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Investigating the Drivers of Knowledge-Based Growth Management Using Fuzzy MICMAC: A Case Study in Iran

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Abstract: Attention to a city's physical development is necessary for urban development plans. In Iran, the rapid physical expansion of cities in the form of unplanned and unbalanced growth due to various reasons, including indiscriminate migration, is considered a fundamental problem. This phenomenon is known as urban sprawl, which is one of the results of this type of growth. The research aims to identify and prioritize the indicators of the realization of knowledge-based growth management (KBGM) in the city of Tabriz, using foresight methods to analyze the effective drivers. The fuzzy linguistic MICMAC method was used to analyze mutual effects by converting linguistic variables into fuzzy numbers. In addition, using the theory of fuzzy sets for experts participating in research, the relationships between the 32 research variables were investigated. This research showed that the city of Tabriz had a scattered, isolated, fast, and unplanned growth, and it has relative compatibility. Despite the possibility of development within the limits of urban growth, most of the construction activities were outside the boundaries of urban growth. Key factors affecting the management of knowledge-based growth in Tabriz city were identified. Based on our findings, the university's reputation, government effectiveness, urban competitiveness, city branding, quality of life, and strategic planning will impact the knowledge-based development process in Tabriz.

Keywords: growth management; sprawl; urban; knowledge-based development; Tabriz

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1. Introduction

Today, cities have become the principal places of work and life for the majority of the population. Consequently, the inhabitants of cities are globally growing, and it is predicted that by 2030, more than 60% of the world's population will live in cities [1]. This growth, coupled with social, economic, and environmental problems, produces instability in cities [2–5].

These issues and problems are caused by urbanization conducted with poor planning tools. This approach reduces the quality of urban life in several areas. It has been implemented without a model of urban livability [6]. Solving the problems of urban settlements is fundamental to managing urban growth properly. By improving the use of space and place, cities will be more livable.

Knowledge is considered a key element in economic prosperity. Today, urban areas are new players in the global economy. They improve citizens' quality of life and attract more human capital, raising their competitive advantages and transforming talents and capital in welfare. Taking a global perspective, the world's finances inevitably achieve significant benefits from knowledge-based growth management [7–9]. This research aimed to identify and prioritize indicators for realizing knowledge-based growth management in the city of Tabriz. For this purpose, forecasting methods have been used to analyze the effective drivers related to the subject. The most crucial reason for adopting these methods was to determine what is necessary for a correct decision; unfortunately, this information is

only sometimes available. This information allows assumptions to be determined, tested, and, if necessary, changed.

2. Literature Review

2.1. Elements of Urban Growth Management

In the modern era, expansion of cities is a common trend. This phenomenon produces migration activities. Government interventions, with a combination of growth management policies and tools to limit external expansion, save the cost of building new infrastructures, protect open spaces, and reduce car dependence. Urban Growth Management (UGM) is related to the future organization of cities by meeting current and projected needs to maximize the benefits of growth. There is a close relationship between urban growth and its management, as it is primarily related to the concentration of people or economic activities (Tisdale 1941; Couch et al., 2005) [10,11]. Secondly, it is essential to achieve efficient urban development, reducing the growth of several areas. This approach leads to achieving the desired social, economic, and environmental qualities [12–14]. The concept of urban growth management, as of recently, aims to reduce cities' ecological footprint or minimize its increase [15]. In comparison to other developed countries, growth management has been far more widely discussed in the US context. Thus, growth management in the US forms the main focus of the present discussion.

The goals of urban growth management are to maintain public goods such as clean air and landscape, minimize external harms caused by land use, such as landfills, and minimize financial costs or tax burdens by delivering cheap public goods and services, preventing sprawl. The right approach is to reduce car travel and energy consumption, create more accessible transportation for people, preserve agricultural land, maximize social justice, improve quality of life, achieve an efficient development model, and compensate the market's imperfections [12,14,16].

The concept of urban growth management has evolved. In the 1960s–1970s, it was about regulating growth with growth boundaries or growth edges. In the 1980s, it moved towards coordination and people's participation in growth management, becoming a comprehensive framework integrating economic, environmental, infrastructure, and quality of life aspects. In the 1990s, it was about smart growth and the move towards a regional approach to managing growth [17]. Urban growth management goes beyond plans and regulations and is a comprehensive concept. For example, it is based on traditional planning tools and the conscious and integrated use of planning (comprehensive), regulations (sectoring, zoning), and financial authority (preparation of appropriate facilities, development cost impact) of the government. Local governments use the above three factors to influence growth and meet anticipated needs. Nevertheless, unlike traditional planning, urban growth management combines rules with incentives to guide new development in a dynamic land market [18].

Although growth management is about regulating and directing land use with tools, it has evolved from regulation to a more complex set of activities benefiting multiple stakeholders beyond a single community [17]. Moreover, it enables communities to improve their quality of life [19]. The above is achieved by creating a wide range of policy instruments to manage the growth and protection of open spaces at the local, regional, and national levels [20,21]. Supposing that growth management is the application of planning tools in a coordinated way to achieve the desired growth pattern, long-term planning with infrastructure, housing, employment, and social services is essential for adequate growth management. Effective growth management is a dynamic process of anticipating and adapting to development needs by harmonizing the goals of creating local competitiveness and aligning local interests with regional interests [22].

In summary, growth management is a comprehensive concept that uses a combination of planning tools to guide growth in desired areas at an optimal rate to limit excessive horizontal expansion and provide effective infrastructure growth and development. Growth management cannot be achieved in isolation but is the result of the combination of five

elements, as shown in Figure 1. Each mentioned component and part is essential in helping manage growth effectively. Planning organizations consider specific regional policies to manage urban growth and allocate resources to achieve it, while executive organizations use regulations and resources to achieve policy goals. Public and political participation strengthens the implementation of these policies by maintaining policy programs. Growth management policies should be evaluated to identify whether the adopted interventions effectively achieve the desired results. Ultimately, planning increases effectiveness by building the infrastructure for future growth. In this section, the above components are briefly discussed.

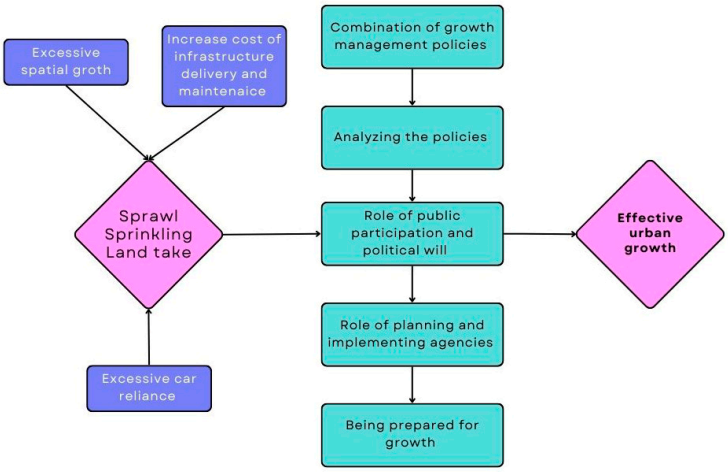

Figure 1. Model showing effective urban growth management components and elements. Adapted after [23].

