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An Analysis of the Spatial Structure of Cities from the Perspective of Spatial Balance in the Distribution of Functions and the Formation of Multi-Core Pattern (Case Study: Tabriz City)

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ABSTRACT: The multi-core spatial structure is one of the important and basic topics in urban planning studies, which is considered both as a framework for evaluating urban development and as a basic spatial development goal. Considering the importance of the multi-core spatial structure pattern, especially for large cities with high populations and diverse and complex activities, the present study aims to evaluate the spatial structure of Tabriz city from the perspective of multi-core pattern development based on the spatial distribution of functions and population across the city. The present study employs a Quantitative Correlational Research method. The documentary method is used for data collection, and various techniques such as mean center, standard deviational ellipse, kernel density estimation, location quotient (L.Q.), nearest neighbor index, and geographically weighted regression are applied for data analysis. The study examines six functions: religious, educational, commercial, healthcare, industrial, and administrative. The findings suggest that the spatial distribution of functional cores, except for industrial and commercial functions, exhibits a single-core spatial structure in the city center. Also, the results indicate that the correlation between functional cores and the population of Tabriz city, based on the spatial regression test, is moderate. Accordingly, an imbalance in the distribution of functional cores in Tabriz City is evident. Therefore, Tabriz is located in a single-core state, and due to the increase in the distribution of administrative and medical functions in the eastern and industries in the western, it can become a multi-core model.

Keywords: *Urban Spatial Structure, Urban Functions, Single-Core Pattern, Multi-Core Pattern, Tabriz City.*

INTRODUCTION

The spatial structure is one of the key concepts prevalent in urban planning and design and has undergone significant changes over the past century, attracting the attention of geographers, economists, and urban planners (Giuliano et al., 2007; Glaeser & Kahn, 2001; Meijers & Burger, 2010; Phelps, 2015). The spatial structure, with all its elements and structural components, interacts with the city and illustrates how these elements are situated and function within the city level. Also, the urban spatial structure embodies the established system and interrelations among physical components and land uses within an urban area, formed based on the reciprocal interactions of urban systems in time and space (Chapin & Kaiser, 1984). This relationship between elements and functions over time, in correlation with social population, economic indicators, and the prevailing management system, has led to the distribution of urban functions in the spatial matrix (urban form) in two forms: balanced and polarized. In this context, balance in the spatial structure of cities from the perspective of an equitable distribution of urban facilities and functions is considered an important indicator for improving quality of life and is a foundation of distributive justice policies (Altschuler et al., 2004; Lloyd & Auld, 2002). Therefore, establishing a balance in urban spatial structure and function distribution is essential for urban development processes. An evaluation of equilibrium and polarization in the distribution of urban functions could serve as a strategic perspective for future urban

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planning and design initiatives.

On the other hand, it can be stated that over the past century, the advent of knowledge and technologies such as transportation has triggered changes in the spatial structure of cities, prompting expansion from the city's center and primary development core towards the periphery, resulting in the formation of new functional centers (Buliung, 2011). Due to its multitude of centers, this novel form of urban structure and development, the multi-core model, can facilitate the formation of relatively uniform and homogeneous structures across the city and appropriately distribute activities; consequently, it is deemed the most appropriate structure for cities with a high population, significant functional density, and complex internal relationships. Given the significance of achieving balance in the distribution of urban functions within a city's spatial structure, as well as the transition towards a polycentric urban model, the primary goal of this study is to examine the distribution of functional cores within the city of Tabriz and assess the potential for its spatial structure to evolve into a polycentric model. Tabriz, the largest city in the northwestern region of Iran, has witnessed extensive changes in its physical and demographic structure from 1956 to 2016. The city's population has approximately sextupled in 60 years (from 289,996 to 1,733,033 people), and its physical expansion has increased almost sixteen-fold (from 1,170 hectares to 19,000 hectares (Statistical Center of Iran, 1956-2016).

Along with this increase in size and population, the city's physical fabric has also undergone extensive changes, including the emergence of various towers and skyscrapers in different parts of the city and the settlement of more than 450,000 individuals in informal settlements, especially in the northern part of the city (Master plan of Tabriz, 2016). Additionally, with the population increase, issues such as increased traffic and air pollution, particularly in the city center, and excessive pressure on certain parts of the city have become evident. Therefore, examining the city's spatial structure from a balanced perspective in the distribution of various functions is essential. This can provide solutions for appropriately distributing functions and populations and rethinking the city's spatial structure, setting the stage for achieving sustainable urban development and realizing a polycentric development model. Furthermore, in cities within developing nations like Tabriz, considering the dominance of a technocracy approach and mounting spatial inequalities that exist across various dimensions, particularly in function distribution, through the identification of spatial structure and the presentation of plans and strategies, it becomes feasible to reduce spatial imbalances and realize spatial justice in the distribution of functions and the establishment of a favorable spatial structure pattern, such as multi-core, and a suitable distribution of functions and population. For this purpose, answering the following questions is the basis of the current research:

- What is the spatial distribution of different functions in Tabriz city?
- What is the spatial structure of Tabriz city from the perspective of development patterns (single-core and multi-core)?

