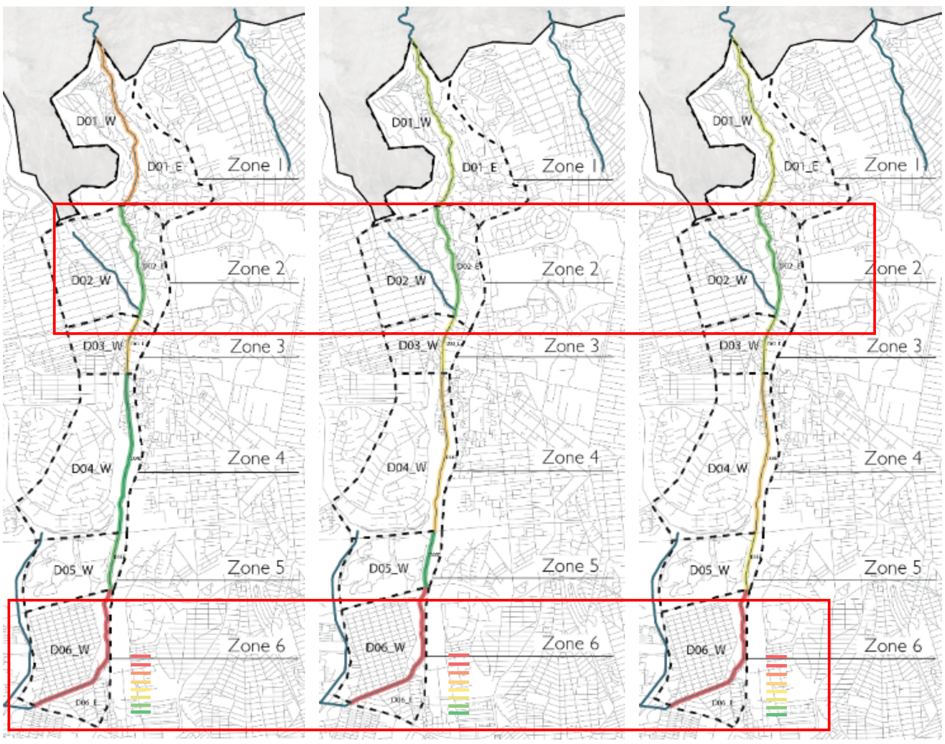

Figure 13. Level of Contrast between sides of the Darakeh river according to Mean Integration per River Length for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