2.2. Urban Growth Management Approaches

A city's physical development is a dynamic process, with growth related to an expansion of boundaries. The transformation of the settlement pattern has two different consequences in regions and cities: the need for new areas for settlements due to population growth, and the urban sprawl phenomenon [24]. The pattern of sprawl has been seriously studied in the urban studies literature since the 1960s. For a long time, it was considered a problem unique to American cities, caused by the availability of cheap land, irresponsible road development, and overproduction of vehicles in this nation. Today, it has become a global phenomenon that most cities in the world experience, especially developing countries [25].

The correct use of land is a central goal in the planning profession, and the efforts of urban managers are based on technical criteria and standards. Since urban growth is inevitable and there is no possibility of stopping physical development in terms of population growth and increasing the quality of life, there is no other choice but to manage and guide the city's growth properly. The necessity of interactive planning is felt for this purpose. Since the beginning of the 20th century, there have been four periods in growth management policies, namely, the period of confronting and controlling growth, the period of growth planning, the period of smart growth, and the period of sustainable growth. The feature of the first period was to respond to environmental concerns. The feature of the second period was to pay attention to legal criteria for better placement of public and infrastructure services. In the third period, more attention was paid to the role of governments and the motivation of citizens. In the fourth period, growth has been seen as an opportunity, and long-term challenges, economic improvement, climate change, and energy supply have been considered.

According to the work of Davani and Zybarak (1998), urban growth during the last century has been influenced by three patterns of "urban boundaries", "rural boundaries", and "development based on transportation lines" (TOD). The first model is derived from

the teachings of Ebenezer Howard and seeks to draw a continuous line around the city and transfer growth to satellite settlements. The second model, based on Benton McKee's ideas, allows the city to grow in some suburban channels [26] and organizes new developments in the form of "Traditional Neighborhood Units" (TND). The third model, while defining separate nodes of development, deals with the arrangement and regularization of the area around the city as a "transitional system" [27]. In establishing this model, "neo-urbanists" such as Peter Calthorpe and Douglas Kelborg played a key role [28].

Bullens (2005) considers that two dominant paradigms have influenced the contemporary urban system in guiding the city's growth. The first model is the European concept that pursues "growth management" through "urban growth limits" (imposing restrictions on suburban expansions by defining limiting lines or building green belts). Ideas such as the limit of urban services, the politicized area of development, urban circles, and designed growth areas are derived from this perspective [29].

The other example (American) was mainly derived from the notions of neo-urbanism and especially "smart growth", which accepted suburban sprawl as an inherent and fundamental reality of the contemporary city.

In the face of urban dispersion and decentralization, the American model attempts to protect the areas surrounding cities by relying on the strategy of "creating compactness" and transportation-oriented developments (TOD) to lessen the constant conflict between the outside and inside of cities.

Growth management policies are a broad set of policy tools with the goals of slowing down growth (especially population growth) within a specific territory, achieving economic development, and ensuring quality of life and environmental quality, along with secondary goals, such as limiting overdispersion. Growth management approaches can be applied at different levels of domain. Arthur Nelson and Casey Dawkins found that growth management contains several techniques to achieve growth and distribute land according to the principles and goals of intelligent growth [30].

Bengtson has also stated that growth management (GM) is a set of government actions that tend to manage growth by controlling the location, quality, and development time [20]. In general, growth management is an attempt to balance the natural development needs of a society with the need to preserve public assets. Harmful interactions should be minimized, and beneficial interactions should be maximized. The advantages and benefits of population increase should be fairly distributed and increased in society. The financial burden should be minimized, and each resident's quality of life should be improved.

Growth management approaches can be divided into four major categories based on Pallagst's classification in the book *Growth Management in the US: Between Theory and Practice* (2007):

Law-based approach: This was proposed in the 1980s as a way of managing the growth of cities around the world, particularly in the United States of America. The purpose of this approach is to apply a set of constraints for growth and open space protection by monitoring and controlling the development and regulation of activities. The most important of these approaches are urban growth boundary, urban growth rings, planning of infrastructure and services, mixing of uses, and zoning.

Financial and market-oriented approach: The purpose of this approach is to use monetary mechanisms to support the development and growth goals of cities, which include taxation, purchase of development rights (PDR) and transfer of development rights (TDR), and density sales.

Design-oriented approach: This was proposed based on the neo-urbanism movement in American urban planning. It includes issues such as a pedestrian-friendly city, human-oriented urban planning, and appropriate urban landscape design to organize the urban environment and the quality of life of city communities.

Participation-oriented approach: This is a newer approach that involves interest groups' involvement in managing the growth of cities and establishes the process of democracy in decision making for the development of cities at regional and local scales.

Knowledge-based approach: In today's era, the economy based on knowledge and services is considered the main driver of urban growth. In this regard, scientists have emphasized the role of clusters and research cluster institutions, technology-oriented companies, human capital, and technical, scientific, and local knowledge in explaining innovative and successful urban and regional growth (Figure 2).

It is a knowledge-oriented city that aims to develop knowledge by encouraging the continuous production of knowledge and citizens' participation in knowledge, evaluating and reproducing, and updating knowledge. Knowledge-oriented city development is a new form of development in the knowledge-oriented era, which aims to bring economic prosperity, environmental sustainability, and economic–social order to cities [31]. It has four main goals: Economic, social–cultural, urban–environmental, and institutional development.

The knowledge-oriented city, on the one hand, emphasizes the development and progress of economic, social, cultural, and information technology activities. On the other hand, it pays attention to the protection of pristine and rich natural environments, urban quality, tolerance and acceptance of multiculturalism, democratic governance rooted in transparency and a specific vision, and the strengthening of social and human capital [32].

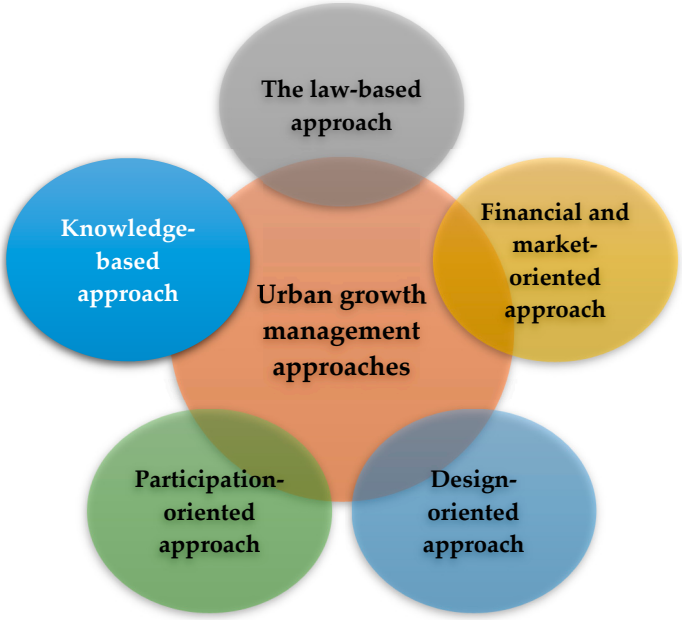

Figure 2. Urban growth management approaches. Adapted after [17].

3. Materials and Methods

The research aimed to identify and prioritize the indicators of the realization of knowledge-based growth management (KBGM) in the city of Tabriz, using foresight methods to analyze the effective drivers. The proposed hypotheses showed that the metropolitan city of Tabriz has moved away from the sustainability model.