Literature Review

The spatial structure of cities is influenced by internal factors and driving and developing forces that create significant changes in the spatial structure, especially in metropolises, by establishing economic, communicative, and physical infrastructures (Smetkowski, 2018; Sweet et al., 2016; Trapero et al., 2015). These forces and stimuli include economic factors, such as income and economic productivity, public investment, and accessibility, as well as physical factors and infrastructure development, such as communication factors, physical growth, and economic and social reconstruction (Fernandez-Maldonado et al., 2014; Lizhu et al., 2013; Wei et al., 2018). Additionally, public investment in the development of service infrastructures and large urban projects, which have a direct impact on the location and establishment of activities, is another key stimulant in shaping and changing the spatial structure (Chen et al., 2019; Criekingen et al., 2007; Li & Monzur, 2018; Priemus, 2019). In this regard, (Criekingen et al. 2007) state that large-scale urban projects undertaken through public investments directly shape and solidify the polycentric spatial structure. On the other hand, the process of globalization and engagement in the global network and economic competition (Goess et al., 2016; Sat, 2018; Taubenböck et al., 2014), as well as foreign investments (Finka, 2009; Smetkowski, 2018), have led to the concentration of economic activities in specific regions based on local conditions and contexts (Hoyler et al., 2008), significantly changing the spatial structure of metropolises. For instance, (Lan et al., 2019) have identified foreign investment as a significant factor in shaping a polycentric pattern in 20 large city regions in China. Therefore, economic agglomeration is one of the primary elements leading to the concentration and formation of new cores (Acheampong & Agyemang, 2016; He et al., 2019a; Nam & Kim, 2017). It signifies access to employment opportunities and direct connections with specialized producers, drastically altering the spatial structure. In other words, the intensification of centrifugal forces fosters an increased interest in economic entities outside the main urban center. Simultaneously, a decrease in transportation costs also increases the tendency to reside in the suburbs and operate outside the principal center. In the 1980s in China, the industry's orientation towards the city outskirts increased due to land reforms, a rise in land prices in the main center, and regulations to remove industries from cities. This change led to the formation of subsidiary industrial centers outside the main center and the emergence of suburbanization and spatial dispersion (Man et al., 2011). In this regard, several studies underscore the role of transportation facilities and proximity to the city's central core as significant influences on the transformation of the spatial structure (Krehl & Siedentop, 2018; Wang & Niu, 2019). Hence, commuting, defined as the daily transition between places of work and residence, is deemed a crucial determinant of access factors (Burger et al., 2011; Ellingsen & Leknes, 2012; Kauffmann, 2015; Veneri, 2010). This factor significantly alters the spatial structure and is linked to the prevailing social, cultural, economic, and political factors influencing it. Based on the presented information, cities' spatial structure has tended towards polycentric development, in which economic agglomeration and transport expansion have had a notable impact. Also, the prevalence of the polycentric pattern in large cities indicates that the single-core city is an outdated or inefficient model. The most appropriate structure for cities with high populations, high activity density, and complex internal relations is a polycentric model, which, due to its multiple centers, can shape relatively uniform and homogeneous structures at the city level and appropriately distribute

activities.

On the other hand, polycentric patterns show a high degree of flexibility in relation to urban developments and can provide many opportunities for a city's future growth and development (Ashik et al., 2020). The examination of the formation of polycentric cities globally indicates that these types of cities have either been shaped as a result of premeditated planning (like Shanghai) or self-organization (like Jakarta) (Champion, 2001). In some cases, urban policies in different aspects have played a significant role in shaping cities like Guangzhou and Shenzhen. In general, the process of forming polycentric cities can be represented in Figure 1.

Figure 1, which combines the theories of Champion (2001) and Wei et al. (2020), shows that population cores expand in the city's periphery due to centrifugal forces. Initially, functional cores (service-commerce) exist in a monocentric form; smaller centers develop around the primary center. Eventually, centers are similar to the main ones in different parts of the city. Furthermore, these functional cores respond to the needs of their local populations and cater to the needs of people from other areas.

In summary, it can be said that developing a polycentric city is a spatial and geographical process in which multiple urban centers attract and expand various functions (Kuang et al., 2009). One of the benefits of multi-core urban planning is the ability to overcome a range of issues typically concentrated around a specific core, such as traffic congestion, environmental pollution, and the formation of urban heat islands (He et al., 2019b). In addition, this type of urban spatial structure provides numerous choices for residents, companies, and other resources within a networked urban system, marking a departure from the limited and enclosed mono-centric city systems of the past (Sýkora et al., 2009). Nowadays, we see an increasing political endorsement for planning strategies promoting polycentric (multi-core) urban development. Furthermore, considering the importance and necessity of realizing polycentric (multi-core) cities, many researchers have conducted extensive studies on the spatial structures of multi-core urban from different perspectives. For example, they have explored urban spatial forms, analyzed urban spatial structures, central systems, and the factors influencing them, utilizing data on land use, building characteristics, and other relevant factors (Chen et al., 2016; Liu et al., 2015; Luo & Li, 2019; Wei et al., 2020; Zhang et al., 2017). Other researchers have adopted a population scale perspective, conducting studies to unearth the relationships between workspace, residential space, employment centers, and urban public activity centers based on resident population, employment, and recreation data (Liu et al., 2018; Niu et al., 2014; Shi et al., 2017). Simultaneously, some researchers have looked at transport and commuting to identify the forms and functions of polycentric cities, scrutinizing data related to transportation facility density, road network density, and smart card records (Guo et al., 2019; Zhang et al., 2017).