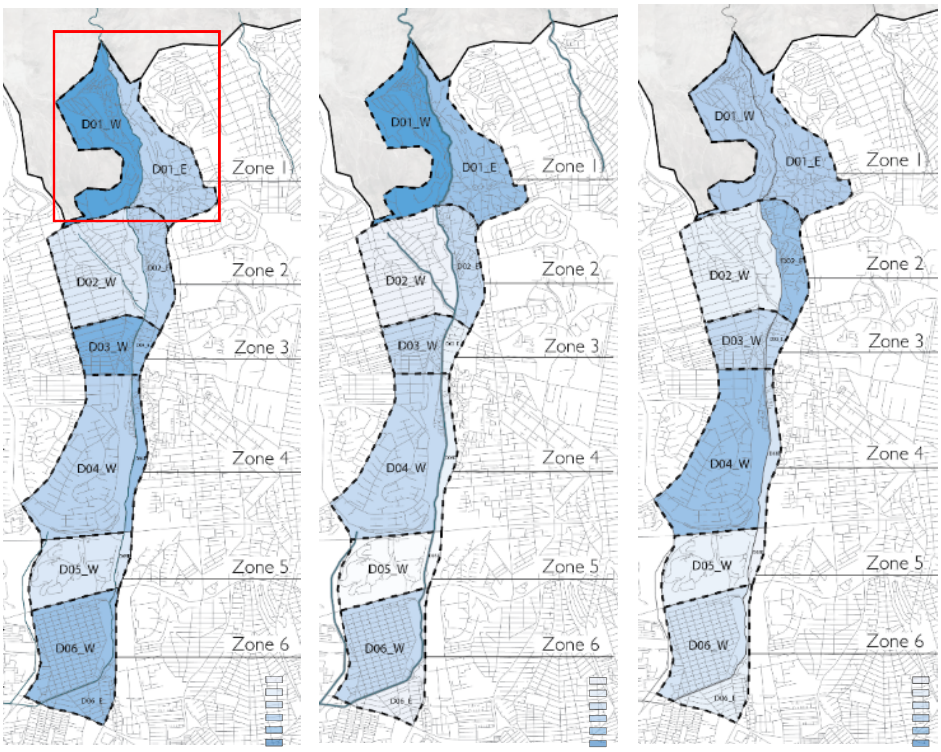

Figure 14. Comparing Mean Choice of river sides of Darakeh river zones for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

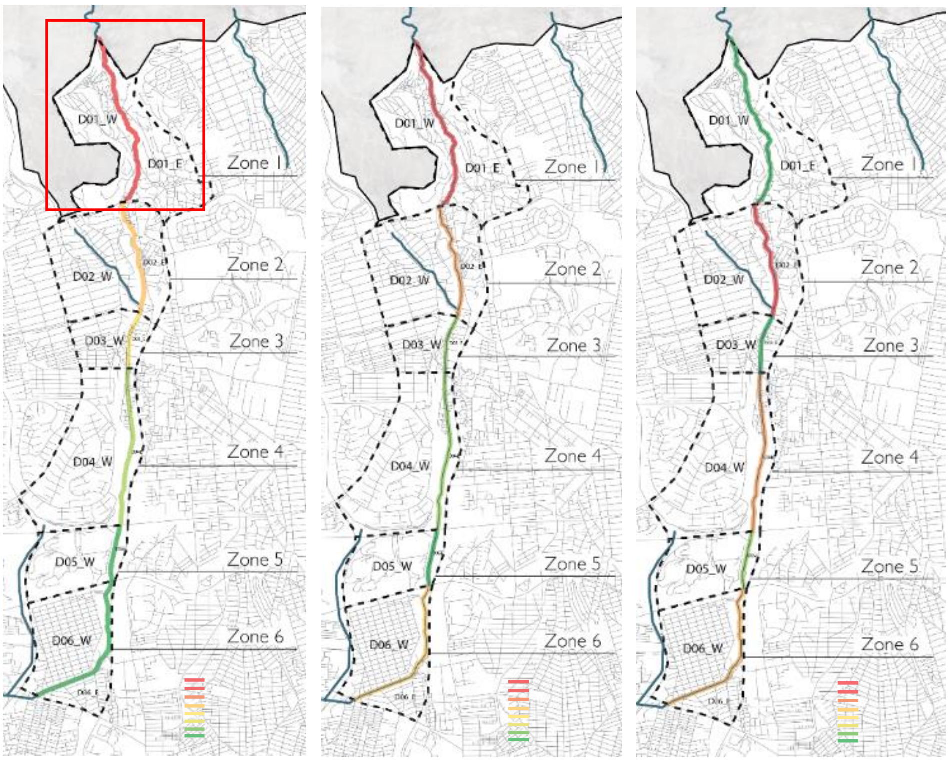

Figure 15. Level of Contrast between sides of the Darakeh river according to Mean Choice per River Length for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

4.4 Farahzad river-valley stage 3: Combined analysis

Farahzad riverside mean integration analysis shows that the middle riversides are the less integrated sides of the river (Fig 16), however, according to the level of contrast analysis, the riversides of zone 3 are more homogenous in terms of integration, thus, more unified (Fig 17). 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 18), 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 (Fig 19).