The management model of the growth of the urban knowledge base was measured and identified by using 32 indicators and variables, which are presented, and the characteristics of the model used in the city of Tabriz: government effectiveness, electronic governance, strategic planning, city branding, effective leadership, strategic partnership and networking, community interaction, social cohesion and quality, GDP, urban competitiveness, foreign direct investment, major international companies, the rate of economic innovation, the amount of research and development, the amount of patent applications, knowledge of creative forces, livability, use of sustainable transport, compatibility with the environment, urban form and density, quality of life, cost of living, affordable housing, sustainable urban development, educational investment, cultural diversity, unemployment rate, broadband access, social sustainability, socio-economic dependency, professional skills, and university reputation.

3.1. Fuzzy Linguistic MICMAC (FL MICMAC)

Fuzzy linguistic MICMAC (Impact Matrix Cross-Reference Multiplication Applied to a Classification) is based on fuzzy set theory [33–36]. The MICMAC structural method analyzes the relationships between variables, especially in extensive systems with multiple dimensions. However, the MICMAC method has two fundamental problems. First, it needs to be clarified precisely how strong or weak the influence or dependence of one variable on other variables is. In other words, experts only give fixed scores of 1, 2, and 3 to the relationship between two variables, while in the real world, the influences of variables on each other are not so precise and complete. Using exact numbers eliminates the uncertainty and ambiguity in the qualitative measurement of the influences of variables.

Another problem is that it is impossible to quickly judge the sum of direct and indirect influences when presenting the finding's results. In the MICMAC method, variables whose sum of influences is more than half the most significant number of influences are considered influential (dependent), and the rest are considered independent. Influence maps are divided into four parts [37]. Fuzzy MICMAC is designed to solve this problem. Based on this, some researchers [38–40] at the University of Granada developed the fuzzy linguistic MICMAC to analyze the mutual influences.

Fuzzy MICMAC aims to provide the possibility of using language fields in the data collection stage. By using this method, experts, including future researchers, can fill the spaces of the matrix of mutual influences with intensive language fields (for example, strong, weak, and so on). Nevertheless, to use fuzzy analysis models [41], experts must introduce ordered strings of words. The working method is such that experts can determine the mutual influences of two variables from weak to very strong. After performing the fuzzy analysis, the output of the matrix of mutual influences can be re-categorized and arranged based on these sequential linguistic fields. In this way, the components of the matrix of mutual influences will be actual words that, unlike numerical data, cannot be directly used for mathematical or software analysis. Therefore, a method for assigning numbers corresponding to these linguistic fields should be used in the analysis. All linguistic variables can be converted into numerical ones using fuzzy logic [42].

The same method is used to convert linguistic variables into fuzzy numbers in Fuzzy MICMAC. Linguistic variables or linguistic fields are similar to qualitative variables. Unlike numerical variables with a quantitative value at the relative and distance measurements, linguistic variables are words or phrases used in human relationships. Fuzzy MICMAC triangular fuzzy numbers (Triangular Fuzzy Numbers (TFNs)) convert linguistic variables into fuzzy numbers. All the numerical calculations of this method are performed with the help of membership functions defined for each linguistic field. Fuzzy functions are used to convert sequential linguistic strings to fuzzy numbers, perform fuzzy calculations, and then convert the results from fuzzy numbers to linguistic strings again (Figure 3).

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-a)/(b-a) & \alpha \le x \le b \\ (c-x)/(c-b) & b \le x \le c \\ 0 & otherwise \end{cases}$$

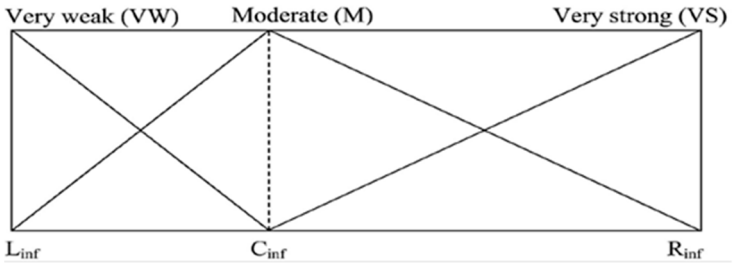

Figure 3. Membership functions used to present the linguistic labels.

According to the above form and function, the principles of defining fuzzy numbers for linguistic fields can be seen. Linguistic strings can be replaced with real numbers (for example, replace the code with two instead of the "average" string and then perform mathematical operations on them). However, this method could be more accurate. For example, codes 1 and 2 are both whole numbers that only consider a narrow range of possibilities between these 2 numbers. In other words, qualitative indicators are a range of values and different possibilities. Accordingly, fuzzy theoretical numbers can be used. For example, for the "weak" code, a membership function starts in a range slightly before the number one (1, 0.5, and 0.25).

3.2. Study Area

Tabriz is a city in the northwest of Iran and is the capital of the East Azerbaijan Province. The earliest elements of the present city of Tabriz are claimed to have been built either at the time of the early Sassanids in the 3rd or 4th century AD, or later in the 7th century. The latitude and longitude are, respectively, 38°8′ N and 46°15′ E (Figure 4).

The estimated population of Tabriz city is approximately 1.6 million people, with a continuously increasing trend. Tabriz is the largest city in northwest Iran and is the nation's center for culture, politics, trade, and government. Tabriz is known for its historical landmarks, including the Tabriz Historic Bazaar Complex, a UNESCO World Heritage Site, and the Azerbaijan Museum. The city lies in a valley surrounded by hills on three sides and is known for its temperate climate, making it a popular tourist destination.

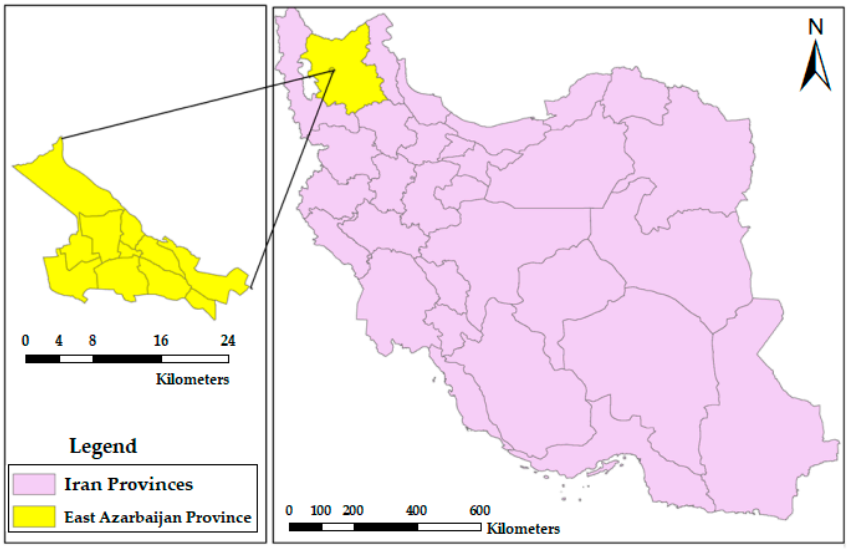

Figure 4. The study area of Tabriz city in Iran.

Additionally, tourism is an essential part of the local economy, with many historical sites and cultural events attracting visitors from both within Iran and abroad.

