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Structural Equation Modeling of Urban Design and Sustainability in Najaf's Traditional Urban Context

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Abstract: In the context of urban planning, the design of urban spaces is recognized as a pivotal factor influencing urban sustainability, with a particular emphasis on inclusivity for individuals requiring special assistance. This study explores the interconnectedness of urban design with sustainability indicators, focusing on human-centric dimensions and the preservation of heritage within Najaf's traditional urban fabric. Through the application of Structural Equation Modeling (SEM) via the Analysis of Moment Structures (AMOS) software, this research aims to elucidate the significance and interrelations of specific urban design indicators, thereby determining their collective impact on urban sustainability. The methodology adopted herein leverages quantitative analysis to delineate the relationships among urban design parameters and their consequential influence on sustainability outcomes. The findings suggest a substantial correlation between urban design practices and the attainment of sustainability, with a notable emphasis on the design factor as a primary influencer. This research contributes to the discourse on urban sustainability by providing a methodological framework for assessing the role of urban design in fostering inclusive and sustainable urban environments. The study underscores the potential of SEM in elucidating the complex dynamics between urban design and sustainability, thereby offering empirical evidence to support the development of informed urban planning strategies.

Keywords: Urban sustainability; Human scale; Urban design; Structural equation modeling; Analysis of moment structures

1. Introduction

Using spatial scales for urban design and transportation systems that support health and sustainability by incorporating more human dimensions in their design, a series of authors shows how important it is to achieve local and global health and sustainability goals through most urban indicator frameworks. Many decisions based on time and space are made during urban transitions, which entail a variety of temporal and spatial acts at the architectural and urban dimensions. Urban design is the most significant factor (Boeing et al., 2022). Theory and practice are incorporated into urban reality and daily living, which are closely intertwined in the creation of urban space (Ataman & Tuncer, 2022).

The first Lancet Series, which examined urban planning, transportation, and health, was published in 2016, and this highlighted how urgent it is for the globe to move toward sustainable urban health. The World Health Organization (WHO) released its 2018 Physical Activity Action Plan, the Global Action Plan for Physical Activity, which included evidence-based recommendations for creating active environments, such as high-density pedestrian and bicycle-friendly areas, low-density urban centers, and high-density transit cities (Giles-Corti et al., 2022).

Sustainable urban design has played an important role in solving the problems of excessive urbanization or the shape of a sprawling city through designing buildings, planning land uses, roads and public squares and placing them under the scope of the human dimension for the long term under the assumptions and future policies of sustainable cities that make them more suitable for living (Al-Mosawy et al., 2021; Shen et al., 2019).

The concept of urban design is used to assess the rapid growth of a city through its physical form and has also given rise to a set of guidelines for identifying the accuracy and reliability of the measurement methods used to evaluate city development. Quantitative methods have been used to characterize densely populated regions and have put forth common markers including density, land use mix, accessibility, density, urban design, and dispersion index. Satellite imagery, digital mapping, and the Geographic Information System (GIS) promote urban shape improvement using novel technologies (Al-Ansari & Al-Khafaji, 2023). Urban design, which is associated with a potential for improving human health, has also been noted. Among these, the promotion of green spaces, walkability, cycling infrastructure, multiple modes of transport, and multiple modes of transport (Al-Khafaji et al., 2021; Hussein & Al-Khafaji, 2023) are emphasized. The main difference from the previous study is that instead of utilizing SEM to design cities, the main objective in urban design is to determine the most important secondary indicators, and to what extent they are linked and affect the various urban sustainability factors through the method of SEM, a process that can be relied upon for future urban design (Kirkkilic & Başar, 2018).

2. Theories of Sustainable Cities

The theory (compact, just, resilient, smart, and biophilia) was linked to new urban development, which was demonstrated through the provision of methodologies for cities to show progress towards achieving goals, namely the transition from sustainable urban cities to new cities capable of change and development with technology. Indeed, urban scholars have focused on various patterns and types of activity that are associated with urban diversity, as theorists have evaluated changes in individuals' conduct. To achieve a much-needed focus on modern technologies and "intelligence" in the city, they aim to transform urban science into practical or structural patterns and an ideal lifestyle. This study focuses on the compact city theory as it explains the landscape and sustainable urban design (Al-Jaberi et al., 2021; Newman, 1992).

3. Compact City Theory

The notion of a compact city was first proposed in 1960. It was inspired by the compact fabric of ancient towns, which had environmental implications and social problems related to urban sprawl. Eventually, it was thought that cities would transform into compact cities. In contrast to the 1960s and 1970s, people were starting to see the impact of sluggish development by 1970, which led to a greater public understanding of the detrimental effects of the growth movement. In 1973, an improved quality of life vision was put out, which gave rise to the pro-lower attitude and the encouragement of compact communities. Reaffirmed was the 1987 Our Common Future study (also known as the Brundtland study), which focused on creating a healthy environment. The compact city and ideas of urban planning have evolved as a more sustainable paradigm for urban growth (Al-Shouk & Al-Khfaji, 2018; Jabareen, 2006).