Upon reviewing various perspectives and research, it becomes clear that the spatial structure of a city consists of two dimensions: morphological and functional. The morphological dimension is represented by population distribution, employment, land usage, transportation networks, and built structure volume (Krehl, 2015). The functional dimension, conversely, is indicated by the flow of goods, services, and interactions between individuals and between people and infrastructure (Wei et al., 2020). Furthermore, from a morphological perspective, a multi-core structure refers to a spatial organization where multiple adjacent centers exist within a single urban system. From a functional perspective, the multi-core structure illustrates the connections between different centers, such as daily commuting flows and the capacity of commercial networks (Acheampong, 2019). Finally, it can be said that the multi-core structure with high flexibility and balanced distribution of functions and population is considered an important urban spatial structure model (opposite to the single-core structure). Based on this, the theoretical model of the research can be drawn as described in Figure 2.

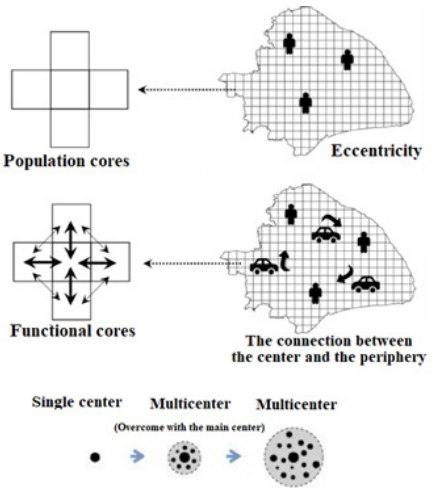

Fig. 1: Transformation of urban spatial structure from single-core to multi-core based on population-functional cores (Champion, 2001; Wei et al., 2020).

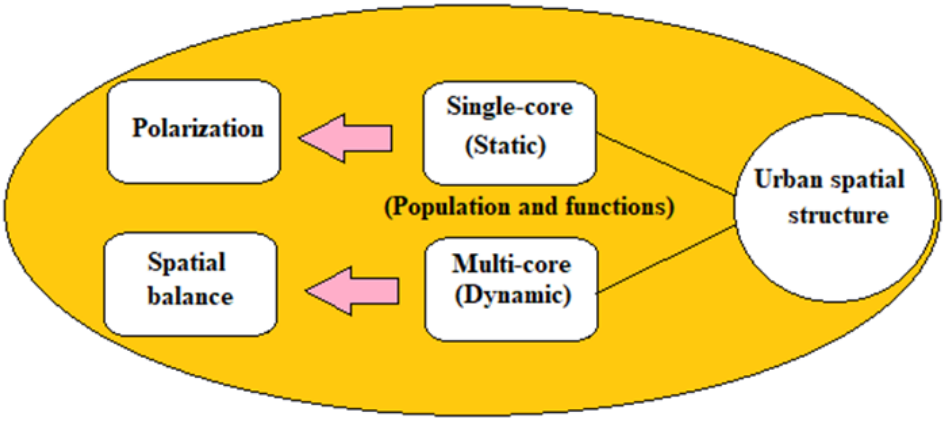

Fig. 2: Theoretical model of research

MATERIALS AND METHOD

The methodology employed in the current study is a quantitative correlational research approach. Information gathering was conducted through documentary methods, such as accessing municipal archives and obtaining statistical data related to the existing land-use patterns and digital maps. In this study, an evaluation of the spatial structure of the city of Tabriz is carried out, with a specific focus on six functional cores: religious, educational, commercial, healthcare, industrial, and administrative. The research data analysis involves assessing these functional cores' spatial distribution and density by utilizing methods such as mean center calculation, standard deviational ellipse, kernel density estimation, and the Location Quotient (L.Q.) method. The Nearest Neighbor Index (NNI) examines spatial relationships among functions. Moreover, the spatial equilibrium is scrutinized, particularly the relationship between functional cores and population distribution, by applying Geographically Weighted Regression. Also, the software used in this research is ArcGIS10.8.

Kernel Density Analysis Method

This method is among spatial analyses in ArcGIS software and is used under density estimation for linear and point features. This analysis is one of the best methods for identifying high-density points, which can be used to understand the concentration and density of a phenomenon.

Location Quotient (LQ)

The L.Q. index or spatial share index is a model that illustrates the spatial distribution of urban uses and the degree of their specialization and polarization. In this model, the relative concentration of a function in a specific area or region is presented compared to the whole area, region, or entire country. The formula for the Location Quotient model is (Equation 1).