The World Crafts Council and UNESCO declared East Azerbaijan's province capital the World's Carpet Capital in 2015. Tabriz has been a place of cultural exchange since antiquity, and its historic Bazaar complex is one of the most important commercial centers on the Silk Road. According to UNESCO Tabriz, the historic Bazaar complex consists of interconnected, covered brick structures, buildings, and enclosed spaces for different functions. Tabriz and its Bazaar were already prosperous and famous in the 13th century, when the town, in the province of Eastern Azerbaijan, became the capital city of the Safavid kingdom. The city lost its status as the capital in the 16th century but remained important as a commercial hub until the end of the 18th century, with the expansion of Ottoman power. It is one of the most complete examples of Iran's traditional commercial and cultural system. Tabriz Historic Bazaar complex has been one of the most important international places

for commercial and cultural interchange, thanks to the centuries-old East–West trading connections and routes and a wise policy of endowments and tax exemptions.

The Tabriz Bazaar's lasting role is reflected in its fabric's layout and in the highly diversified and reciprocally integrated architectural buildings and spaces, which have been a prototype for Persian urban planning. The Tabriz Historic Bazaar Complex was officially protected in 1975 and since then has been covered by special stewardship measures. The UNESCO recognized buffer zones to protect and save cultural heritage sites. Three different protection areas have been established (a nominated area, a buffer zone, and a landscape zone), which are subject to special regulations incorporated into the planning instruments. (Figure 5).

(**a**) (**b**)

Figure 5. (**a**,**b**) Tabriz historical Bazaar complex base.

There are just 11 cities that have been named World Crafts Cities. Tabriz is in the lead as the city that best represents Muslim cities on the list. Additionally, in 2018 this city was chosen as the hub of Islamic tourism.

Tabriz is recognized as the second largest industrial city after Tehran's capital due to its capacity for numerous industrial plants and businesses. It has a diverse economy, including automotive, machine manufacturing, food processing, and textiles. The city is also a hub for trade and commerce, with a large bazaar district and a history of commercial activity dating back centuries. In recent years, the government has made efforts to develop the technology sector in Tabriz, focusing on IT and software development.

The university has played an essential role in the city's development. Tabriz University is a public research university located in Tabriz, Iran. Founded in 1947, it is one of the oldest and largest universities in the country. The university has several faculties, including engineering, natural sciences, humanities, law, and medicine, and offers undergraduate and graduate programs in various disciplines.

Tabriz University is known for its strong academic programs and reputation for producing good research in natural sciences, engineering, and social sciences. The university has approximately 25,000 students, with a large campus with modern facilities and vibrant student life. The University of Tabriz has its main campus in Tabriz, as well as three other satellite campuses, Aras International Campus, Miyaneh Technical College, and Marand

Technical College. By total area, this makes the University of Tabriz the second largest campus in Iran.

The university provides a well-educated workforce for local businesses and industries, and its research and development activities have contributed to the growth of new technologies and industries in the region.

Tabriz University is a leader in research and has a solid scientific and technological innovation tradition. The university has several research institutes and centers dedicated to advanced materials, renewable energy, and nanotechnology.

The university collaborates with local businesses and government organizations on initiatives to promote economic development, such as technology transfer and incubation programs. Moreover, the university has a significant impact on the cultural and social life of the city, hosting cultural events and fostering a vibrant intellectual community. Overall, the relationship between Tabriz University and the city's economy is mutually beneficial, with the university helping to drive economic growth and the city providing a supportive environment for the university's educational and research activities. Tabriz University represents a strength in higher education and research in Iran, and its impact on the region's cultural, intellectual, and economic life is significant.

4. Results

Analyzing mutual or Cross Impact is a widely used method in research. In the real world, most events and issues are related to other events and issues, and analyzing these mutual relationships is essential. In the method of mutual influences analysis, researchers attempt to predict the influence (or probability of influence) of one variable on another variable and calculate the sum of these mutual influences. To achieve this goal, Michel Godet introduced structural analysis using MICMAC software as one of the components of strategic foresight [43]. The main idea was to make it possible for experts participating in research to use the fuzzy set theory to fill in the tables of mutual influences using qualitative values to achieve quantitative numerical values. For experts, it is usually easier to use qualitative expressions based on experience in a specialized field. Therefore, linguistic variables can be considered a suitable solution.

Furthermore, by utilizing linguistic factors, a level of uncertainty and ambiguity is incorporated into expert judgments due to the intensity of impacts, rather than being substituted by real numbers with the assistance of qualitative variables that encompass a range of numerical values. In addition, at the stage of presenting the findings in impact ranking tables or with the help of impact maps, it is possible to attach linguistic labels to the results using fuzzy logic. Based on this, MICMAC Fuzzy Cognitive Linguistics [33–36] analyzes interaction influences. MICMAC Fuzzy aims to enable linguistic fields in the data collection phase. Using this method, current experts and experts participating in a future research panel can fill the spaces of the matrix of mutual influences with strong linguistic fields (for example, strong, weak, and so on). However, to use fuzzy analysis models, experts must introduce ordered strings of words. The working method is such that experts can determine the mutual influences of two variables from weak to very strong. After performing the fuzzy analysis, the output of the matrix of mutual influences can be re-categorized and arranged based on the same ordered linguistic fields [44].

To use this technique, it is essential to choose the linguistic values (pre-defined by fuzzy triangular numbers) that will be used to express the level of influence/dependence of one element on another (see Table 1). After that, the experts set the impact range for each pair of elements using linguistic values. Finally, the upper- and lower-order ideals describe a new set of linguistic values for the overall dependencies and influences [45,46].

Table 1. Determination of global influence and dependence of a variable with numerical values (left) and linguistic labels (right).

(Left)					(Right)				
Var	V1	V2	V3	inf	Var	V1	V2	V3	inf
V1	0	0	1	1	V1	Null	Null	Low	Low
V2	0	0	3	3	V2	Null	Null	High	Med
V3	0	1	0	1	V3	Null	Low	Null	Low
Dep	0	1	4	0	Dep	Null	Null	Med	Null

Source: [47].

An aggregation operator was applied to determine the linguistic label corresponding to a variable (see Table 1: right). The information obtained from this operator enabled ordering and plotting the variables analogously to MICMAC. This knowledge, along with the linguistic labels assigned to a variable, enabled us to assess the outcomes as relative and absolute, as illustrated in Figure 6.

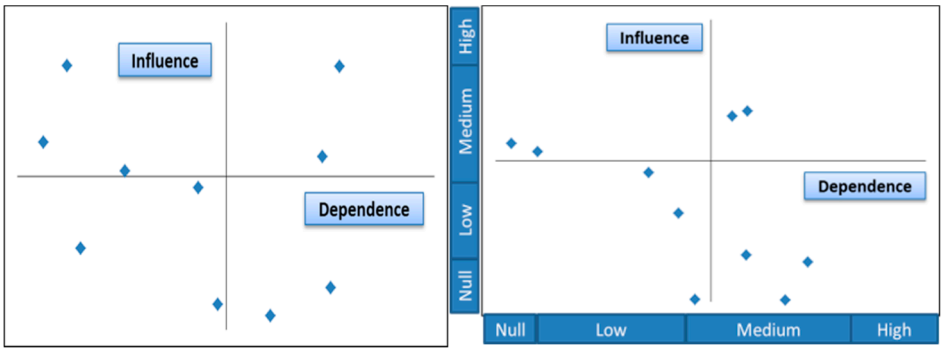

Figure 6. Influences–dependences map in MICMAC (**left**) Influences–dependences map with linguistic labels (**right**).