3.1 Objectives of the Integrated Theory

Strengthening the dense, dense, and compact composition of the urban form through the amalgamation of goals and other requirements. It also tries to achieve a high level of economic, environmental and social sustainability in the city, thereby ensuring the city's resources are largely untouched and waste is minimized. The compact urban city has been incorporated into the sustainable urban development agenda, thus encompassing the concept of a city-city (Jenks & Burgess, 2000).

3.1.1 Characteristics of the theory

Urbanization is a strategy to lessen the impact of climate change by alleviating its influence. It prioritizes environmental protection in the long run to create a vibrant and economically important urban environment on a large scale (Dempsey et al., 2011). Urban containment aims to preserve nature and encourage local identity with a developed urban structure that is more efficient for the land it occupies. Figure 1 shows the endogenous social processes, through interactions with nature and the proximity of places, which give space for experimentation and self-organization to enhance the conditions for density increase, making cities more humane (Moroni, 2016).

Among the trends that fall under its umbrella are high-density cities, mixed-use cities, green transportation-oriented development, new traditional neighborhoods (TND), and urban villages (Conticelli, 2020).

3.1.2 Urban sustainability

Using the SEM method, the compact city theory is developed to work on how and why urban sustainability can be studied by exploring the connections between urban design and indicators of sustainability.

Figure 1. Compact fabric of the Turkish city of Mardin

3.1.3 Green transit-oriented development (TOD)

The well-known architect and urban planner Peter Calthorpe published Metropolis New American: Environment and Society in 1993, which offered the first concept of TOD. With an emphasis on growth-focused elements like density, mixed use, and place-making, TOD was first created to create smaller, walkable neighborhoods surrounding existing transit stations. However, it has since proven to be a promising tool for ending "the vicious cycle of sprawl and reliance on a compact area development system that slows the spread of sprawl" (Petkar & Hamand, 2012). Then the concept evolved to integrate with environmental dimensions, which necessitates planning practices. More sustainable to create a more adaptive, responsive and robust approach, leading to a new concept called Green TOD. One of the early and strong proponents of green TOD is Cervero & Sullivan, describing it as an environmentally friendly version of TOD, where TOD can be combined with green urbanism (Alrobaee et al., 2023; Cervero & Sullivan, 2011).

Green TOD is a combination of urban and mobility concepts that prioritizes both pedestrian and cycling infrastructure and automated mobility, leading to significant environmental benefits. Energy self-sustaining systems and efficient building designs, in conjunction with resource management systems, aid in resource conservation, waste reduction, and emissions control, while also providing us with energy independence (Alaskary & Alrobaee, 2022; Niu et al., 2021).

The city's environmental footprint is significantly reduced by leveraging the strategic placement of activities and uses near transportation hubs, along with facilities that facilitate a shift from car to public transportation and replacing trips with walking and cycling. In addition, the model indicators include the typical shift from cars to public transportation and replacing trips with walking and cycling via mixing land use with green construction with sustainable community designs (Al-Abayechi & Al-Khafaji, 2023; Huang & Wey, 2019).

Several factors are derived from the trend as follows:

- Land use: The creation of dense patterns and spatial plans that prioritize the city's vertical rather than horizontal expansion, the reunification of various occupations with the principle of mixing (housing and workplaces), the promotion of a sense of place (belonging), and the revitalization and reconstruction of old and abandoned areas are all made possible by land use planning, which is crucial to solving the issue of land availability in urban areas (Shemirani & Hodjati, 2013).
- Accessibility: The goal of green transportation is to minimize the negative effects associated with transportation and the urgent need for transport in urban areas. The ability to reduce energy consumption, pollution, and other sources of disturbance, as well as improve safety and security (traffic safety), is a crucial factor for the economic, social, and environmental development of cities today and in the future. Through the diversity of environmentally friendly means of transportation, freedom of movement and comfort, by increasing opportunities for personal transportation, the transportation network is used intensively and over short distances to support densification. Therefore, the transportation options available are high-capacity (Abdulameer et al., 2024).
- Energy and the environment: Landscapes play a significant role in the city since they make up a significant portion of its land and serve a variety of aesthetic, social, environmental, and commercial purposes. These include providing open places for play, amusement, relaxation, and leisure. Concerning energy efficiency, cutting back on consumption to cut carbon emissions, attaining environmental sustainability, cutting back on energy use, and offering infrastructure services to improve access to water and water services, as well as the creation of an

environment free of barriers with high permeability and network connectivity (Cervero & Sullivan, 2011; Endangsih et al., 2022).

• Social and economic inclusion: The trend seeks to achieve more efficient economic activities and benefits positively by creating a place to focus activities close to each other and resolving the tension between the complex and the place to spread economic prosperity and social stability. Densities with high population densities promote the creation of more jobs, the reduction of unemployment and poverty, and the provision of a high-quality standard of living by lowering family travel costs and raising income to get to a self-sufficient metropolis (Al-Salam et al., 2021; Woo, 2021), as shown in Table 1.