Equation 1:

$$LQ = \frac{\frac{Mi}{M}}{\frac{Ri}{R}}$$

In this equation:

LQ = Location Quotient.
Mi = Land use I in a particular region.
M = Total land use in that same region.
Ri = Land use I in the city.
R = Total land use in the same city.

Nearest Neighbor Index (NNI)

The Nearest Neighbor Index provides a straightforward and efficient approach to assess the concentration of points within a specific geographical area. This test allows for the examination of point distribution clustering. When the Nearest Neighbor Index yields a value of one, it indicates a random distribution of the analyzed data. A value less than one suggests a clustered distribution, while a value greater than one signifies a uniform and random data distribution. Furthermore, a Z index value below one and negative indicates a clustered distribution.

Geographically Weighted Regression (GWR)

GWR (Geographically Weighted Regression) is a localized spatial statistical method. It is employed when the units of measurement for the variable under consideration vary from one location to another, facilitating the analysis of spatial heterogeneity (Mennis, 2006). The mentioned regression is an extension of the linear regression model that analyzes the spatial and locational features of the study area (Sheng et al., 2017). GWR produces spatial data that indicates spatial variations in the relationships between variables. The resultant maps from these data play a pivotal role in identifying and interpreting spatial heterogeneities (Mennis, 2006).

Study Area

In terms of geographical context, Iran is the world's eighteenth-largest country. It is situated in the northern and eastern hemispheres, nestled in the western part of the Iranian plateau within the Asian continent, and is categorized among the countries of the Middle East. Iran spans an area of 1,745,150 square kilometers and shares its northern boundaries

with Armenia, Azerbaijan, Turkmenistan (all part of the former Soviet Union), and the Caspian Sea. To the east, it neighbors Afghanistan and Pakistan; to the West, Turkey, and Iraq; and the south, it adjoins the Persian Gulf and the Gulf of Oman.

Tabriz, the capital of the East Azerbaijan Province, stands as one of Iran's principal cities. As the largest city in the country's northwestern region, Tabriz is recognized as the hub for administrative, communicative, commercial, political, industrial, cultural, and military affairs. Following Tehran, Mashhad, Isfahan, Karaj, and Shiraz, Tabriz is Iran's sixth most populous city (Figure 3).

RESULTS AND DISCUSSION

Spatial Distribution of Functional Cores in the City of Tabriz

To examine the spatial distribution and area of the current status of the functional cores under study, statistical information from the municipality and the land use map of Tabriz City were utilized. The evaluation of the area of various functions in Tabriz suggests that the majority of religious and commercial functions are in Regions 8 and 4, the majority of administrative functions are in Regions 2 and 1, the majority of educational functions are in Regions 3 and 4, the majority of medical functions are in Regions 2 and 3, and the majority of industrial functions are in Regions 6 and 7. Table 1 examines the area of the functions under investigation in the city of Tabriz, broken down by region.

Table 2 also shows the spatial analysis of functional cores and their distribution density in Tabriz city.

The analysis of the spatial distribution of urban functions reveals that most of these functions' average centers and centroids are