4.1. System Analysis and Inter-Relationships of Factors

In this section, the initial matrix must be formed first. The relationships between the 32 research variables were derived from the matrix. The number zero indicates that the variable of row *i* does not affect column *j*, the number one indicates the weak influence of the variable of row *i* on column *j*, the number two indicates the moderate influence of the variable of row *i* on column *j*, and the number three indicates the strong influence of the variable row *i* on column *j*. Finally, the symbol P indicates the potential influence of the variable row *i* of column *j*, which the experts did not use in this research. In addition, the following table shows each variable's driving forces and degree of dependence. The driving force of each variable is the final number of variables (including the variable itself) that can contribute to their creation [48]. The degree of dependence is the last number of variables that cause the said variable (Table 2).

In this research, experts are urban planners, academic staff in urban management, and urban managers in the municipality of Tabriz. By analyzing the results in the first step using a simple method, it can be found that the influence of variables can be measured by considering the number of communication groups in the matrix. A variable directly affecting a limited number of variables has a negligible impact on the whole system. The direct effects of a variable can also be checked by considering the relevant column in the matrix. As a result, the sum of the numbers in each row represents the influence of the relevant variable, and the sum of the numbers in each column represents the graph of that variable's influence, so all variables and their surroundings can be represented by displaying them in a conceptual diagram with coordinate axes (Influences-dependences), as shown.

Table 2. The direct and indirect influence of knowledge-based urban growth management factors on each other.

Variable Name	Direct Influence		Indirect Influence	
	Defuzz Direct Influence	Defuzz Direct Dependence	Defuzz Indirect Influence	Defuzz Indirect Dependence
1: Government effectiveness	50.67	61.5	46.10	46.5
2: Electronic governance	45.17	56.83	45.87	46.36
3: Strategic planning	48	49.5	45.96	46.08
4: City branding	51.33	49	46.13	45.95
5: Effective leadership	46.33	35.67	45.83	45.30
6: Strategic partnership and networking	48.17	45.83	45.90	45.91
7: Community interaction	41.33	57.83	45.56	46.31
8: Social cohesion and quality	52	56	46.09	46.24
9: GDP	62.83	50.67	46.62	46.11
10: Urban competitiveness	59.5	55.67	46.43	46.27
11: Foreign direct investment	61	40	46.53	45.51
12: Major international companies	61.67	47.33	46.53	45.91
13: The rate of economic innovation	56.83	50	46.31	46.02
14: The amount of research and development	45	50.5	45.83	46.08
15: The amount of patent applications	54.17	67	46.20	46.67
16: Knowledge of creative forces	52.83	52.17	46.11	46.22
17: Livability	55.33	55.83	46.25	46.28
18: Use of sustainable transport	59.33	62	46.44	46.52
19: Compatibility with the environment	56.33	60	46.34	46.47
20: Urban form and density	61.17	63.83	46.45	46.61
21: Quality of life	60.33	48	46.50	45.90
22: Cost of living	52.5	51.5	46.17	46.13
23: Affordable housing	53.67	56.17	46.21	46.35
24: Sustainable urban development	59.67	53.83	46.42	46.18
25: Educational Investment	53.83	53.33	46.2	46.17
26: Cultural diversity	63	72.17	46.55	46.87
27: Unemployment rate	57.33	58.17	46.37	46.47
28: Broadband access	50.5	54	46.10	46.17
29: Social sustainability	48.5	57.5	45.97	46.32
30: Socio-economic dependency	46	54.83	45.92	46.26
31: Professional skills	38.67	56.83	45.52	46.41
32: University reputation	77.17	46.67	47	45.91

Source: Authors' calculations using FLMICMAC software.

As shown in Table 2, some of the knowledge-based growth management criteria have a significant impact on the whole system. Accordingly, the system's three most influential direct variables are university reputation, cultural diversity, and foreign direct investment. In this regard, factors such as university reputation and GDP have the most direct influence.

Other influential and indirect influential results can also be seen in Table 2. By observing these results, it became clearer that some knowledge-based growth management factors influence each other (and the whole system). In other words, the change and improvement in the status of some indicators of growth management, such as university reputation, will lead to the relative progress of the system and eventually move towards sustainability goals. In this regard, the government's effectiveness variable will significantly affect achieving the goals of knowledge-based growth in Tabriz city.

4.2. Visualization of Linguistic Results

In this section, researchers used two plans of absolute and relative information to depict the results obtained from linguistic values. The description of these plans is described below.

Thermal map of linguistic results: First, to have a general perspective of the whole system and the intensity of influence and dependence of the interactions that take place

within it, the indicators and their influence and dependence were determined at the end of the MICMAC Fuzzy linguistic process (Figure 7a,b). Each square in the image corresponds to a possible interweaving of the influence and dependence of different indicators in different parts of the system. The intensity of the red color indicates the number of indicators integrated with the results. The mentioned figure can be used for two direct and indirect actions, which depict these results. As a result, the whole system's behavior in this plan can be analyzed and interpreted more. The summarized form of this step depends on the settings of number n in the software, which should assign odd values (9, 5, and 3), and the measurement of this step is up to the expert.

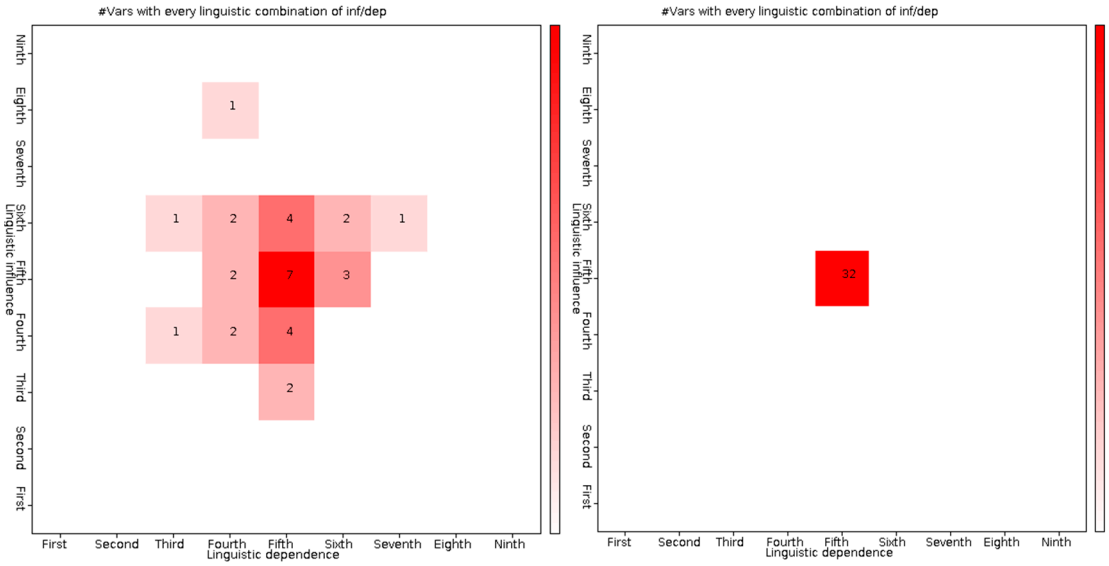

Figure 7. (**a**,**b**). Heat map of the direct and indirect method.