Table 1. Main and sub-factors and indicators for the research on green transit

Factors	Indicators	Secondary Indicators
Land use	Land use mix, spatial and functional continuity, and density	Horizontal and vertical mix, rate of change in land use, developmental density, and density (net, total)
Accessibility	Traditional transmission patterns, intelligent transport modes, functional proximity, and traffic safety	Pedestrians, bicycles, private cars, buses, automatic transmission, electric transmission, electromagnetic machinery, distance traveled from the housing unit to various services and activities (transportation axes, neighborhood centers, recreational areas), road accidents, bus shortcuts, and emergency
Energy and the environment	Landscaping, energy efficiency, waste recycling, energy patterns, pollution patterns, biodiversity, and networks	Gardens, green areas, community gardens, urban blue spaces, energy density, performance factor, waste species, waste management, conventional energy, renewable energy, aerobic, soil, noise, plant diversity, animal diversity, water supply, electricity supply, and sewage supply
Social and economic inclusion	Participatory, employment, investments, and digital embedding	Social media, community participation in decision-making, availability of job opportunities in the public and private sectors, residential, health and capital investment, e-commerce, visa cards, and digital currency

4. Methodology

The study draws from a wide range of prior research on sustainability criteria and how they relate to compact city characteristics, both theoretical and practical. Through the presentation of this literature, the study topic was created with a lack of clarity on the relevance of statistically significant indicators, thereby identifying a knowledge gap. According to the study, these variables are essential to the creation of a compact city. The goal of the study is to identify the essential indicators, how they relate to and differ from one another, and how they affect the urban design element (Figure 2).

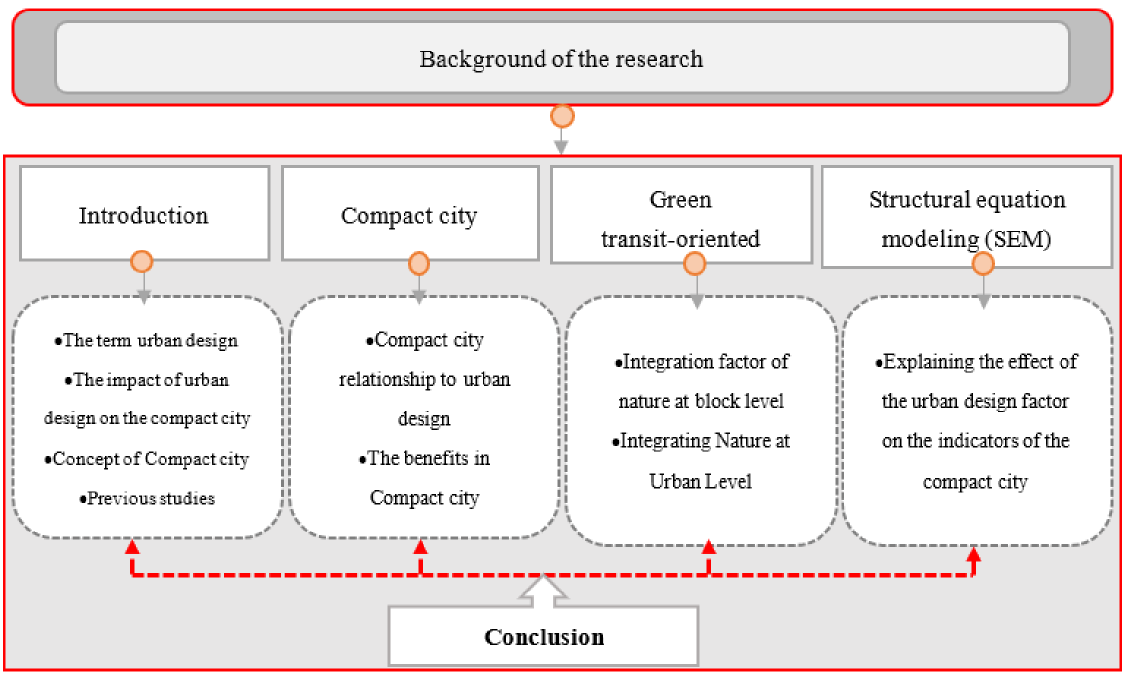


Figure 2. Methodology

The AMOS program, also known as the new generation based on an exploratory affirmative method, allows the implementation of statistical analysis of all factors with the possibility of achieving correlation and interpretation of variance. The AMOS program is one of the newest methods and programs used to test virtual models of phenomena in various sciences. It is the best statistical program to use complex and overlapping data if the researcher is studying multiple variables (Byrne, 2013).

Reasons for choosing the program: This precise statistical method was chosen as a result of the structural construction of factors and indicators presented in a hypothetical model for realistic data. In addition, it contains a graphical editor that allows the model to be viewed in an easy and clear visual manner, aiming to prove the aim of the study, i.e., understanding the effect of factors extracted from the integrated city theory and their relationship with sustainability by building the standard model. It is assumed that the factors have direct and indirect influences. And 200 experts used them to predict the next 20 years.