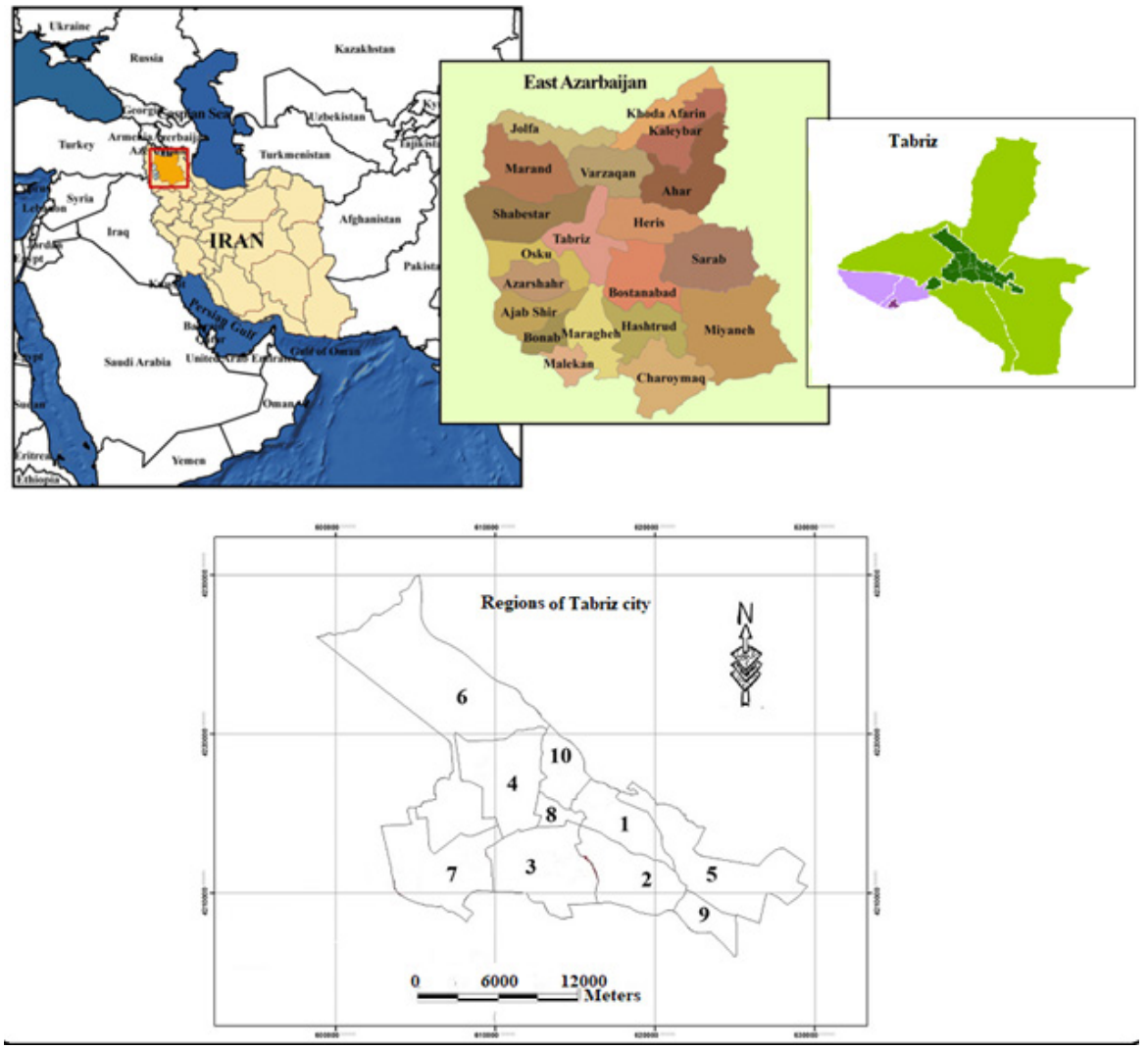

Fig. 3: The geographical positioning of Tabriz in Northwestern Iran and its ten-region division.

Table 1: Assessment of Urban Functions Area in the Decentralized Regions of Tabriz City (Square Meter)

Region	Religious	Educational	Commercial	Healthcare	Administrative	Industrial	Population	Area (Hectares)
1	30851	254518	450785	93308	434054	41310	249484	1541
2	22327	273199	288763	297807	527448	157466	212551	2080
3	39347	473443	448545	198175	729047	39748	210542	2785
4	57304	468903	603354	75722	181421	536587	94087	2540
5	11414	317794	318007	23016	36822	2003936	303988	3153
6	16780	299278	281495	36713	196526	5779666	303587	7218
7	17787	156671	518920	9755	99058	3236611	301257	2892
8	96174	93132	661929	11943	148061	16451	44855	388
9	1608	6620	65308	461	9247	90994	48855	803
10	42692	203528	263652	110127	72767	57393	257741	1051
Total	336285	2547078	3900757	861026	2434449	12230163	2026947	24451

Table 2: Spatial Analysis of Functional Cores and Their Distribution Density in the City of Tabriz

Functional Cores	Geometric Center	Average Centers	Standard Deviation Ellipse	Kernel Density Estimation
Religious	Centroid of the urban function in Region 8	The pattern of functionality expansion from the northwest to the southeast	Distribution of the central core in regions 8 and 4 and the sub-cores around the central core, especially in the central and northern regions of the city	
Educational	Centroid of the urban function in Regions 8 and 3	The pattern of functionality expansion from the northwest to the southeast	Distribution of the central core in Regions 8, 3, and 10 and the formation of a second core in Region 1	
Commercial	Centroid of the urban function in Region 8	The pattern of functionality expansion from West to east, with a greater tendency to the north	Formation of strong cores in the northern part of the city and regions 1, 4, and 10	
Healthcare	Centroid of the urban function in Regions 8 and 3	The pattern of functionality expansion from the northwest to the southeast	Strong core in the city center and regions 8 and 3	
Administrative	Centroid of the urban function in Region 8	The pattern of functionality expansion from West to east	Distribution of the central core in Region 8 and subordinate centers in Regions 1, 2, 3, and 4	
Industrial	Centroid of the urban function in Region 8	The pattern of functionality expansion from the northwest to the southeast	Polycentric distribution in the West of the city (northwest and southwest)	

concentrated within the city center, particularly in regions 8 and 3. Except for industrial and commercial activities, the spatial distribution of functions follows a single-core spatial structure centered around the city center (Figure 4). Additionally, the standard deviation ellipse further indicates the concentrated distribution of functions in the city center, extending towards Tabriz's eastern and somewhat northern parts (Figure 5). Considering the development limitations in the northern region, functions are anticipated to expand more toward the eastern areas. As a result, it can be concluded that Tabriz exhibits a clear emphasis on its city center, while the eastern part maintains a relatively balanced state in certain functions, indicating a partial manifestation of bipolarity in the city's spatial structure.

