COMPARITIVE HISTORICAL NETWORK ANALYSIS OF URBAN NETWORK FORMATION: BARCELONA, TEHRAN, TABRIZ.

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This study aims to explore the similarities and differences in the expansion of streets and cities over time by using betweenness centrality in three cities: Tehran, Tabriz, and Barcelona. Each city has unique characteristics that have influenced changes within them. The research compares the emergence of urban networks in these cities, emphasizing their diverse historical backgrounds. Barcelona, Tabriz, and Tehran each have distinct historical influences, from Roman to Islamic and Catholic, Sasanian Empire to Black Sheep Turkmen, and Islamic urban development, respectively. The quantitative analysis reveals variations in urban network development and changes in centrality over time. Economic and religious-political factors played a significant role in shaping the initial core of each city and its road networks. Preservation of these elements contributed to the diversity of dispersal and access points within each city. The road network's development was closely tied to the physical growth process, with communication networks expanding even before new regions formed, highlighting their importance as connectors throughout the country.

Key Words: *Betweenness Centrality, Iran Historical Cities, Road Network, Urban Formation.*

1.INTRODUCTION

The street is one of the important elements of the modern appearance of the city. Significant changes in the shape of cities are achieved by adding this element to the urban design system. These changes affect not only the physical part but also the historical and cultural structure "[1]." Under the influence of historical or political changes over the past decades, these urban networks have taken on different faces, and their size continues to grow as people's needs grow. Road and street layouts are especially vital because they assist residents to easily access the many crucial parts of a city. Various road designs bring about various levels of transportation infrastructure efficiency, accessibility, and utilization "[2]." In Iran, urbanization and modernism perform important roles in the creation of spaces, geographical regions, road pattern allowing the establishment and evolution of rural and urban areas to be examined "[3]." Iran's cities have a rich history, with their growth and creation affected by a variety of factors such as commercial routes, cultural exchanges, and topographical limitations. Considering the historical the formation of these cities provides valuable insight regarding their distinctive urban environments as well as their proximity of other places within Iran. We can acquire a new viewpoint on Iran's urban growth by looking into the theory of "betweenness centrality" and its relation to the past evolution of cities.

Furthermore, as compared to the process of growth and modifications in the Iran urban road network, the city of Barcelona is an appropriate choice for comparing to the cities of Iran as it shares plenty of similarities in terms of historical background as well as similar factors such as religious or economic factors in the formation. Following the original core of the city, alterations were made over time to preserve historical and economic relevance, which influenced the design of the city and its infrastructure significantly. The comparison focuses on Tehran and Tabriz in Iran and Barcelona in Spain. It will consider the betweenness centrality of their individual road networks, which refers to the value of nodes or intersections that promote efficient transportation movements. The analysis will include several elements, such urban growth patterns, transport facilities, road connectivity, and overall road network functionality. The primary focus of this comparison will be on the centrality of betweenness in the road networks to reveal how much the urban planning modifications can affect the expansion of road network. Likewise, other factors influencing urban growth, such as cultural, historical, and geographical features, will be considered because alternations in each of them can simply carry out the new design for expansion. Likewise, to give an in-depth understanding of the purpose and relevance of betweenness centrality in these cities' road networks, the study will draw on existing data, network analytic methodologies, and related literature.

2.LITRETURE REVIES

This literature review examines the relationship between the historical development of cities in Iran and Barcelona, and betweenness centrality in their respective transportation systems. The purpose of this review is to identify historical contexts and patterns of urban development that have shaped these cities, and to explore the transport network impacts of betweenness centrality.

(1) Urban Development and Road Network Centrality in Tehran, Tabriz, Barcelona:

Purzargar et al. (2020) "[1]." conducted a study to explore the impact of street-linings and physical changes on the modernization and development of Tehran. Their findings revealed that the adoption of European street patterns had a notable influence on various aspects of the city resulting in a more modern city. Noori et al. (2020) "[4]." employed nine centrality measures to assess the structural importance of streets. They used a Stacked Denoising Autoencoder (SDAE) to predict the functionality of streets and applied logistic regression for classification. The research indicated that regularly organized grid patterns with repetitive layouts had a greater impact on shaping the functionality of road networks compared to less regular spatial structures. Similarly, Jamshidi (2018) "[5]." discussed the evolution of urban fabric and public spaces in Tehran, highlighting the challenges of finding suitable space for new public areas. The study revealed that some of the remaining areas in the city were residual spaces created by infrastructural networks. Moreover, Asbagh (2018) "[6]." presented a historical overview of Tabriz's urban development, providing valuable insights into the city's growth patterns through a comprehensive literature review.

Fukuyama and Hato (2012) "[7]." introduced an indicator of link-mediated centrality for pedestrian activity zones. They discovered that plazas, which have been part of urban renewal strategies since the 1980s, are situated in areas with low mediating centrality. Marshall (2004) "[8]." delves deeply into how Barcelona has become a model for urban planning and economic regeneration. The city's redesign of square parks and streets during the 1980s, along with hosting the 1992 Olympics, significantly increased international awareness of its urban development. Porta et al. (2012) "[9]." examined three street centrality indices and their association with various economic activities in Barcelona. They found a correlation between street centralities and the location of economic activity that underscores the crucial role of street centrality in shaping the city's economic landscape.

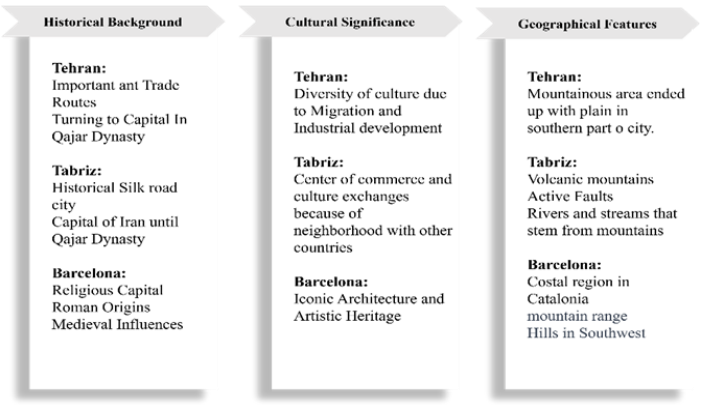


Fig.1 Summary of Cites Features

(2) Network Analysis in Urban History:

There are several interesting urban phenomena that can be predicted using network analysis measures. Their explanations of the significance of junctions in transportation networks have been helpful (Garrison, 1960) "[10]."; (Garrison and

Marble, 1964) “[11].”; (Kansky, 1963) “[12].” (Haggett and Chorley, 1969) “[13].” studying the characteristics of urban history network considering the temporal dimension. Meanwhile, geographic information science provides many technical tools for the study because history of networks is a kind of spatial network (wang,2019) “[14].”. Network analysis has also been instrumental in understanding the growth mechanisms and analysis multiple urban sites in different stage (El Gouj, Lagesse,2021) “[15].” and utilizing geo-located social media data to understand human interactions (Hawelka et al., 2014) “[16].” (Hu et al., 2013) “[17].”