In this research, the researchers chose $n = 9$. In the present study, the heat maps show the linguistic values of the system's middle based on the results. As seen in Figure 7b, the indirect method results are shown shortly and concisely. The goal was to hide part of the results and direct results to a matching answer to avoid getting trapped in the disadvantages of many linguistic processes after long calculations. In our case study, these designs allowed the expert to control the system at first glance. In other words, most factors show a moderate level of influence. In addition, heat maps act as a factor aggregating method because those aggregate variables with the same impact and influence can play a similar role in the system.

4.3. Fuzzy Influence–Dependence Level with Deterministic Information

MICMAC analysis shows that measures located in the penetration zone have high penetration power and low dependence. In other words, these measures affect other measures but are less affected by other measures. MICMAC software shows two types of analysis and analytical graphs. One is direct influences, and the other is indirect influences. As evident in Figures 6 and 7, the influence and dependence of each index in a two-dimensional plan on two levels, direct and indirect, have been presented.

The distribution of variables based on direct influence and dependence shows that most variables are scattered around the diagonal axis of the plane. Except for a few limited factors that significantly impact the system, the other variables have almost the same status. Each marked point in the figure represents a variable placed by a pair of deterministic and definite values for the non-fuzzy overall influential and dependence sub-criterion in different system regions. Triangular fuzzy numbers, explained earlier, are the results of linguistic sets that have been calculated. In this regard, researchers can classify each

variable's role in the system by constructing its influence and dependence according to other criteria.

The distribution and dispersion of variables in the dispersion plane indicate the system's stability or instability. In the Cross Impact analysis method, if the current diagram is L-shaped, it indicates a stable system because the factors are generally either influenced or dependent, and there are few dual and complex factors. Nevertheless, if the resulting diagram is placed in the form of an elongated oval around the diagonal axis of the diagram, it indicates an unstable system [43].

In the direct method, the researcher can observe the output results of the northwest and southeast variables in the weak to medium degree of influence and dependence. In contrast, the variables in the northeast and those in the southwest of the system indicate a moderate to substantial degree of influence and dependence. Based on these findings, the university's reputation, government effectiveness, urban competitiveness, city branding, quality of life, and strategic planning will impact the knowledge-based development process in Tabriz. All the factors from two direct and indirect methods with a very high degree of influence and a significant difference from other variables are known in Figures 8 and 9. They have been repeated with both direct and indirect methods.

It seems that, on one side, there are the trend and approach of researchers and, on the other side, there are the attention and needs of policymakers, managers, and related organizations.

The idea of urban foundation knowledge management and applying foresight methods is necessary for proper management, reducing environmental and economic consequences, and making more appropriate decisions.

One of the fields of using the FLMICMAC method is related to housing research. In addition, the use of the structural MICMAC method is a suitable approach for measuring theoretical and qualitative data.

In this way, it is possible to compare the main indicators two by two and finally provide a suitable model for housing development indicators.

It can also be used in evaluating urban livability, with this method and converting qualitative data obtained from the opinion of experts and specialists into numerical data (FLMICMAC).

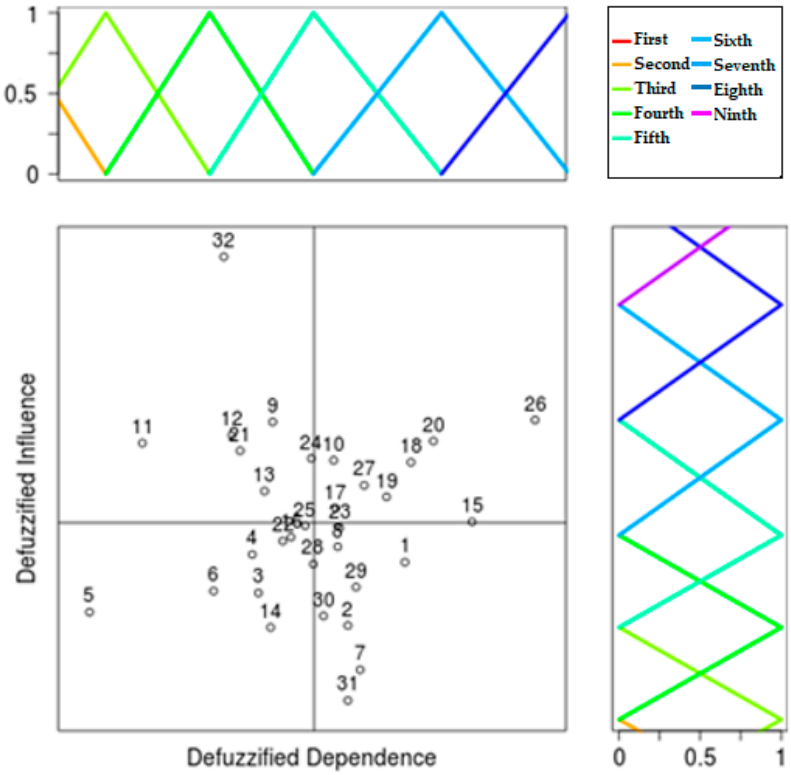

Figure 8. Fuzzy influence–dependence chart with the direct method. (Output by FL MICMAC software).

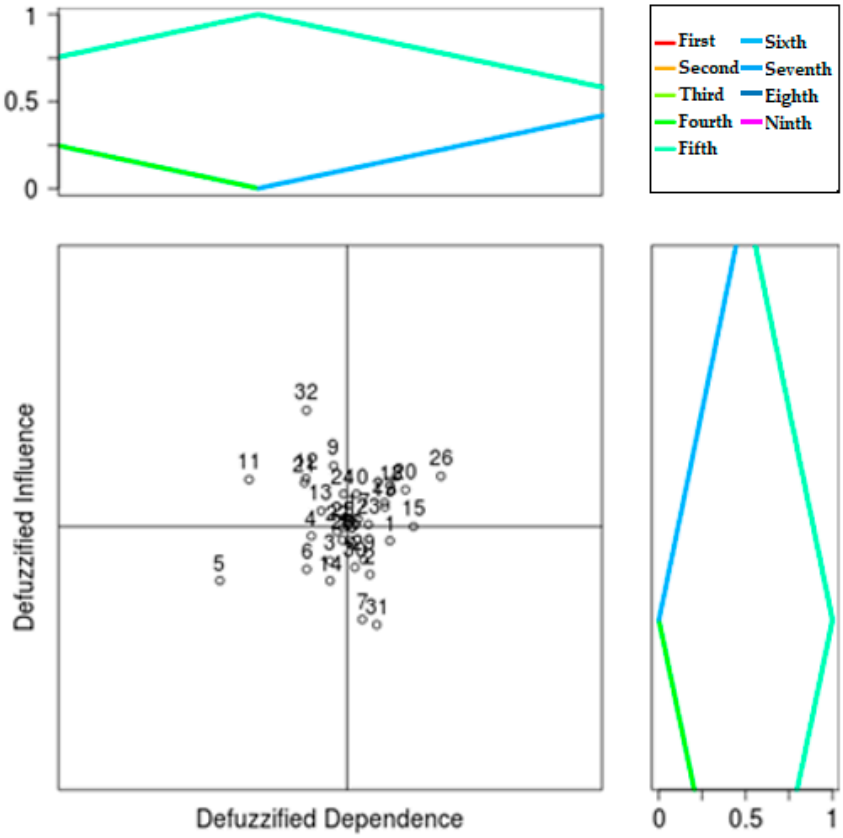

Figure 9. Fuzzy influence–dependence chart with the indirect method. (Output by FL MICMAC software).