An alternative method for investigating the spatial distribution of functional cores utilizes the location quotient or L.Q. This has been calculated for each function, using the area of the urban functions under study within the ten regions of Tabriz concerning the areas of the regions and the city as a whole. The location quotient model posits that if the L.Q. value in a location is less than 0.99, this demonstrates that the location possesses a minimal share of that activity. If the index is between 1 and 1.99, this denotes a relative concentration of the activity in that location. Finally, an L.Q. index exceeding 2 signifies a high activity concentration within the specific location.

The obtained results (Table 3) indicate that among the six main functions examined, two functions - medical and administrative - in regions 2 and 3, four functions - religious, educational, commercial, and administrative - in region 8, two functions - religious and medical - in region 10, administrative function in region 1, and industrial function in region 7 had a high location quotient over 2. In this regard, it can be stated that Tabriz has four functional cores, namely regions 2, 3, 8, and 10, and due to the formation of specialization in these areas, the

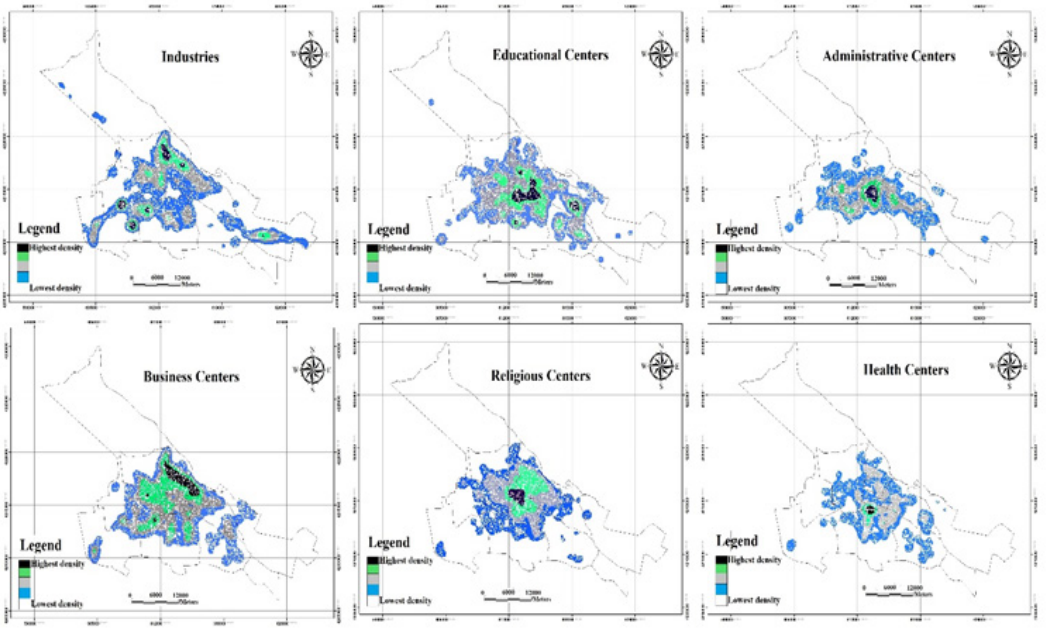

Fig. 4: The pattern of functional core distribution across the city of Tabriz

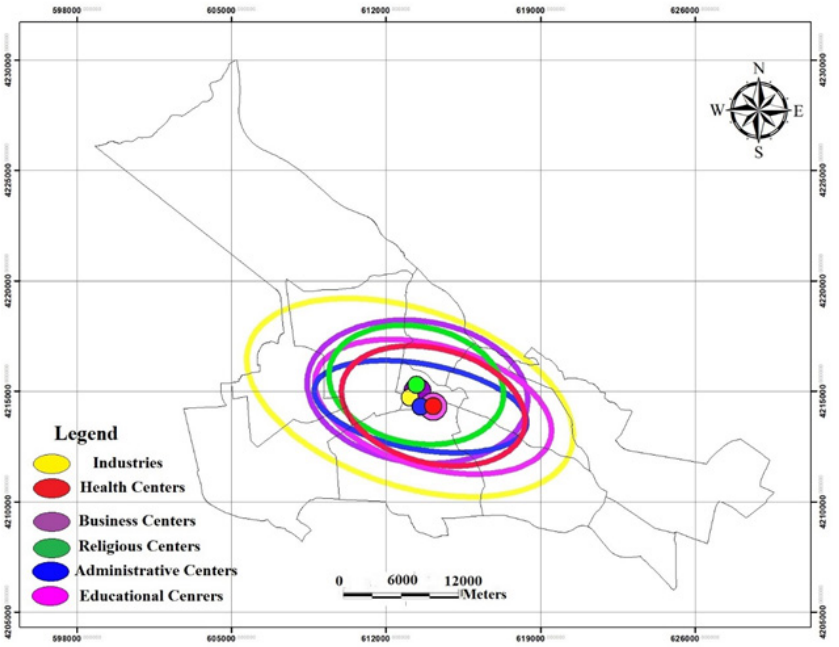

Fig. 5: The center of gravity and standard deviation ellipse of function distribution across the city of Tabriz

potential to form a multi-core city in Tabriz is possible. It can also be noted that Region 8 of Tabriz has a high concentration of religious and commercial functions. Region 7 is also considered the sole industrial hub of the city.