(3) Betweenness Centrality and Urban Expansion:

Betweenness centrality is a metric measure that calculates the number of shortest paths as well as the node's importance to the network than just connectivity (Aristotle,2012) “[18].” (Cardillo et al., 2006) “[19].”. High centrality in each key node represents the vital role of these nodes to keep the connectivity in entire network and removing that might bring disruption or irregularity in function (Freeman,1979) “[20].” (Brandes,2001) “[21].” (Giraud & Perret, 2016) “[22].”. The road networks of Tehran, Tabriz, and Barcelona were compared based on betweenness centrality, providing valuable insight into urban planning changes' consequences on network expansion and functionality (Porta et al., 2006) “[23].”

We seek to provide an in-depth overview of the value of network analysis for shaping urban areas. This review leverages on a range of relevant academic works, available data, networking analytic tools, along with related literature to deliver a complete evaluation of these cities' road networks and their implications on urban development and planning.

2.METHODOLOGY

We outline calculating a set of betweenness centralities for road networks from the 18th to the 21st century. For three case studies in Iran (Tabriz and Tehran) and Spain (Barcelona). The QIS method was employed to study and examine the evolution of each city network by taking into consideration its centrality. The software takes advantage of the *“v.net.centrality”* tool, which can be utilized particularly to vector data by identifying the shortest distances between nodes or points then displaying them in a clustered shape. The indication will be explained as follows.

(1) Betweenness Centrality Theory

Betweenness centrality was devised as a general measure of centrality.it applies to a wide range of problems in network theory, including problems related to social networks, transport“[24].” To compute betweenness centrality of a road network, it needs to be represented as a graph. In most cases vertices and edges correspond to crossings and road segments, respectively “[25].”.

The conventional betweenness centrality for a vertex or an edge is defined as follows **Equation 1**:

$$C_b(k) = \sum_{i \neq j \neq k} \sum_{j \neq i \neq k} \frac{g_{ij}(k)\mathrm{l}).}{g_{ij}} \qquad \text{(1a)}$$

Where Cb is degree to which a node is located on the shortest path and gij is the number of shortest paths between nodes i and j ,gij(k) is the number of shortest paths between nodes i and j. finally, K is a node that has potential to be passed as a shortest path.

The betweenness centrality of a node fluctuates from 0 to 1, with a higher value representing more importance or centrality within the network. The importance of this model for road network analysis lies in its ability to detect critical nodes serving as a key point in addition to improving the efficiency of overall connectivity.

The length of the route is a crucial factor in route selection, and the type and number of edges and nodes are important in calculating the best routes. There is a high probability of selecting an efficient route when the shortest route is known. Although studies of betweenness centrality and transportation networks have been conducted in various contexts, we focus on the historical formation adds a unique perspective which offers insights into the long-term development and transformation of urban spaces. In this research, we consider the opportunity to find out how various historical, cultural, and topographical variables influenced their road networks and urban layouts. Moreover, the comparative study of Tehran, Tabriz, and Barcelona allows to recognize historical formation similarity and differences, in addition to the function of betweenness centrality enables to optimize and made more resilient considering their historical

context. This comparison by implementing the betweenness centrality with the value of history fills a gap in the literature and adds to a better understanding of the connection between the evolution of history and betweenness centrality.

3.HISTORICAL FORMATION AND DEVELOPMENT OF URBAN PLAN

(1) Case Study: Tehran

a) Qajar Era

Tehran was a village outside the ancient city of Ray, which lay at the foot of mount Damavand, the highest peak in the country and at the intersection of two major trade highways "[26]." After the land reforms of the sixties which took place on a large scale all around the country, a massive number of landless peasants moved to Tehran to find jobs and a better life. These increases of people movements caused the city to expand its border. In this period, the city's structure was very simple and limited to its walls and gates. Public and open spaces are placed in the inner part of the city and the main market in Tehran was in the center of the inner city facing one of the city's main squares. Tehran's first street links the residential area and open spaces with the commercial area, which includes the market and main square.

After 60 years, the city limits were expanded by the order of the king and the surrounding gates and walls were moved to a wider area, but a part of the city's inner areas were destroyed for the development of streets, resulting in a new form of streets. While their style was largely European, they created a new type of street with diverse purposes by maintaining the traditional and Islamic style (Atashinbar,2010). At the beginning of this period, the city consisted of only one main center which kept its linear shape, over the time, after adopting the westernized style to Iran, the number of main centers of the city was increased, which are connected to each other through newly built roads and paths then they turned the city of Tehran into a multi-centered city "[27]."

b) Pahlavi Era (1921-1979)

The expansion of the city during the Pahlavi period was aimed at modernizing and implementing the western style. By destroying all the walls enclosing the city, space was made available for the construction of new routes along the city center. As a result of these changes, the city, which was previously a linear city with a path in the center, became a city with many wide streets that connected many open spaces and markets. During this period, open spaces, including wide streets, parks and green spaces, main squares and several streets were built for the purpose of walking and shopping. Due to the growth of the oil industry in Iran during the 1920s and 1940s, Tehran became the country's industrial capital. These economic changes caused significant changes in the heart of society, resulting in the formation of the middle class "[28].".

The construction of wider streets and boulevards, which were adapted from European models of that era, was one of the most important renovations. In this new European style, all the historical parts of the city were demolished, and large streets and squares were designed to allow vehicles to move more easily. because of development in society and increasing people needs, the Shah decided to construct a series of road networks called "open space matrix" to transport services and goods easily"[29].".These changes occurred simultaneously in both the inner and outer parts of Tehran, so that the streets of the outer parts of the city were altered in the similar way as the inner streets, and the buildings were built in a rectangular shape next to the streets.

In 1941, part of urban formation occurred because of the Second World War. At this time, due to poverty and famine, massive group of villages migrated to big cities like Tehran, the city's population intrusively doubled within a decade, then the government had no plans to broaden urban infrastructure, including residential areas and streets in this city "[30]." Between 1956-1946, New residential areas were built. The major purpose of designing their construction was military politics. Although most people, especially merchants, still lived in the central parts and near the Bazaar. afterward, with the development of Iran's oil industry resulted in plenty of factories were formed in marginal areas, with respect to the massive migration of people to Tehran to find jobs happened. Additionally, development of road networks which resulted in the enlargement of the city of Tehran also transfers of peripheral sections to the inner city "[31].".