4.1 Model Formulation

200 sample responses to a questionnaire were used in this study. They were examined using AMOS software and SEM (Fatimah et al., 2022). There are two primary phases of model formulation that must be completed throughout the drafting process. The first step, which illustrates how the elements relate to one another, is represented by the basic model (Purwanto, 2023). The final structural model, which is the second step, shows how the secondary indicators for the urban design factor relate to and affect the other urban sustainability elements. Since these components cannot be measured, there are major indicators and sub-indicators for each element that can be measured. It takes two steps of study to estimate the measurement model. Prior to determining the validity of the factor structure of this variable, each latent variable's factorial structure must first be measured for stability.

The information was collected through an organized questionnaire, distributed through social media and also through interviews. The sample size consisted of 200 questionnaires that were distributed to experts using a five-point Likert scale, consisting of six basic factors for urban sustainability. The response rate was very good. Therefore, all models were considered correct and more effective for analysis.

4.2 Composite Reliability

When analyzing the sample structure, the Cronbach's alpha coefficient is computed to determine the internal stability and the degree of cohesiveness of the elements together. Stability is achieved when the magnitude of the alpha Cronbach coefficient is more than 0.70. However, the stability coefficient rises with the amount of questionnaire items in this sort of stability, which tries to quantify measurement mistakes (random errors). The alpha coefficient is one of the key indicators used to measure the strength of correlation and cohesion between the paragraphs of the prepared questionnaire before beginning the modeling process in the structural equation. This is because the alpha coefficient provides a high degree of confidence in the validity of the response and aids in estimating the degree of measurement. It is devoid of chance and enables the assessment of the dependability of variables. The alpha coefficient, which is one of the most often used techniques for evaluating reliability, spans from 0 to 1, with higher values nearer 1 denoting a more trustworthy scale and 0.7 as the acceptable threshold (Collier, 2020). Internal consistency is seen by looking at the Cronbach's alpha analysis results for every factor that was employed in this work. The findings of the Cronbach's alpha analysis demonstrated that it is not less than 0.70, as the internal consistency value varied between 0.7 and 0.9. This suggests a high degree of internal consistency in the study's dimensions and a high accuracy percentage, with the land use factor having the lowest value at 0.726 and the social integration factor having the highest value of 0.846. Table 2 displays the model's overall value, which is 0.828.

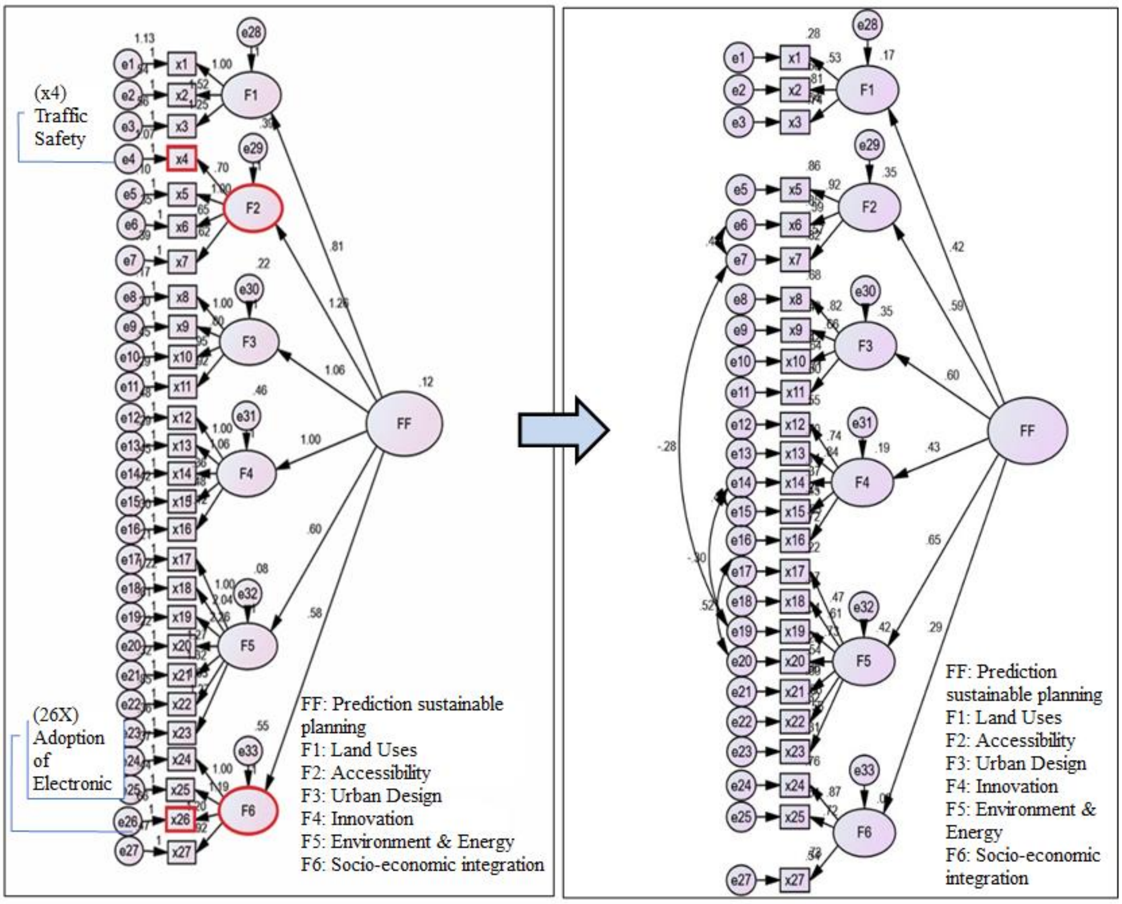
Table 2. Analysis of Cronbach's alpha

No.	Factors	Cronbach's Alpha Values Per Factor
1	Land uses	0.726
2	Accessibility	0.734
3	Urban design	0.797
4	Innovation	0.803
5	Environment & energy	0.776
6	Socio-economic integration	0.846
The total value of the model is 0.828.		