Overall, it can be stated that the city of Tabriz is currently observable as bipolar, with the central region (Region 8 and, to some extent, 10) and the eastern part of the city (Regions 2 and 3) allocating most of the functions to themselves. However, considering that Regions 1 and 7 also had a location quotient above 2 in two functions, and with the trend of function expansion in the north of the city, with appropriate

Table 3: Calculation of the L.Q. index of urban functions in the ten regions of the city of Tabriz

Region	Religious	Educational	Commercial	Medical	Administrative	Industrial
1	1/46	1/59	1/84	1/80	2/84	0/05
2	0/78	1/26	0/87	4/09	2/56	0/15
3	0/99	1/63	1/01	2/03	2/64	0/03
4	1/65	1/77	1/49	0/85	0/72	0/42
5	0/26	0/97	0/63	0/21	0/12	1/27
6	0/17	0/40	0/24	0/14	0/27	1/6
7	0/45	0/52	1/12	0/09	0/34	2/24
8	18/02	2/31	10/73	0/88	3/85	0/08
9	0/15	0/08	0/511	0/02	0/12	0/23
10	2/96	1/86	1/58	2/99	0/70	0/11

planning and a balanced distribution of functions in other areas (south and West), the prerequisites for developing a multi-core structure can be established in the city of Tabriz. Conversely, areas 5, 6, 7, and 9 have exhibited the lowest concentration of functions, highlighting the imperative of appropriate urban planning to facilitate the distribution of functions within these regions.

The Spatial Distribution Pattern of Urban Functions and the Spatial Balance of Function Distribution with the Population

This section begins with evaluating spatial relationships in the urban function distribution using the Nearest Neighbor Index (NNI) statistical test, followed by applying the weighted regression method to examine the spatial balance in the function and population distribution. The results from the NNI test, applied to the study data, reveal that the test value and the Z index for functional cores are both less than one. This finding indicates a clustered distribution pattern of functional cores throughout Tabriz (Table 4).

Based on spatial regression analysis, an evaluation of spatial correlations between the functional cores and the population of Tabriz city reveals a moderate correlation between these two variables (Table

Table 4: Distribution of Functional Cores in the City of Tabriz Based on the Nearest Neighbor Average Test

Functional Cores	Z-Score	N.N. Ratio Index	Significance Level	Distribution Pattern
Religious	-85.18	0.46	0	Clustered
Educational	-101.85	0.51	0	Clustered
Commercial	-67.09	0.46	0	Clustered
Medical	-84.73	0.53	0	Clustered
Administrative	-48.61	0.63	0	Clustered
Industrial	-93.15	0.35	0	Clustered

Table 5: Geographically Weighted Regression of Functional Cores and Population Relationship

Functional Cores/Population	Determination Coefficient	Adjusted Determination Coefficient	Akaike Information Criterion (AICc)	Error Variance
Religious/Population	0.49	0.47	53.72	0.017
Educational/Population	0.65	0.62	8.19	0.024
Commercial/Population	0.73	0.69	-14.24	0.009
Medical/Population	0.20	0.17	35.78	0.039
Administrative/Population	0.25	0.23	44.38	0.027
Industrial/Population	0.33	0.31	37.79	0.021

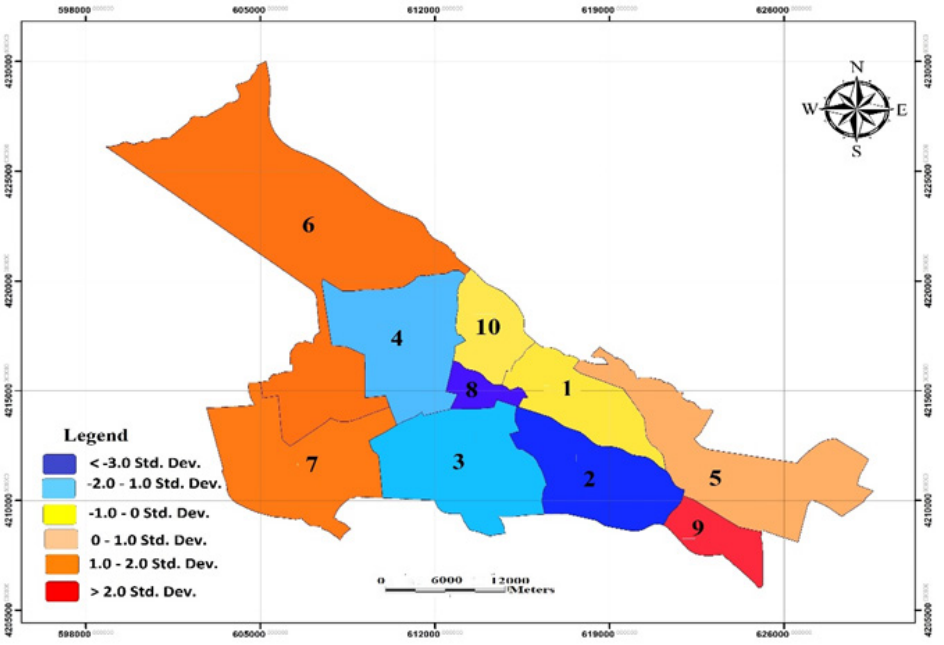

Fig. 6: Relationship Between Functional Cores and population based on Geographically Weighted Regression

5). This finding underscores an imbalance in the distribution of urban functions across Tabriz city. In addition, within the functional cores, the most balanced distribution in urban areas—considering the existing population—is associated with commercial and educational functions. In contrast, the least balanced distribution is observed in a medical function. The Akaike information criterion further suggests a small sum of squares error concerning functional cores and population, evidenced by a variance in the error that is less than 0.05.