It should be noted that the southern segments were extremely dense, and the structure of their streets was narrower and lacked basic infrastructure. For example, the streets of the southern part are intricated without a specific pattern. In this time streets shift to medium size and connector elements between the different sections "[32]." On the other hand, some alterations began to emerge since the number of vehicles increased rapidly leading to

removing the squares to provide wider streets along with green spaces next to them.

c) Islamic Revolution (1979-present)

A major part of the physical transformations was the destruction of modern urban elements and features, which marked the transition from history and religion to western culture, and during the destruction of urban elements during this period, Iranian buildings were not preserved, as the main goal of this revolution was to create more Islamic elements "[33]." following the Iran-Iraq war in 1980-1988, the trend of immigration doubled, and due to the destruction of residential areas in the border cities, people migrated to Tehran. Because of the Soviet united invasion, even neighboring countries, such as Afghanistan, sought refuge in Iran.

Throughout time, the government's goal was to urbanize the marginal areas as much as possible, however, it tried to maintain open spaces for the activities of dweller living around these areas, but only green spaces such as parks and other open spaces were preserved. new peripheral areas that were created in the following years were often adjacent to roads. The scenery of these suburbs simply became illustrated as asphalt streets with the least green space, grey blocks of concrete and confined parks and sport zones inside them "[34].". Today, the expansion of the city in the north and south directions has made less progress, while the first transformation in the direction of this axis happened in the 19th century "[30]." Because of the increase in population density in Tehran, the authorities decided to turn the marginal parts into independent cities. In this regard, more than 50 major intra-urban and extra-urban highways connect the inner parts and neighboring cities to Tehran.

(2) Case Study: Tabriz

a) First Era:

the shape of the city was a collection of various elements such as residential areas, bazaars, arks, caravanserais and mosques, fields. Additionally, a high gate was formed around the city. Also, a new bazaar was built adjacent to the old bazaar which was a large street with two sides. On the other side, stores were created in European style"[35]."The road network of Tabriz, like other traditional cities of Iran was based on the social and environmental characteristics of its surroundings which caused the non-geometric and irregular state of the routes. Most of the routes were very narrow, these routes had a relatively radiant texture with the main routes such as the bazaar. Plus, the city gates ended up with other gates through the routes leading to this main street "[36]."

b) Second Era:

The conventional texture and twisting alleys transformed that resulted in old buildings being destroyed for the broadening of the streets. One of the significant features of this era was the construction of main streets along the railway, as well as the creation of boulevards and new wide streets around also instead of gates and walls enclosing the city "[37]." This development led to the change of the structure of the city from an irregular shape and structure based on pedestrian movement to a regular shape and structure suitable for cars.

c)Third Era:

During this period, the city was becoming a metropolis, which caused a decrease in public and open spaces and an increase in the appearance of streets, although in 1970, with the presentation of a comprehensive plan, the level of access and connection between these parts increased. Also, consecutive trips to perform daily activities by people indicated the creation of a scattered form of urban development"[38]."In recent decades, the city of Tabriz has developed more than its capacity and its natural and physical characteristics, while the inner part of the city is becoming empty, and the residential areas are moving to the suburban areas due to the emergence of socio-economic problems which caused imbalance and irregular physical enlargements outskirts city.

(3) Case Study3: Barcelona

a) From 3rd to 14th century:

From the 3rd century the old walled city only had two major streets where the residential areas started to grow up also the core of city easily linked to the gates of city wall. Therefore, the new neighborhoods began to rise enclosing the center of city caused the expansion of city wall. According to Busquets 2004, "city followed an orthogonal plan, with square or rectangular blocks, based on two primary axes: a horizontal axial order (northwest-southwest) and a vertical one (southeast-northeast), which would define the city's future design." "[39]." It should be noted that the shape of the two major roads adopted from the "ROMAN GREED" style known as the "Cardo" (north-south) and "Decumanus" (east-west) system, which provided a structured layout for the city "[40]."

b) From 15th to 20th century:

It was a time of organic growth and architectural styles, resulting in narrow, winding streets, known as the Gothic Quarter. Historic buildings, hidden courtyards, and hidden squares were common along these streets. The expansion leading to building the new part only for religious and political reasons at that time, only wealthy people could live there. Afterwards, in the late 18th century, the density of activity and inhabitants rose, resulting in dreadful living conditions in certain areas, triggering for the city wall to be demolished. The main objective of removing the wall was to make inland accessible from the coast, where most industry was positioned. During the first three decades of the nineteenth century, the old town became the hub of the industrial system, which increased the number of major infrastructures such as roads and trains to transport products and people. massive migrations to rural areas enhanced the framework for constructing the metropolis in Barcelona in the twentieth century.

c) From 20th Century to Present

The road network was modified along with the development of new districts that extended the boundaries between rivers to define a new urban reality that authenticated the shift from city to metropolis. Due to the expansion of the arterial network in Barcelona in 1966, the ring road was built.

As one of the reasons for building this road was to link the Olympic areas, its boundaries extended further towards the river, transforming the way nearby municipalities were mobilized. In addition, it facilitated action within the city by removing pressure from the center and turning congested streets that violently entered it into tranquil streets. Currently, introducing a 21st-century street model to every green hub in the Barcelona Superblock represents a significant shift from the way urbanization of public space had previously been conceptualized: it involves changing priorities and uses from those designed for cars to those designed for people.