Specific criteria were used to estimate the initial structural model. The primary indications for each element are represented by three to eight paragraphs in the model's parameters, which were established after the standards and corresponding indicators were shown to be stable. The degree of missing data (2-20% for each indicator) and the average correlation between indicators and factors were both between 0.5 and 0.8, while the primary factor's correlation with other factors varied from 0.3 to 0.5. The closer the value to 1, the better (Kline, 2018). Following the discovery that the original structural model subgraph (a) of Figure 3 did not satisfy the criteria for goodness of fit, a number of changes were made to the model until it was deemed acceptable, as shown in subgraph (b) of Figure 3, and Table 3. Under the applicable model, the statistical model explains how the numbers fit the standard indicators. Although the good fit index (GFI) index of 0.85 and the adjusted GFI (AGFI) of 0.801 are not at the optimal level, they are still regarded as good values because they are getting close to 0.9. The scale of the inputs and indicators is the primary reason for this model analysis, but there are other factors as well. In addition to the repeated responses due to the expert nature of the sample, there may be contradictions. Since the model is regarded as one of the most restricted, it also has a lot of degrees of freedom. Generally speaking, a model becomes impractical and unusable the closer it gets to being too perfect (Malkanthie, 2015; Zeng & Li, 2021).

Table 3. Analysis of model fit test/goodness of fit/factorial structure

Indicator Name	Goodness of Fit Results (Criterion)	Default Model Values (Before Modification)	Default Model Values (After Modification)
Chi-square	Less than that is non-functional	690.431	385.124
Df/cmin ratio (i.e., chi-square division by the degree of freedom)	The value of this ratio is less than 5.	2.164, so the value of the degree of freedom is 319.	1.453, so the value of the degree of freedom is 265.
GFI	GFI ≥ 0.90	0.763	0.85
AGFI	AGFI ≥ 0.90	0.687	0.801
Tucker-Lewis index (TLI)	TLI ≥ 0.90	0.734	0.905
Normed fit index (NFI)	NFI ≥ 0.90	0.634	0.911
Comparative fit indices (CFI)	CFI ≥ 0.95	0.758	0.908
RMSEA	≤ 0.05	0.089	0.056



(a) (b)

Figure 3. The basic structural mode before/after modification

5. Impact of Factors

Through reviewing Figure 4, the following can be found:

• The environment and energy factor recorded the highest value of 0.65, indicating that the fundamental structural model of the forecast achieves a strong fit for urban planning elements. This figure shows that efforts are being made to forecast renewable energy sources in order to lessen pollution and climate variability and to promote the expansion of green and blue areas, which are essential to sustainability. Recycling and biodiversity preservation are vital practices that are required for civilization to advance in all spheres.

• With a value of 0.60, the urban design element is equally significant as the preceding component. It is seen as crucial to the preservation and construction of historical structures while developing the city and buildings in accordance with human principles that are compatible with both nature and man. This element has the potential to turn the city into a monument that captures the spirit and individuality of the locals. Emphasizing unique architectural designs and integrating smart building technologies can reduce energy consumption and create a sustainable city for both the present and the future.

• The value of the accessibility factor is 0.59. It is a high figure that significantly affects the forecast for the future. In cities, one of the most prevalent issues is transportation. The development of access-problem solutions must be done in an environmentally sound and sustainable manner. Thus, to achieve urban sustainability, one must rely on a sophisticated transportation system that makes use of technology and is close to all purposes.

• The land use factor was 0.42. Based on moderate density and both horizontal and vertical variety, the ratio is excellent. One of the key markers of sustainable cities is this.

• The component of social and economic integration was valued at 0.29. Given that four out of the seven sub-indicators for this component had a negative influence, bringing the impact down to an acceptable level, the impact rate is acceptable. This provides an in-depth analysis of how the community uses technology, electronic social communication, and websites to fulfill its need for products and services. The aspect of social and economic integration has been significantly impacted by this.

After confirming that the fundamental standard model is compliant with the scales, the overall structural model is tested to forecast the causes and relationships between the independent and dependent variables. To make sure that one-dimensional measurements are applied to the model factors through SEM using the AMOS software, all factors are gathered collectively. As shown in subgraph (a) of Figure 3, the direct and indirect impacts of statistical significance on the components of the presumptive prediction model are simulated. To identify indicators of statistical and non-statistical importance and subsequently reject them, the effects of secondary indicators for each element independently on the remaining factors are assessed.

5.1 Impact of Secondary Indicators

The structural test for the secondary indicators of the urban design factor is carried out. The following is discovered by examining the connections between these indicators (Figure 5).