Moreover, based on the output layer of the geographically weighted regression and depicted in Figure 6, the final results indicate that the most desirable relationship between functional cores and population corresponds to regions 2 and 8.

CONCLUSION

Spatial structure manifests influential forces acting over time in space, illustrating the order and relationships among physical elements and uses in urban areas. Gradual and step-by-step changes in the spatial structure take place to adapt to needs, fostering spatial balance in the distribution of spatial functions concerning communication axes, population, and urban form. However, changes in spatial structure, driven by influential factors such as society, economy, and existing political and managerial systems, do not always move towards spatial equilibrium. These changes sometimes lead to spatial inequality and polarization in the city's spatial structure. One of the theoretical approaches to achieving spatial balance involves the realization of multi-core centers within the spatial structure of cities. In this context, the present study aims to evaluate the spatial structure of Tabriz City from the perspective of the distribution of functional cores, its alignment with population distribution, and the realization of a multi-core spatial structure. The findings of this study suggest that the distribution of various functions within the city of Tabriz occurs in a clustered pattern.

In most cases, the city's functional cores are configured in a single-core spatial structure centered around the city's core and areas 8, 2, and 3. The expansion of functional cores has also predominantly been from West to east in Tabriz and, in some instances, northward. Furthermore, the results indicate that the spatial relationship between the urban functional cores and the population of the metropolis of Tabriz has been moderate, at around 59 percent. This illuminates the imbalance in the distribution of urban functions within Tabriz based on its population.

From a broad perspective, considering the distribution of functional cores, the results identify the following two patterns in line with the spatial structure of the metropolis of Tabriz:

a) Primary Center (Predominant Model)

Due to its commercial function, the city's central sector is the city's primary center where most of the population movement is observed. Increased mobility trends in various hours of the day are directed toward this area. Aside from the number of people employed in this region, which attracts a significant crowd to the main center daily, the existence of diverse functions, particularly commercial ones like Tabriz Bazaar, draws a large influx of citizens to the city center for various purchases, as well as some administrative and healthcare services. Moreover, this area's urban role and function are amplified by suburban, inter-regional, national, and even international functions, all of which contribute to the population's mobility toward the main city

center for shopping, commerce, administrative services, and healthcare services.

b) Subsidiary Centers

In recent years, the subsidiary centers in Tabriz have expanded and evolved in diverse functions. For instance, the dispersal of administrative services from the central district, the establishment of well-equipped healthcare centers such as the Valiasr International Hospital in the eastern part of the city, and the construction of commercial complexes across various regions have all induced human movements at different urban scales. The presence of specific functions, such as industries in the West, has also facilitated population movements in these areas. However, unlike the city center, which is consistently and continuously used over time and fulfills its role and functions, secondary centers have a sectional function. Therefore, it can be stated that subsidiary centers, while recognizing citizens' preferences and benefiting from composite functions, should facilitate the formation of a polycentric city pattern.

Based on the research results, it can be concluded that the dominant spatial structure in the city of Tabriz, from the perspective of various functional aspects, has predominantly been single-core and clustered, with a few exceptions. On the other hand, existing approaches in urban space have resulted in the polarization of the city across various dimensions. This can be seen in the dualism present in the social and physical structure of the city (informal and formal residences), as well as between the eastern and western regions of the city. The Western areas, in particular, have been disadvantaged regarding access to various functions. Therefore, to achieve spatial balance in the distribution of functional cores relative to population, it is essential that strategic planning is incorporated into urban development schemes.

The research proposes the following strategies to establish a multi-core spatial structure in the city of Tabriz:

- Distribute administrative services evenly across all sectors, reducing the centralization of these services.
- Regulate the impact of land brokers and real estate speculators to mitigate the spatial imbalances they cause in the value of residential and commercial lands.
- Locating and establishing functional cores considering the population increase in the western and northern parts of the city.
- Foster connectivity and coordination between essential city elements, such as different activities and population distributions across various regions.
- Developing the functions of subsidiary cores to alleviate pressure on central areas.

AUTHOR CONTRIBUTIONS

A. Asadi performed the literature review, interpreted the data, and prepared the manuscript text and edition. M. Ahadnejad Reveshty performed the analysis and interpreted the data. H. Tahmasebi Moghaddam performed the literature review, compiled the data, and manuscript preparation.

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CONFLICT OF INTERESt

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and falsification, double publication and, or submission, and redundancy, have been completely witnessed by the authors.

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