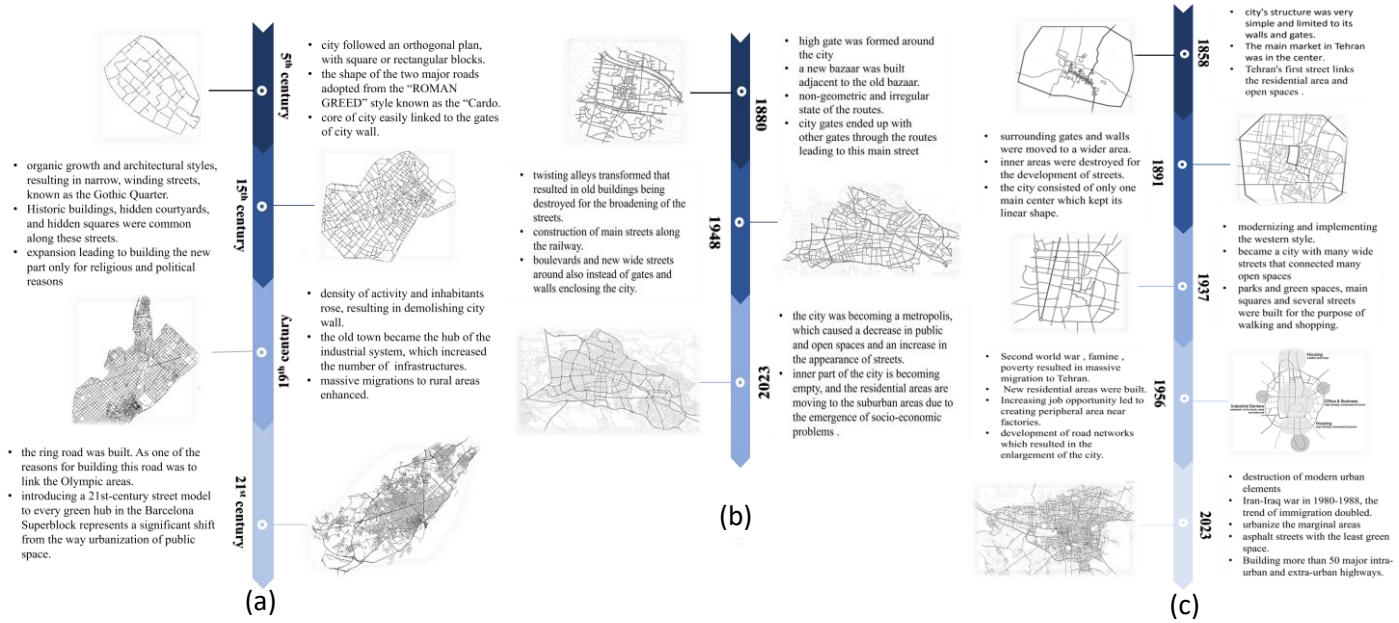


Fig.2 Expansion of Barcelona(a), Tabriz(b), Tehran(c).

Timeline	Historical Development of road network in Barcelona	Historical Development of road network in Tehran	Historical Development of road network in Tabriz
Pre-19th century	Historic Barcelona was characterized by winding, narrow streets.		
19th century	With wider streets and better urban planning, expansion and modernization efforts began.		
Pre-20th century		minimal road infrastructure, primarily narrow lanes, and old bazaars.	restricted roads and narrow paths in its historic core.
Early 20th century		With wider avenues and boulevards influenced by European urban planning, modernization initiatives began.	Modernization projects began with wider roadways and enhanced urban planning.
1920s-1930s	Improvements to roads and infrastructure		
1940s-1950s		Tehran's road network has been greatly widened, including the structure **of Vali-asr Avenue.**	Tabriz's road network has been significantly expanded to meet the city's rising population.
1950s-1960s	Roadway expansion to accommodate the city's growing population		
1960s-1970s		Developing highways and ring roads to decrease traffic congestion.	Highways and arterial roads, Tabriz was linked to neighboring countries for trade purposes.
1979s-1988s		The impact of the Iran-Iraq War and revolution on the transportation system by shifting it from European to Islamic style.	The impact of the Iran-Iraq War and revolution on roads by shifting it from European to Islamic style.
1980s-1990s	Improved and modernized road infrastructure continues to be a priority.		
1990s-2000s	Implementation of new transportation projects, including bus rapid transit (BRT).	Post-war reconstruction projects, road rebuilding, and improved handling of traffic. Tehran's metro system began to grow.	In post war- Improve the functioning and security of its road network to facilitate logistical and military activities.
2010	Increase pedestrian and bicycle lanes, as well as pedestrian zones, to promote sustainable transportation.	Finalization of several metro lines to ease traffic congestion. - Continued plans to upgrade and extend the road network, including the Tehran-North Freeway.	Several national highways, like Turkish boundaries. Ring road system to assist relieve traffic congestion in the city center.
2023-current	Congestion reduction and public transportation improvements ongoing	Continued concerns with traffic congestion and air pollution. - Investments in public transit and bicycle promotion aim to reduce reliant on cars.	Create pedestrian zones and parks within the city to enhance the quality of life and urban mobility.

Fig.3 Overview of Cities Urban Growth

4.ROAD NETWORK ANALYSIS (BASED ON BETWEENESS CENTRALITY)

(1) Tehran Network (From 18th Century to 21st Century):

Road networks have always played a crucial role in meeting the needs of Tehran's residents since the city's inception. The development of these networks was influenced by factors such as demographic changes, the growth of industrial areas, and geographical constraints. In 1896, the road network in Tehran displayed varying levels of connectivity, with the western residential areas having the highest.

Gates, through which many people entered the city, also had significant connectivity. However, routes ending at the Bazaar had lower connectivity, suggesting potential accessibility challenges for those working there. The Qazvin gates in 1896 served as vital arteries connecting neighboring cities to Tehran, explaining the high connectivity in the western part of the city.

Extensive urban development efforts by the administration, coupled with the introduction of automobiles in Iran, spurred a flourishing construction of roads and the creation of a specialized network called the matrix to enhance accessibility to goods and services. The removal of enclosure walls had a profound impact on centrality distribution, resulting in more contiguous and convenient road networks. This transformation concentrated a significant betweenness in the city's core, driven by the establishment of government buildings and new, commercial, and pedestrian areas. Additionally, economic development led to the concentration of commercial activities in the bustling bazaar and the east-west migration of industries and factories in the southern part of the city, further boosting betweenness, particularly in the south where longer roads connected the east and west. Since 1980, Tehran's rapid development, fueled by migration due to the Iran-Iraq war, prompted the government to evolve the city's outskirts to meet growing needs, resulting in the current state of Tehran's road network, shaped by decades of development.

In 2023, Tehran's central part has the highest centrality, and this centrality has expanded in all directions as the city has developed. The Tehran-Karaj freeway, oriented east-west, exhibits medium to high centrality, especially due to its intersection with the bustling bazaar, which experiences the highest traffic and demand. However, the northern part of the city has seen less centrality due to geographical constraints and its position in the foothills. Initially, residential areas in the north were primarily connected by secondary and tertiary roads and had limited links to the central part of the city. But in recent decades, the creation of a north-south artery has improved accessibility, allowing the city to thrive despite these limitations.