5. Discussion

The rapid growth of cities worldwide happened when the cities could not provide services to their rapidly growing urban population. This phenomenon caused the sprawling and loss of land on the edge of the cities and increased illegal and marginal settlements. Sustainable urban economic development is one of the essential fields of urban management.

Fundamentally, this development is based on knowledge-based urban management. This knowledge can lead to urban businesses, proper urban development, and sustainable urban income. In order to attend to sustainability, knowledge is key.

Among the effective sub-indicators in sustainable development, a related criterion is the correct management of resources and the proper management of urban development. The management of knowledge-based urban growth is based on the goal of sustainable development, preventing the destruction of the environment and rural areas around the city. Consequently, it leads to the prevention of scattered urban growth, and, at the same time, it emphasizes smart, knowledge-based, and sustainable urban growth combined with proper management.

In general, the concept of urban knowledge management is adopted in most urban fields, such as transportation, housing, urban development and growth, urban planning, and urban management. It is essential to adopt foresight models in urban growth management to reduce the vulnerability of the urban environment and control the management of urban peripheral spaces, reducing traffic and the loss of agricultural land. It is suitable for formulating urban and transport plans and managing the real estate market, industry, and agriculture. Tourism development should also be carried out in a more appropriate way. Urban growth should be systematic and based on knowledge and sustainable development. It should reduce horizontal land use and use worn-out urban fabric, vertical, and compact urban development.

6. Conclusions

Although there are more sophisticated ideas about decision making processes for knowledge-based urban growth policies, a city knowledge approach can guide decision making for better urban futures. Urban growth management is a field where policymakers use knowledge-based urban development variables.

In the management of knowledge-based growth, the goals of the institutional urban development perspective are based on the following elements:

- The knowledge democratization of organizations and human resources;
- The creation of institutional processes of interdisciplinary collective learning;
- The organization of essential knowledge;
- The creation of continuous communication between actors, stakeholders, and resources;
- Strategic planning, organizing, and facilitating the necessary knowledge-based activities.

This vision powerfully creates knowledge governance that provides knowledge-based urban development through "governance and planning" and "leadership and support." Therefore, the systems do not reflect a strong influence among the variables. Key factors affecting the management of knowledge-based growth in Tabriz city were identified. Based on this research, the university's reputation, government effectiveness, urban competitiveness, city branding, quality of life, and strategic planning will impact the knowledge-based development process in Tabriz. The fuzzy linguistic MICMAC's ability to use heat maps is one of its benefits. The heat maps demonstrate if the system's parameters significantly affect or depend on one another. In other words, these maps give to the decision maker a means for measuring the system's robustness based on the relationships between the many existing components. The additional advantage of the heat maps is clustering the factors in an optical mode, because the factors with the same range of influence/dependence may have the same role in the system. Despite being better in some variables, our system's overall strength is in the medium and lower variables.

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References

1. Akande, A.; Cabral, P.; Gomes, P.; Casteleyn, S. The Lisbon ranking for smart sustainable cities in Europe. *J. Sustain. Cities Soc.* **2018**, *44*, 475–487. [CrossRef]
2. Molan, A.S.; Ziari, K.; Pourahmad, A.; Hataminejad, H.; Parsa, M. Situation Analysis of Cities in Ardabil Province in Terms of Health Indicators. In *Proceedings of the International Conference on Computational Science and Its Applications*; Lecture Notes in Computer Science; Springer: Cham, Switzerland, 2019; Volume 11621, pp. 628–641.
3. Ghafarian, M.; Parizadi, T.; Shamai, A.; Khatibizadeh, M.R.; Shaheswar, A. Spatial Analysis Livability of Urban Neighborhoods (Case Study: 18th Region of Tehran). *Environ. Res.* **2017**, *7*, 45–58.
4. Saganeiti, L.; Pilogallo, A.; Scorza, F.; Mussuto, G.; Murgante, B. Spatial Indicators to Evaluate Urban Fragmentation in Basilicata Region. In *Proceedings of the Computational Science and Its Applications—ICCSA 2018*; Lecture Notes in Computer Science; Springer: Cham, Switzerland, 2018; Volume 10964. [CrossRef]
5. Molaei Qelichi, M.; Murgante, B.; Feshki, M.Y.; Zarghamfard, M. Urbanization patterns in Iran visualized through spatial auto-correlation analysis. *Spat. Inf. Res.* **2017**, *25*, 627–633. [CrossRef]
6. Safdari Molan, A.; Ziari, K.; Pourahmad, A.; Hataminejad, H. Providing a Livable Housing Development Model for Increasing Urban Livability (Case Study of Tehran). In *Proceedings of the International Conference on Computational Science and Its Applications*; Lecture Notes in Computer Science; Springer: Cham, Switzerland, 2019; Volume 11621, pp. 660–674.