(i) *P35*, which represents the adoption of the humanitarian scale, is a statistical function that has an impact on the factor of ease of access and is a good indicator of sustainability. Cities today are oriented towards the human dimension by giving priority to humans in the design of buildings, roads and public places, where proximity is achieved in all uses and services to overcome difficulties in particular. People are determined to make cities livable.

(ii) *P37*, which represents the memorial scale, is a statistical function that significantly affects the social and economic integration factor. The community requires significant historical monuments that serve as eye-catching summaries of history in order to communicate key information and events that draw tourists. It is a process of commemorating the events of the past and creating an identity that reflects the history and culture of the community to contain them. Historical symbols indicate the values of society.

(iii) *P41*, which represents the inclusion of buildings in preservation, is a statistical function and is adversely affected by the environmental and energy factors. Heritage buildings are affected by air, noise, or water pollutants, which in turn cause a significant change in the weather. Therefore, it is difficult to preserve their sustainability and make them a beautiful tourist destination.

(iv) *P42*, which represents the inclusion of buildings with architectural styles, is the experiences and knowledge of the architectural style and features for generations during a specific period. It determines the nature of the city so that new and imitative styles can be reshaped. In addition, it is a statistical function that strongly affects the social and economic integration factor. Time and synchronized with its development to encourage society to design public buildings based on beautiful architectural styles.

(v) *P43*, which represents reliance on smart and self-controlled lighting. It is a statistical function and has a strong impact on the land use factor. The vertical mix of land uses allows a large amount of light to enter and relies on it instead of electrical energy. It also has a significant impact on the innovation factor through sensor technologies, which control windows or convert them into solar panels by combining glass particles with perovskite metal to transform them into a solar panel, thereby converting it into clean and sustainable energy.

(vi) *P44*, which represents the adoption of smart and self-controlled ventilation, is a statistical function and has an inverse effect on the land use factor. To obtain self-ventilation, a large amount of wind must be allowed to enter. Therefore, it depends on the building types and the density inside the building. As for the rest of the indicators, the signature and planning for use were not statistically significant, as shown in Figure 6.

As explained previously, the environment and energy factors give the highest values in correlation due to several reasons. The most important reason is the experts' answer and the importance of the environment in sustainability. It is followed by the urban design factor, as it gives importance to the human dimension and standards for making sustainable future cities. The ease of access factor plays an important role in the future transportation system. For the city, the factors of land use and innovation have average values because the choices are different if they have different answers, and the least significant factor is social and economic integration since the behavior of the community is one of the most difficult measures and cannot be tested or counted.