(2) Tabriz Network (From 18th Century to 21st Century):

In 1880, Tabriz had limited betweenness centrality, indicating that only a few areas in the city were well-connected in terms of the shortest travel routes, which is crucial for managing traffic flow. The city's layout was disorganized, with streets scattered randomly, and there were no established secondary or tertiary roads to link different parts. Simple streets near the market and city gates were primarily used by workers.

The highest betweenness was observed along the silk road, an important commercial route, and near a river that connected the north and south parts of the city via bridges. However, as urbanization and industrialization began in Iran, there was an increased need for labor. People migrating to Tabriz for work sought jobs closer to their homes, leading to the emergence of new residential areas and the necessity for new streets to facilitate easy commuting.

Figures show that there was a significant increase in betweenness in the south and west-south parts of the city where new residential areas and industrial factories were established. The central core of the city also had a high betweenness, extending from west to east, while the outlying areas had lower betweenness.

The text discusses the growth of Tabriz due to post-war immigration and the 1979 revolution, which led to increased transportation demands. To meet these demands, the government divided land into smaller residential zones. In Tabriz's outskirts, many routes have been developed and are still being constructed to connect the city's network to international road networks. This is expected to boost commercial and economic benefits by facilitating trade between countries. The high concentration of betweenness in the city center is also explained by the presence of historical buildings and sites where the first streets were built, which now serve as the basis for future expansions. These areas are currently used as a bazaar, attracting both tourists and locals, necessitating improvements in the route network to ensure easy access and smooth traffic flow.

(3) Barcelona Network (From 5th Century to 21st Century):

In the 3rd century, the old walled city of Barcelona had only two major streets, with residential areas developing around them. The highest betweenness centrality in the city's road network was concentrated at the intersection of these main streets, where socioeconomic and religious activities thrived, as the city center was the forum, dedicated to public life and

business. As one moved toward the city gates, the centrality levels significantly decreased. However, in the 14th and 15th centuries, Barcelona underwent substantial changes with the construction of a third wall that separated the suburbs from the western land. This new wall encircled religious facilities, resulting in narrow, winding streets known as the Gothic Quarter. The highest betweenness in the network remained around the center of the old city, while intermediate betweenness was found along the third wall. The newer part of the city was primarily occupied by the wealthy, while the old town maintained its betweenness characteristics. Market division led to a dispersion pattern of high to medium levels of betweenness within and neighboring districts. Despite its proximity to the sea and natural ports, areas near the sea had relatively low betweenness centrality, mainly due to the wall enclosing shipyards and hindering maritime access.

In the 19th century, betweenness centrality was concentrated in the north and near the harbor, with the market serving as a hub. In the 20th century, the city expanded its boundaries, leading to a shift from a city to a metropolis. High betweenness began to migrate towards peripheral areas, driven by socioeconomic activity in the center and the need to reduce congestion. The development of new residential areas around new arterials aimed to alleviate this pressure, but the uneven distribution of high betweenness indicates neglect of peripheral areas and public transportation infrastructure. This has prompted a reevaluation of metropolitan highways based on socio-spatial equity.

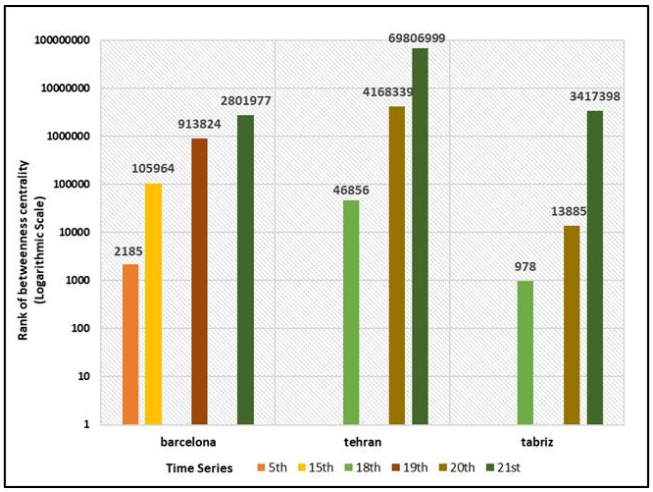


Fig.4 Betweenness Centrality Rank Overtime

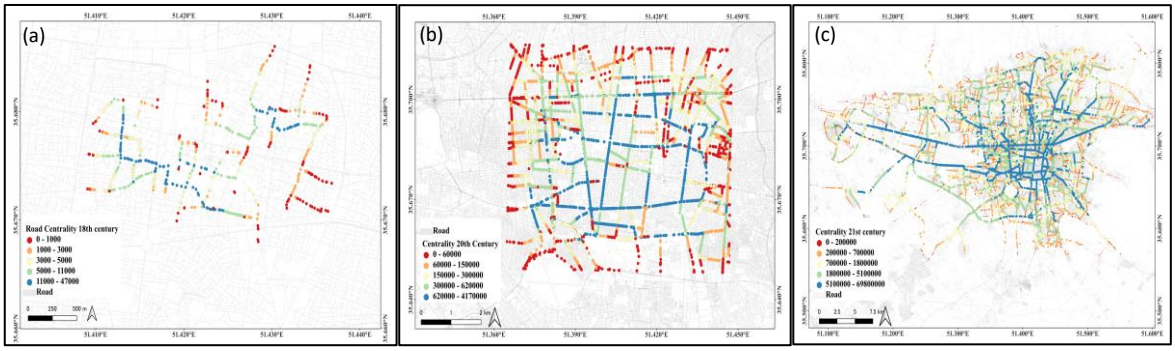


Fig.5 Overview of Betweenness Centrality in Tehran 18th(a),20th(b),21st (c)

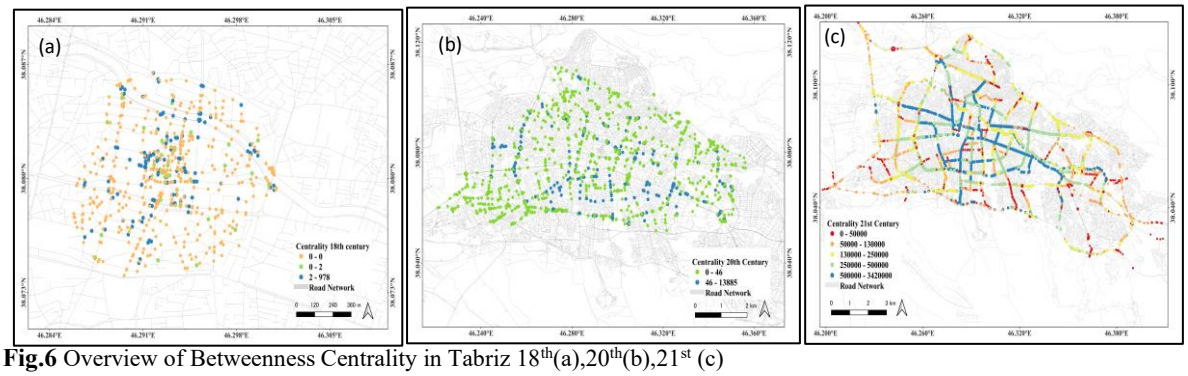


Fig.6 Overview of Betweenness Centrality in Tabriz 18th(a),20th(b),21st (c)