7. Aliakbari, E. Structural Analysis Drving Forces Knowledge Based Urban Development Case study: Tehran Metropolis. *J. Res. Urban Plan.* **2020**, *11*, 1–20.
8. Carrillo, F.J. Knowledge-based value generation. In *Knowledge-Based Development for Cities and Societies: Integrated Multi-Level Approaches*; IGI Global: New York, NY, USA, 2010; pp. 1–16.
9. Rittgasszer, I. Knowledge-Based Urban Development, as a New Development Paradigm. In *Regional Growth, Development and Competitiveness*; University of Szeged: Szeged, Hungary, 2013; pp. 36–46.
10. Tisdale, H. The Process of Urbanization. *Soc. Forces* **1942**, *20*, 311–316. [CrossRef]
11. Couch, C.; Karecha, J.; Nuissl, H.; Rink, D. Decline and sprawl: An evolving type of urban development—Observed in Liverpool and Leipzig. *Eur. Plan. Stud.* **2005**, *13*, 117–136. [CrossRef]
12. Ervin, D.E.; Fitch, J.B.; Godwin, R.K.; Shepard, W.B.; Stoevener, H.H. *Land Use Control: Evaluating Economic and Political Effects*; Ballinger Pub. Co.: Pensacola, FL, USA, 1977.
13. Porter, D.R. *Managing Growth in America's Communities*, 2nd ed.; Island Press: Washington, DC, USA, 1997.
14. Nelson, A. Growth management. In *The Practice of Local Government Planning*; Hoch, C.J., Dalton, L.C., So, F.S., Eds.; American Planning Association: Chicago, IL, USA, 1999; pp. 375–400.
15. James, P.; Holden, M.; Lewin, M.; Neilson, L.; Oakley, C.; Truter, A.; Wilmoth, D. Managing Metropolises by Negotiating Mega-Urban Growth. Harald Mieg and Klaus Töpfer. In *Institutional and Social Innovation for Sustainable Urban Development*; Routledge: Oxford, UK, 2013.
16. Nelson, A.C.; Duncan, J.B. *Growth Management Principles and Practices*; American Planning Association: Chicago, IL, USA, 1995.
17. Pallagst, K. *Growth Management in the USA between Theory and Practice*; Routledge: London, UK, 2007. [CrossRef]
18. Nelson, A.C.; Pendall, R.; Dawkins, C.J.; Knaap, G.J. *The Link between Growth Management and Housing Affordability: The Academic Evidence*; Brookings Institution Center on Urban and Metropolitan Policy: Washington, DC, USA, 2002; pp. 117–158.
19. Carter, P. Techniques for coordinating and managing growth. *J. Urban Plan. Dev.* **1993**, *119*, 84–95. [CrossRef]
20. Bengston, D.N.; Yeo-Chang, Y. Seoul's greenbelt: An experiment in urban containment. In *Policies for Managing Urban Growth and Landscape Change: A Key to Conservation in the 21st Century*; Bengston David, N., Ed.; Gen. Tech. Rep. NC-265; Department of Agriculture, Forest Service, North Central Research Station: St. Paul, MN, USA, 2005; pp. 27–34.
21. Bengston, D.N.; Youn, Y.C. Urban Containment Policies and the Protection of Natural Areas: The Case of Seoul's Greenbelt. *Ecol. Soc.* **2006**, *11*, 1–3. [CrossRef]
22. Porter, D.R. *Managing Growth in America's Communities*, 2nd ed.; Island Press: Washington, DC, USA, 2008.
23. Jain, M. *Analyzing Effectivity of Urban Growth Management in the National Capital Region Delhi, India*; Shekar Verlag: Aachen, Germany, 2013; p. 232.
24. Abedini, A.; Khalili, A. Measurement of Urban Sprawl Using Spatial-temporal Data (Case Study: City of Urmia). *Motaleate Shahri* **2018**, *7*, 63–76.
25. Hutchison, P. *Encyclopedia of Urban Studies*; Sage Publication: London, UK; New York, NY, USA, 2010.
26. Cullingworth, B.; Nadin, V. *Twon and Country Planning in the UK*; Routledge: London, UK, 2006.
27. Pourjohari, A.; Majedi, H. Spatial Evaluation of Urban Growth Management Mechanism in Iranian Cities. *Urban Manag.* **2010**, *8*, 35–48.
28. Duany, A.; Plater-Zyberk, E. Lexicon of the New Urbanism. In *Time—Saver Standards for Urban Design*; Watson, D., Plattus, A., Shibley, R.G., Eds.; Mc Graw-Hill: Boston, MA, USA, 1998; pp. 5.11-1–5.11-4.
29. Bollens, S.A. Urban Growth Boundary. In *Encycopedia of the City*; Roger, W.C., Ed.; Routhledge: London, UK, 2005.
30. Nelson, A.C.; Dawkins, C.J. Urban Containment Policies and Housing Prices: An International Comparison with Implications for Future Research. *Land Use Policy* **2004**, *19*, 1–12.
31. Yigitcanlar, T.; Lonnqvist, A. Benchmarking knowledge-based urban development performance: Results from the international comparison of Helsinki. *Cities* **2013**, *31*, 357–369. [CrossRef]
32. Yigitcanlar, T. Planning for knowledge-based development. *J. Knowl. Manag.* **2009**, *13*, 228–242. [CrossRef]
33. Zadeh, L.A. Fuzzy sets. *Inf. Control* **1965**, *8*, 338–353. [CrossRef]
34. Zadeh, L.A. Fuzzy sets and systems. In *Proceedings of the Symposium on System Theory*; Polytechnic Press of Polytechnic Inst. of Brooklyn: Bronklyn, NY, USA, 1965; pp. 29–37.
35. Zadeh, L.A. Fuzzy sets as a basis for a theory of possibility. *Fuzzy Sets Syst.* **1978**, *1*, 3–28. [CrossRef]
36. Zadeh, L.A. Toward a perception-based theory of probabilistic reasoning with imprecise probabilities. *J. Stat. Plan. Inference* **1997**, *105*, 233–264. [CrossRef]
37. Arcade, J.; Godet, M.; Meunier, F.; Roubelat, F. Structural analysis with the MICMAC method & Actor's strategy with MACTOR method. In *Futures Research Methodology, American Council for the United Nations University: The Millennium Project*; BCNA: Buenos Aires, Argentina, 1999; pp. 1–69.
38. Villacorta, P.J.; Masegosa, A.D.; Castellanos, D.; Lamata, M.T. A Linguistic Approach to Structural Analysis in Prospective Studies. In *Advances on Computational Intelligence*; Greco, S., Bouchon-Meunier, B., Coletti, G., Fedrizzi, M., Matarazzo, B., Yager, R.R., Eds.; Communications in Computer and Information Science; Springer: Berlin/Heidelberg, Germany, 2012; Volume 297. [CrossRef]
39. Villacorta, P.J.; Masegosa, A.D.; Lamata, M.T. Fuzzy linguistic multicriteria morphological analysis in scenario planning. In Proceedings of the Joint IFSA World Congress and NAFIPS Annual Meeting (IFSA/NAFIPS), Edmonton, AB, Canada, 24–28 June 2013; pp. 777–782. [CrossRef]

40. Villacorta, P.J.; Masegosa, A.D.; Castellanos, D.; Lamata, M.T. A new fuzzy linguistic approach to qualitative Cross Impact Analysis. *Appl. Soft Comput.* **2014**, *24*, 19–30. [CrossRef]
41. Amato, F.; Tonini, M.; Murgante, B.; Kanewsky, M. Fuzzy definition of Rural Urban Interface: An application based on land use change scenarios in Portugal. *Environ. Model. Softw.* **2018**, *104*, 171–187. [CrossRef]
42. Zadeh, L.A. The Concept of a Linguistic Variable and Its Application to Approximate Reasoning-1. *Inf. Sci.* **1975**, *8*, 199–249. [CrossRef]
43. Godet, M. *Strategic Foresight La Prospective*; Cahiers du LIPSOR: Paris, France, 2008.
44. Talebiyan, H.; Molaei, M.M.; Gharari, F. Structural Analysis with Fuzzy MICMAC in Strategic Foresight. *J. Iran Futures Stud.* **2017**, *2*, 75–104.
45. Ranjbarnia, B.; Murgante, B.; Molaei Qelichi, M.; Rustaei, S. A Comparative Study Employing CIA Methods in Knowledge-Based Urban Development with Emphasis on Affordable Housing in Iranian Cities (Case: Tabriz). In *Proceedings of the Computational Science and Its Applications—ICCSA 2017*; Lecture Notes in Computer Science; Springer: Cham, Switzerland, 2017. [CrossRef]
46. Gorane, S.J.; Kant, R. Modelling the SCM enablers: An integrated ISM-fuzzy MICMAC approach. *Asia Pac. J. Mark. Logist.* **2012**, *25*, 263–286. [CrossRef]
47. Castellanos, D.; Masegosa, A.D.; Villacorta, P.J.; Novoa, P.; Pelta, D. Improving scenario method for technology foresight by soft computing techniques. In Proceedings of the 4th International Seville Conference on Future-Oriented Technology Analysis (FTA), Sevilla, Spain, 12–13 May 2011.
48. Asan, S.S.; Asan, U. Qualitative cross-impact analysis with time consideration. *Technol. Forecast. Soc. Chang.* **2007**, *74*, 627–644. [CrossRef]