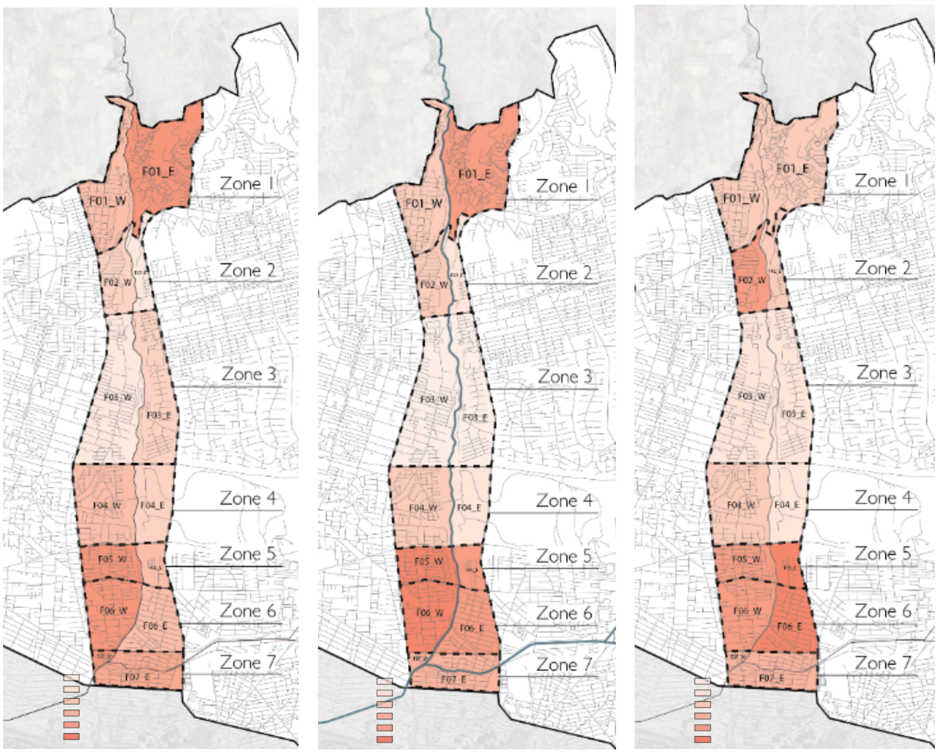

Figure 16. Comparing Mean Integration of Farahzad river side networks in each zone for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

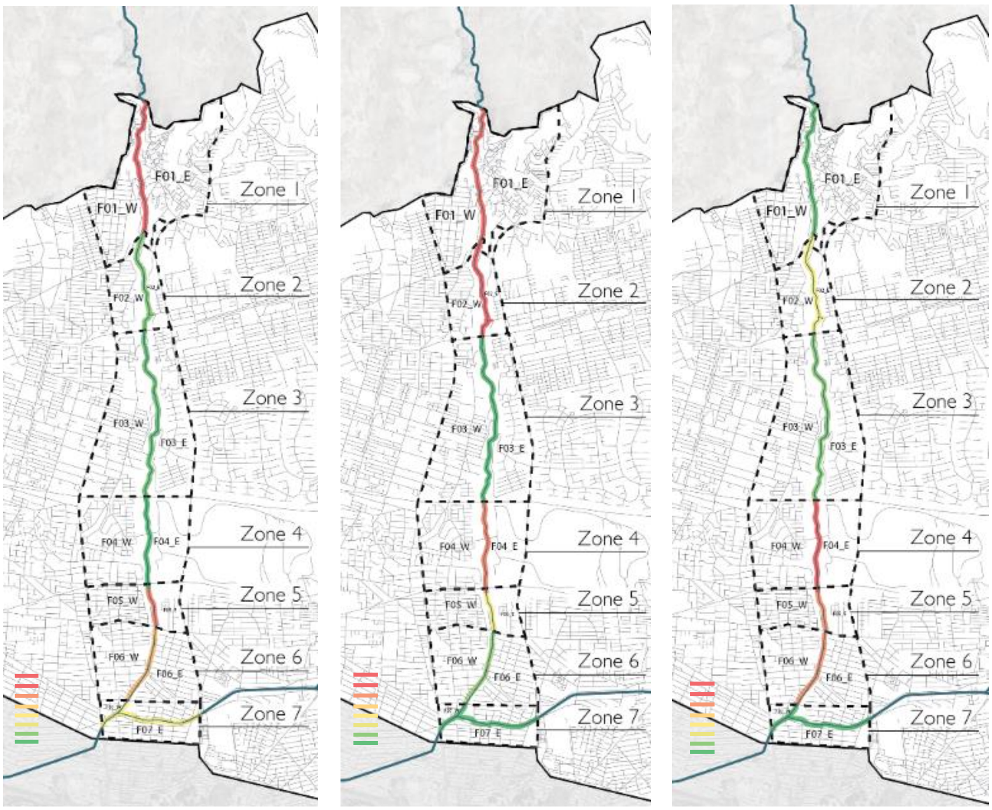

Figure 17. Level of Contrast between sides of the Farahzad river according to Mean Integration per River Length for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