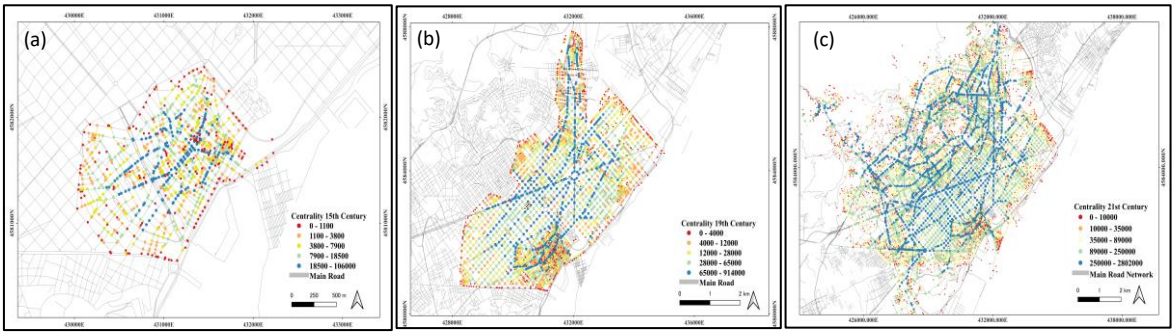


Fig.7 Overview of Betweenness Centrality in Barcelona 15th(a),19th(b),21st (c)

Year	*Key point of betweenness centrality in Barcelona*	*Key point of betweenness centrality in Tehran*	*Key point of betweenness centrality in Tabriz*
5th century	**Number of nodes 120 / edges 153** **Key nodes:** highest betweenness centrality occurs at the intersection of two main streets where most socioeconomic or religious activities take place due to the center of the city was the forum.		
15th century	**Number of nodes 980 / edges 1401** **Key nodes:** The higher betweenness is concentrated around the center of the old city and the mediate betweenness is only found along the third wall. Because the new part was constructed only for religious and political reasons at that time.		
18th century	**Key nodes:** The distribution of high betweenness has become considerably more regular and structured after the city's streets were renovated to accommodate broader avenues and boulevards.	**Number of nodes 544 / edges 3198** **Key nodes:** high level of betweenness is allocated to the gates and residential area in west and Bazaar have a moderate or high range betweenness, indicating that connectivity was not very crucial	**Number of nodes 452 / edges 500** **Key nodes:** because of irregular shape of street and random connection between some parts resulted in spreading of high betweenness very atypical entire city.
19th century	**Number of nodes 3124 /edges 5010** **Key nodes:** Betweenness centrality in the 19th century growing moves towards the new section located in the north and another place adjacent to the harbor. However, it appears that the market is still acting as a hub.	**Key nodes:** vital arterial connecting neighboring cities to Tehran, introducing cars may explain the high betweenness in west of Tehran.	**Key nodes:** high betweenness along the silk road, increasing the facilities to meet needs of growing population. Built new residential area led to move betweenness towards west east since these places located nearby the factories.
20th century	**Key nodes:** development of new districts that extended the boundaries between rivers to define a new urban area that shifts from city to metropolis. the level of high betweenness began to migrate towards peripheral areas as well.	**Number of nodes 5030 /edges 5271** **Key point:** Iran-Iraq war in this decade resulted in people migrating to Tehran which led to evolve the outskirts of the city to meet these needs. Betweenness stating to shift towards peripheral areas	**Number of nodes 1432 / edges 1122** **Key nodes:** revolution directed unexpected growt to meet transportation demands. Divided land into smaller pieces in outskirts for developing residential and tourist buildings nearby the boundaries in west effect the betweenness around these places.
21st century	**Number of nodes 9484 /edges 14831** **Key nodes:** The irregular distribution of high betweenness in the entire city. Extending the road towards inside and vice versa and metropolitan highways are being reconsidered everywhere based on a new concept of socio-spatial equity.	**Number of nodes 30175/ edges 125417** **Key nodes:** Tehran-Karaj freeway has a medium and high centrality. its intersection with the bazaar, this road has the greatest centrality in the middle which has the highest amount of traffic and demands.	**Number of nodes 4666 / edges 21956** **Key nodes:** High betweenness occurred in west f 2 reasons: boost the global trade by adding international routes and boosting tourist industry t bring benefits for government. rectifying the route to smooth flow traffic.

Fig.8 Summary of Centrality and Network Features for Tehran, Tabriz, Barcelona

5.IMPORTANCE OF SQUARE IN CENTRALITY

A square represents the importance of a node (or actor) in a network as a mediator or intermediary. Additionally, those can facilitate information flow or interactions. There are several public squares in Tehran and Tabriz, each with its own characteristics. The Azadi Square in Tehran, for example, is a significant square because of its historical significance and central location. As well as connecting different parts of the city, the square hosts various events and gatherings. In Tabriz, the Clock Tower Square holds both political and historical significance since it is near the municipal building through which information or services can be transferred to other places. Neighborhoods are connected by these squares, cultural and social events are held, and urban mobility is facilitated. Moreover, Barcelona Plaça renewed and changed the urban functions to make it more walkable without crossing, vehicles to serve only pedestrian traffic, keeping the main objective of creating squares to become places for shifting flows of information and activities.

As shown in **fig.9**, the value of betweenness has increased significantly and continuously during the past decades or centuries, while when it focuses on squares as mediators, the values are fluctuating because of some reasons, including dilution of influence, an increase in redundancy, and a change in the purpose of networks. As a result of abrupt changes in the urban network in Iran, the demand for communication increased and the number of squares increased after the Pahlavi era to equalize accessibility to services, resulting in decreasing mediation value, since as the network expands, new nodes or connections may duplicate existing mediators' roles and when multiple paths bypass a previously important mediator, its mediating centrality may decrease.