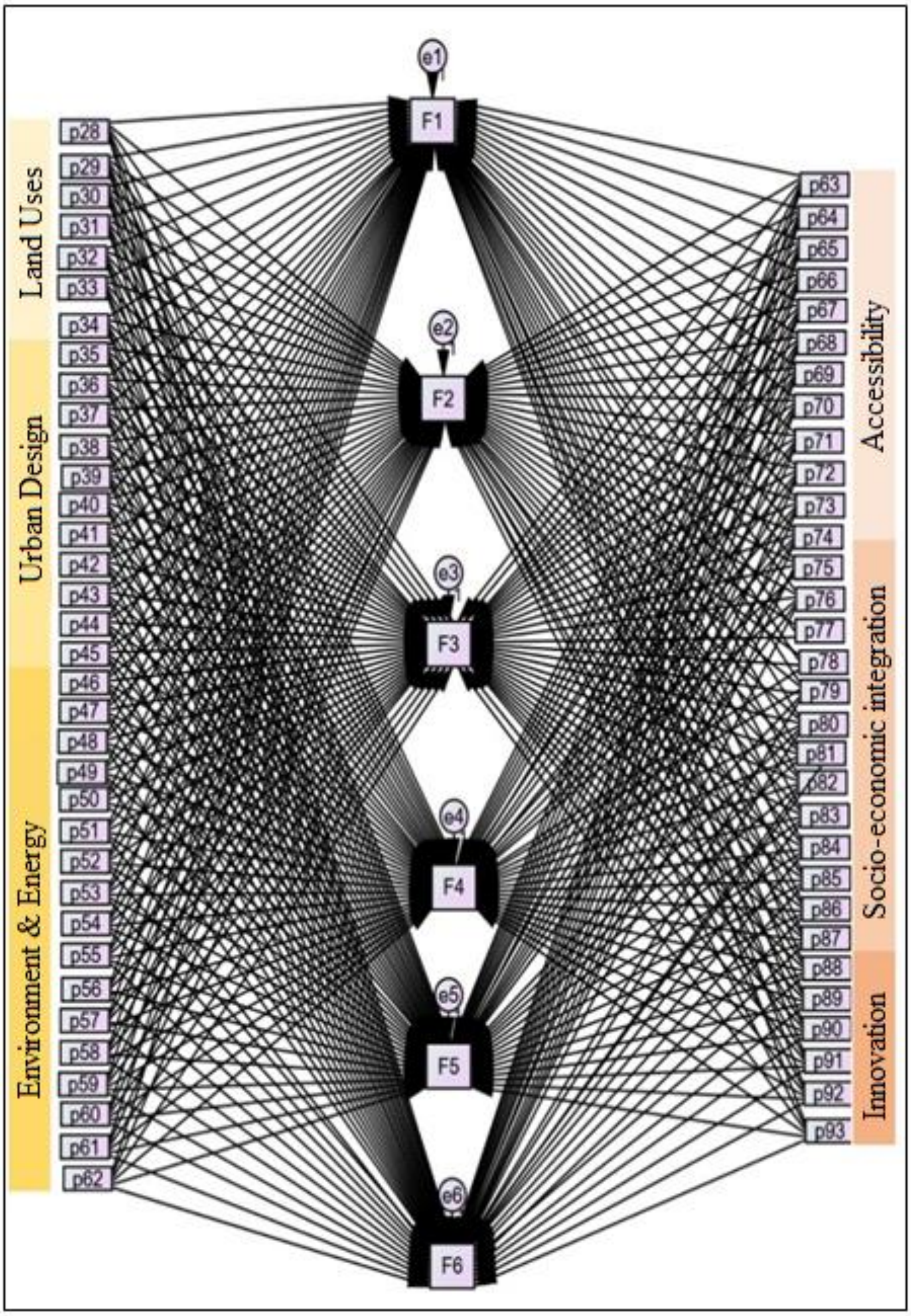


Figure 4. The relationship between main factors and urban sustainability

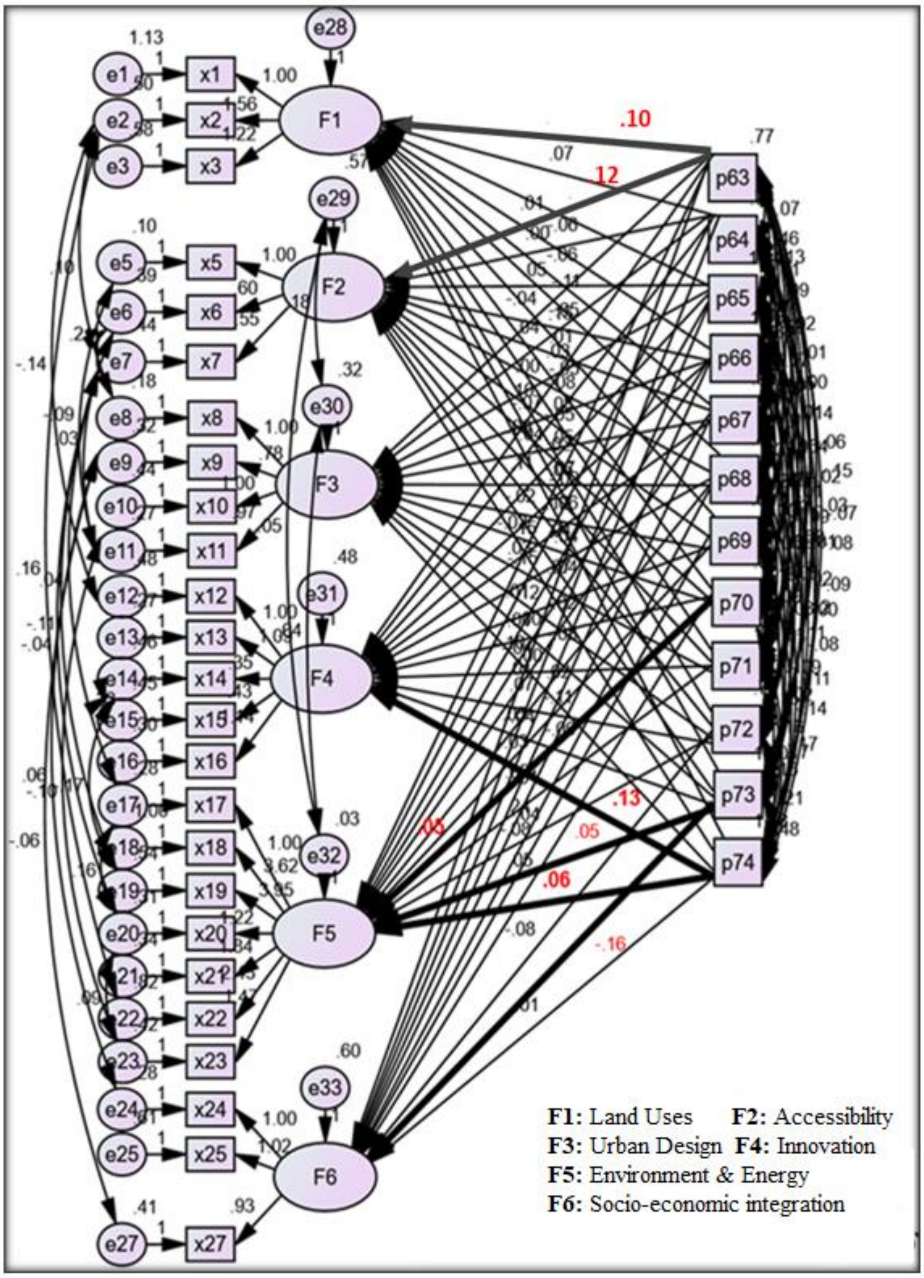


Figure 5. The relationship between secondary indicators and urban sustainability

5.2 Application of Urban Design Indicators to the Study Area

Urban design is an important factor for the city. This factor includes measurements, mass, space, and the height of buildings. The AMOS program's SEM results clarify the importance of this indicator in the city of Najaf.