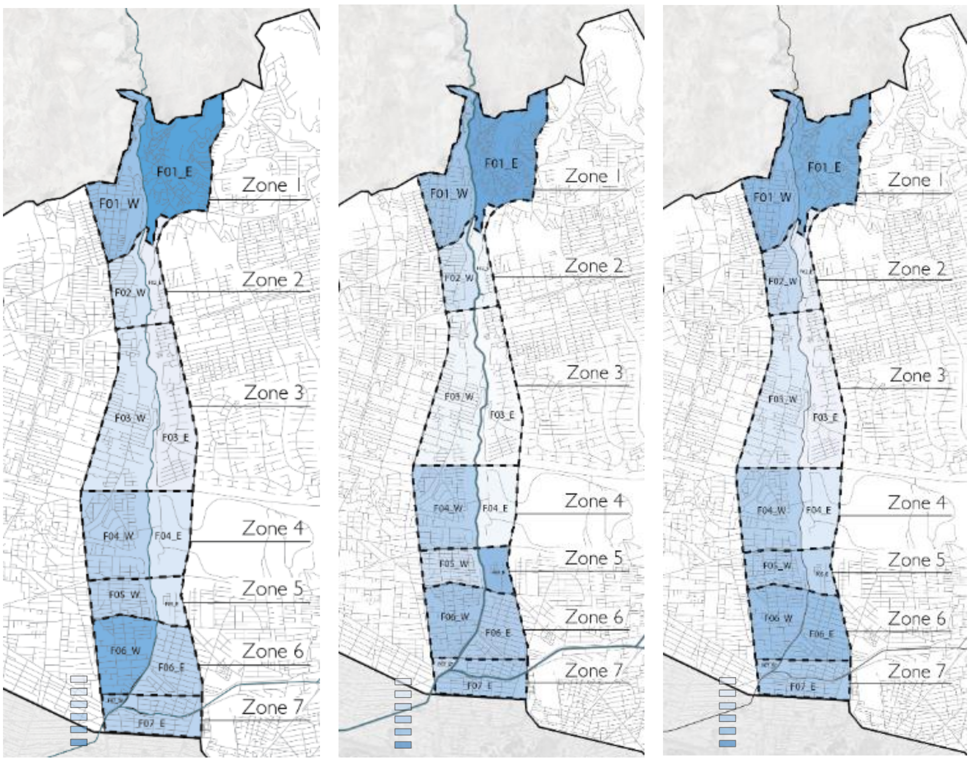

Figure 18. Comparing Mean Choice of river sides of Farahzad river zones for three radii of 400 (Left), 800 (Middle) and 1600 (Right). Author

Figure 19. 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

5 DISCUSSION

5.1 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 20), which suggests that these organic structures still work as the local centres within the city according to the historical maps (Fig 21). 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 although the rivers might have been a reason for the emergence of the first villages, with the establishment of urban structure – in some parts – the connections between the village and the river are 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.