	TimeLine	Name of Central Squares	Value of Betweenness	Value of Mediating
TEHRAN	18th Century	Sabzeh Meydan Square	6208	0.001684059
	20th century	Ferdosi Square	1433971	0.000742173
		Railway Square	765663	0.00039628
		Gazvin Square	1747499	0.000904444
	21st century	Enghelab Square	991614	8.68679
		Azadi Square	37917372	0.000332166
		Toopkhaneh Square	29275752	0.000256463
		Tajrish Square	8400610	0.000256463
TABRIZ	18th Century	Bazaar main Square	978	0.06623
	20th century	Shohada Square	59819	0.107940489
		Clock Tower Square	111426	0.201062822
		Naderi Square	502714	0.907123073
	21st century	Beheshti Square	2895578	0.001889349
		Tabriz University Square	1127954	0.000735984
		Clock Square	2885442	0.001882735
BARCELONA	5th Century	Plaça de Sant Jaume	1375	0.022826881
	15th century	Plaça de la Catedral	30510	0.002819332
		Plaça Reial	8111	0.000749512
	19th century	Plaça d'Espanya	23255	0.000162723
		Plaça de Guadi	207531	0.001452165
	21st century	Gran Clariana	1620434	0.001113858
		Mossen Jacint Verdaguer	1984414	0.001364052
		Plaça de Francesc Macia	1336802	0.000918894

Fig.9 Overview of Emergence and of Square/Plaza in Iran and Spain

6. RISK ASSESSMENT IN REGARGARD OF CENTRALITY IN NETWORK

A vulnerability in a road network is defined as the failure to maintain regular connection between two nodes. subject to the purpose of the roads, this dynamic behavior changes or adjusts to operate a better role for commutes. Earthquakes may cause considerable damage to transportation infrastructure. Betweenness centrality can assist in identifying vital network nodes or sections which act as vital links and have a high risk for disruption through an earthquake.

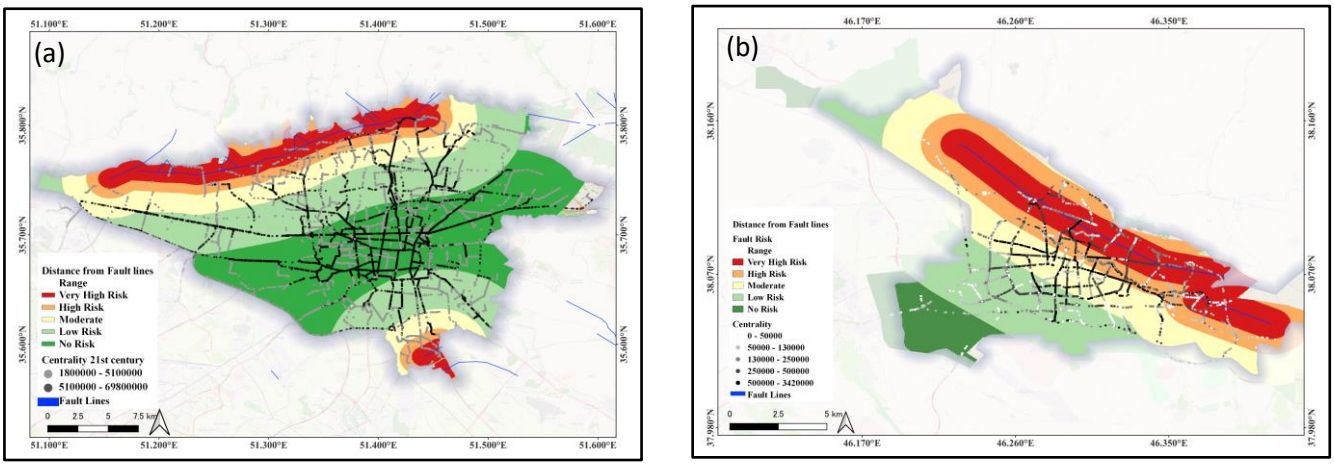


Fig.10 Risk Assessment in Tehran(a) and Tabriz(b).

7. COMPARING NETWORK DEVELOPMENT POLICY

Several cities, including Tehran, Tabriz, and Barcelona, have undergone significant urban transformations driven by a range of historical and contemporary urban policies. Tehran's rapid urbanization, fueled by rural-to-urban migration and economic growth, has necessitated the expansion of its road network, historically emphasizing modernization through the demolition of historical areas and the creation of wider streets. Recent policies in Tehran now prioritize sustainability, public transportation, and environmental concerns alongside road network expansion. Tabriz has also experienced a shift from its historical layout to a modern city structure, with urban policies supporting industrialization and economic growth, necessitating road network expansion. Challenges related to scattered urban development and infrastructure demands have prompted a focus on economic development and connectivity improvement. In contrast, Barcelona has leveraged its historical urban layout to shape contemporary policies that prioritize sustainability, pedestrian-friendly design, and reduced car reliance, aligning with modernization efforts aimed at improving mobility while mitigating environmental impacts. Balancing road network expansion with sustainability objectives is a common challenge across these cities.

As predicted, seismic risks frequently arise, with most epicenters located near or even inside the city, enhancing the amount of exposure and infrastructure damage. In the case of Tehran, extensive and active thrust faults encompass the northern and southern sides, engaging directly with the city's basement. Since the bulk of new residential areas formed in the west and east because of increased migrant movements caused by war and the development of new industries on these sides.

It should be noted that in terms of historical background and the core of commercial or political structures, have a high density of roads and population, which is critical to preserving the whole network since it serves as the city's heart. Approach could potentially be generalized to Tabriz because in both Tehran and Tabriz, a common urban design system produces similar results during development and destruction during an earthquake, however, one aspect that makes it unique than Tehran that is its location on Iran's most important transportation axis. Although this transportation axis is surrounded by a series of faults and the occurrence of danger is inevitable in it. As it appears on the **Fig.10** most of the earthquake epicenters are within and close to the city boundary, which is important since Tabriz is an important hub for connecting Iran with its neighbors.

(1) Assessing the feasibility of implementing Super/Mini Blocks to IRAN Network:

The superblock concept in urban planning, as exemplified in Barcelona, represents a systematic strategy aimed at transforming designated urban areas into pedestrian-friendly zones. Under this model, the road infrastructure is redesigned to promote pedestrian and non-motorized modes of transportation. This study seeks to undertake a comparative analysis between Barcelona's superblock strategy and the urban contexts of Tehran and Tabriz

in Iran. The primary objective is to investigate whether, despite geographical variations and unique urban challenges, the Barcelona model could be feasibly applied in Iranian cities.