The metric of urban design is the relationship or ratio between the height of buildings to the width of streets and alleys, as this value is the ratio between the fit of buildings to spaces and their connection to give a sense of belonging and greatness to the place. It includes three sub-indices, namely, humane, friendly, and memorial. After entering the metric into the SEM using AOMS, the indicators remain, which have a strong connection and influence on urban sustainability factors as follows:

(1) The human scale: According to the ratio of the height of buildings to the width of space, as well as field survey data, it was found that the value of the ratio reached 1:2. This type appears clearly on commercial streets. The survey was conducted on Al-Rasul Street, where the width of the street ranged from 12 meters, and the heights of the buildings varied from three to five floors. The value is 1:2, which is within the limits of the humanitarian scale of 3:1-2:1. It is classified as strong containment, which gives a very high degree of containment, thereby achieving the human dimensions of belonging, privacy and safety. It appears on the main streets of the old city (Figure 6).

(2) Commemorative scale: This scale works at the general level of the city, which contains the monuments or historical commemorative signs of the city and can be clearly seen within the public squares and streets. According to the scale, the Holy Shrine is considered the most important historical monument or memorial building for Najaf Governorate and at the regional level, as it gives the symbolism of the place. Its sanctity makes a person feel intimidated and dominated after seeing the symbolic and spiritual dimensions of the place (Figure 7).

Figure 6. The human scale

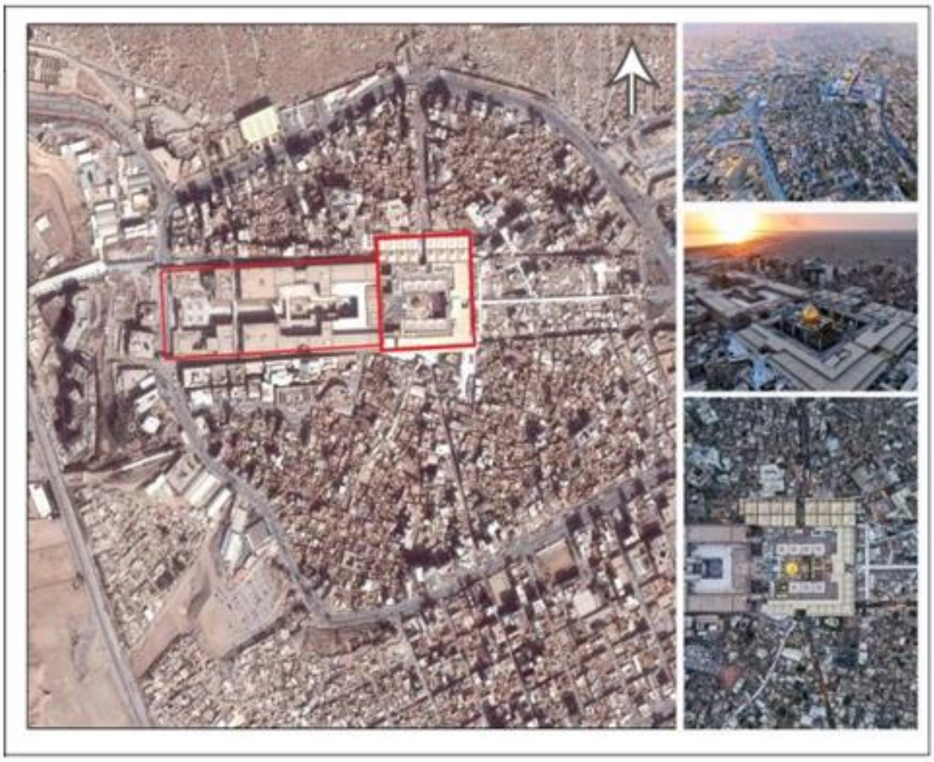


Figure 7. The commemorative scale

6. Conclusion

This study created a model to explain the connection between urban sustainability and the urban design component. Additionally, it permits each component to utilize the observed variables as secondary variables. It is crucial to research and analyze the prediction of urban design factors. It aims to address upcoming difficulties and quick changes while meeting requirements by creating new technologies. By creating long-term strategies for alternative energy, forecasting and simulation models contribute to future economic success and environmental security.

A significant aesthetic component of the city tells history in a manner akin to temporal art. This element includes indicators, such as scales, mass, area, and building height. Nonetheless, the AMOS software retains three primary indications derived from the SEM results: scales, building age, and, notably, automation due to its diverse interactions with other model components.

It is possible to extract observed variables from the SEM that correspond to latent variables. Furthermore, the component analysis technique facilitates the estimation of these variables, enabling the examination of variation and the evaluation of model precision. It can be shown as a route diagram or an equation to help visualize and validate the concept.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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