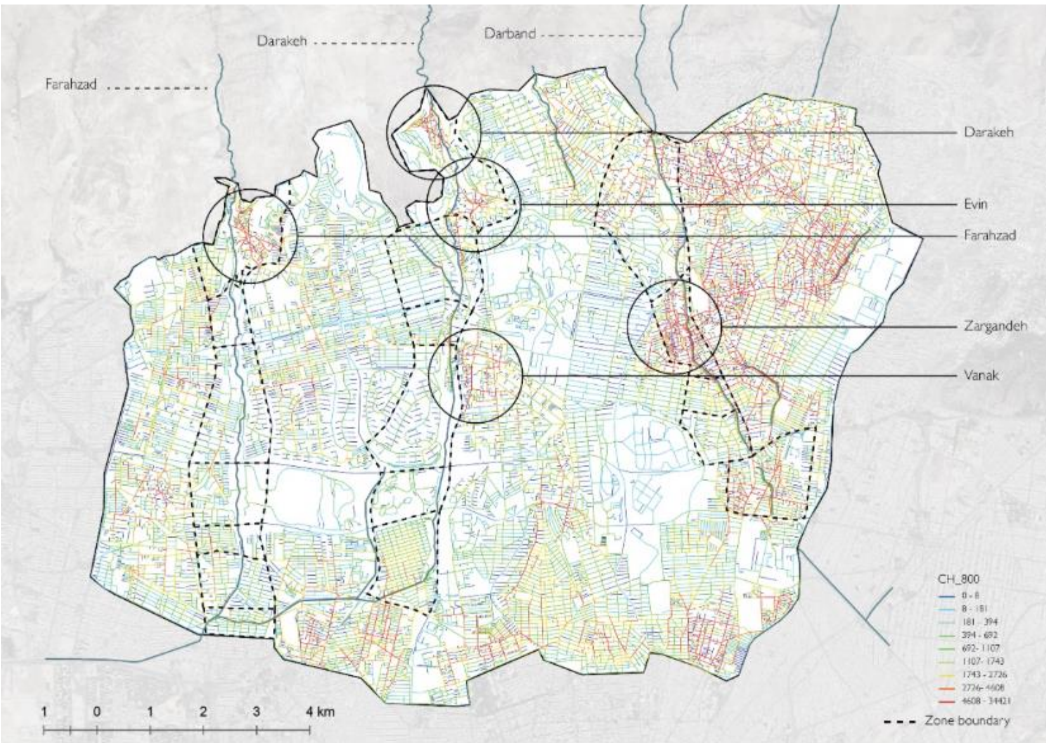

Figure 20. Choice analysis radius 400 of the three river areas of Darband, Darakeh and Farahzad with the overlay of the zone divisions. The identified areas indicate the existing remainder of the old villages along the rivers. Author