Fig.12 provides an illustrative representation of the distinctive urban growth patterns observed in Tehran and Tabriz. Tehran's urban development has primarily concentrated on expanding the width of its central streets, a phenomenon that poses significant constraints on the implementation of superblocks or mini blocks. The city's map highlights a limited number of potential locations suitable for the establishment of super or mini blocks. This constraint is primarily attributed to the persistent flow of traffic, making it hard to divert traffic away from primary routes, a prerequisite for creating spaces compatible to the installation of super or mini blocks.

In contrast, Tabriz presents a more favorable scenario for the creation of pedestrian-friendly zones, owing to its deliberate preservation of historical areas and lower traffic volume. These factors create an enabling environment for the potential implementation of block plans. In this context, if streets can be reconfigured or unified, traffic may be readily redirected onto adjacent roadways, facilitating the establishment of super or mini blocks. This comparative analysis underscores the intricate interplay between urban design, traffic management, and historical preservation, offering valuable insights into the adaptability of the Barcelona superblock model within the distinct urban landscapes of Iranian cities.

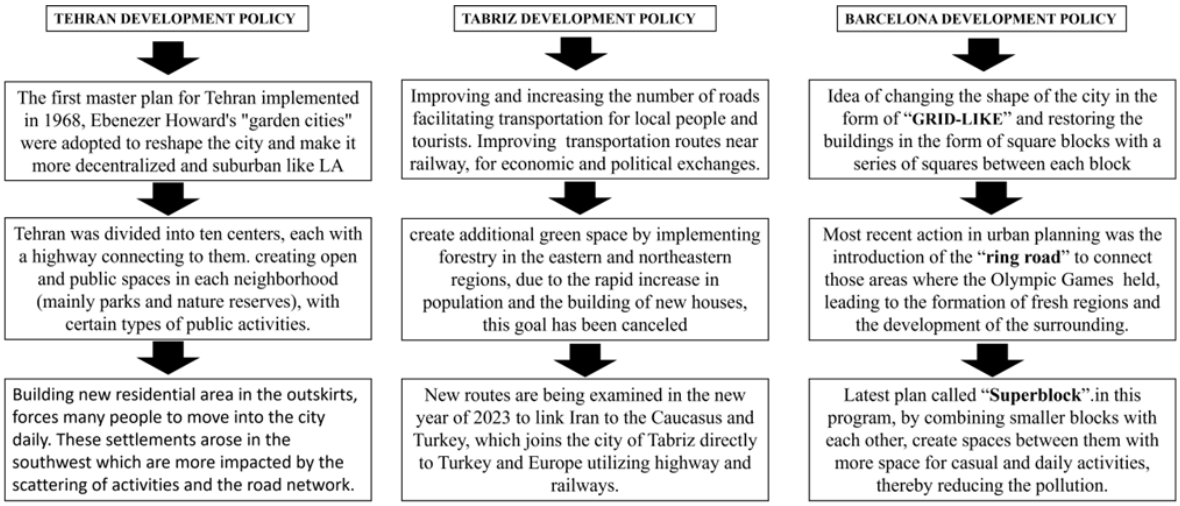


Fig.11 Overview of Urban policies in Iran and Spain.

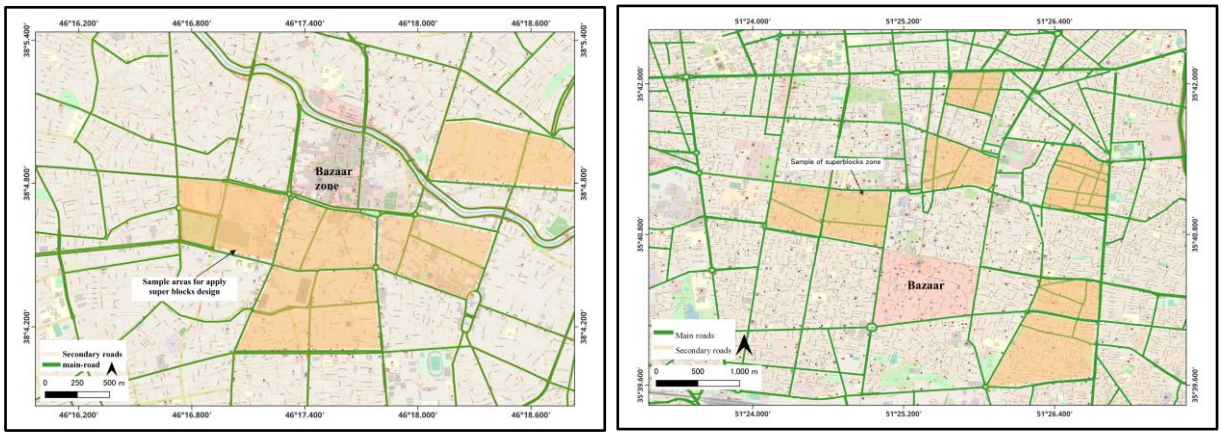


Fig.12 Simulation of Implementing New Policies to Iran Cities Adopted from Barcelona

8.CONCLUSION

This paper explores the historical evolution of cities in Iran and Spain, with a focus on the influence of changes in road networks for commercial, political, and religious purposes. The study employs a comparative approach, examining urban growth patterns in Tehran, Tabriz, and Barcelona using the betweenness centrality metric to assess the significance of various road segments in shaping city development. Additionally, the analysis evaluates the vulnerability of these road sections and nodes to earthquakes, shedding light on the risks associated with disruptions during seismic events. Tabriz's rapid, unplanned expansion in the north-east, driven by uncoordinated growth, is contrasted with Tehran's multifaceted urban growth stages, which include pre-1960, post-1960 land reforms, and post-1979 Iranian revolution periods. The vulnerability assessment highlights similarities between Tehran and Tabriz in terms of urban design and earthquake exposure due to shared historical growth patterns.

The paper's uniqueness lies in its comparative examination of Iran and Barcelona, emphasizing historical road network formation, betweenness, centrality, and the influence of disasters on urban morphology and open space creation. By analyzing these diverse contexts, the study identifies key patterns and factors that have shaped road networks and highlights the importance of understanding historical developments to grasp current vulnerabilities. Furthermore, the comparison of betweenness centrality reveals disparities in urban planning and infrastructure.

The study also assesses the feasibility of implementing Barcelona's road network policy in Iran, offering insights into the complexity of urban planning and the potential for creating inclusive, sustainable, and livable urban environments in these diverse cities. It acknowledges the introduction of green belts in response to regulations banning construction in agricultural lands, a policy implemented in Tehran and Tabriz. This research serves as a foundation for future development plans, emphasizing the significance of considering past modifications as the basis for present road network planning and advocating for the adoption of feasible urban planning strategies from other countries, particularly for cities with similar physical characteristics.

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