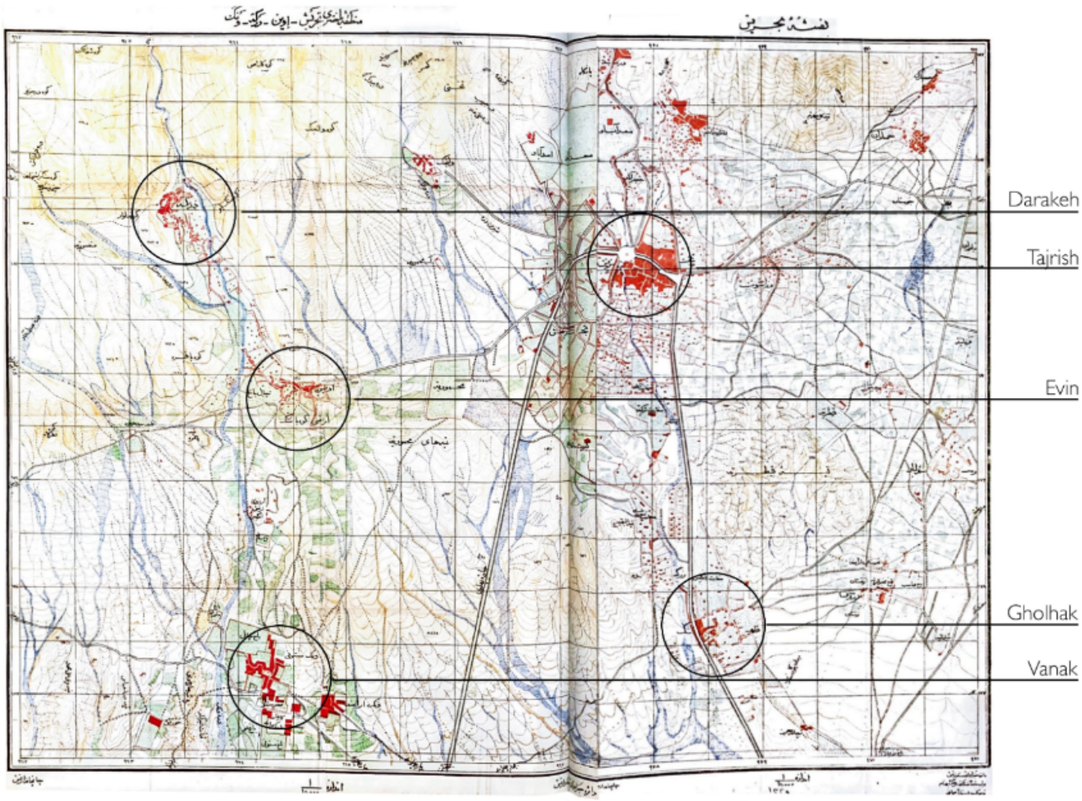

Figure 21. The map of northern suburbs of Tehran in 1950. The identified areas are the initial villages along the Darband and Darakeh river. Map Source: Shirazian, Reza. 2017. “Tehran Mapping: Bank of maps and locations of old Tehran”

5.2 Analytical interpretations: addressing the research questions

The First stage of the study yields some valuable information about the direct connection of the river and the city which are the bridges that link the city network on each side of the river. This is the most tangible way of telling whether a river section is working as a link. In these case studies, the zones with more bridge density have higher coverage on street segments within 5-minute walking distance like zone 3 on Darakeh river. This can mean that the city is more centralized and packed around the river in these sections which could make that part of the river more locally engaged with the city structure. However, this is just a superficial study and cannot provide a measurement of the extent to which the river acts as a link in that section.

Another way of understanding the city structure around the river is by taking the average integration and choice of the whole segments per length on each side of the river zones. In this manner, an overall understanding of the whole structure of the city network and movement on each side can be captured and compared. The result of this comparison between sides gives the level of contrast that can be interpreted as an extent to which the river section acts as a barrier. The higher level of contrast the more the two sides are different in terms of movement and network structure. So, as an example, it could be understood that zone 1 in Farahzad river is much more severed and structurally different from one side to the other, even though the density of the bridges is relatively high.

By looking at the results of all three stages together, it can be concluded that although the density of physical bridges on the rivers may be a prerequisite for making a link between the river and the city, it is not necessarily dissolving the river in the city's neighbourhood structure. The river can still be a border between sides making two different structures of movement along its length. Although the findings of this research paper are limited on the topographical coupling, it can be assumed that this is an issue that needs to be considered with care in studying the city river relationship in not so flat cities like Tehran.

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 and structural 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.

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 solely on the findings of this study, it is impossible to form a comprehensive classification for the small urban rivers, However, this endeavor can offer an in-depth approach to the studies around urban rivers that are to be adopted in the future to gather enough data to form a distinguished collection of river studies base on the method presented in this paper. Additional studies on other cases or qualitative observations can be adopted to validate this study and lead to 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.

6 CONCLUSION

It is worth mentioning that the methods opted for this study is experimental and only suggests a novel approach for studying the small urban rivers in a more structured manner that could be used as a cornerstone for all similar studies on small urban rivers. The line like characteristic of the rivers that is weaved organically into the city network, makes them hard to study as a complete object hence the sectioning method. Nevertheless, identifying the effective boundary of the rivers are very much closely linked to many aspects such as scale and formal structure of the city network and topographical features. This paper has brought to light the complexity of studying the rivers as protracted natural landmarks of the city with all their socio-structural elements that define them as a part of the city structure.

As a general outcome, this study reveals that the city of Tehran and its small rivers are not independent structures and interact with one another on many levels. Furthermore, 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. However, this can only be confirmed by more comprehensive studies on all aspects. 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.

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. The significance of this study lies in devising a framework for studying the urban rivers based on their spatio-social dimensions. Accordingly, the methodology defined in this paper 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.

This paper 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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