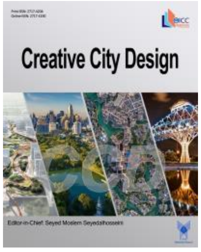

J. Creat. City Des. 2026; 09(02): 201-219

Journal of Creative City Design

https://doi.org/10.57647/ccd.2026.0902.12

Research Article

Analyzing and Evaluating Smart City Indicators Toward Achieving a Justice-Oriented Smart City (Case Study: Mashhad City)

Jamileh Mohammadzadeh Allah Verdi Khani, Katayoon Alizadeh*, Hamid Jafari

Department of Geography, Ma.C., Islamic Azad University, Mashhad, Iran

***Corresponding author:** k.alizadeh@iau.ac.ir

Article History:

Received:
08 November 2025

Revised:
04 January 2026

Accepted:
08 February 2026

Published online:
27 May 2026

Published in Issue:
30 June 2026

Abstract

Aims: Despite the widespread adoption of smart city initiatives, growing evidence indicates that technology-driven urban development does not inherently lead to spatial justice and, in some contexts, may intensify existing socio-spatial inequalities. This challenge is particularly evident in rapidly expanding metropolitan cities, where uneven access to smart urban services reflects deeper governance, design, and infrastructural imbalances. Addressing this critical gap, the present study examines how smart city dimensions influence urban justice outcomes in Mashhad, Iran, with particular attention to spatial disparities across urban districts.

Methodology: Based on survey data collected from 384 residents using a multi-stage cluster sampling method, urban justice is conceptualized as equitable spatial access to smart urban services, opportunities, and quality-of-life components across different socio-economic areas. From a creative city design perspective, smart city initiatives should be understood not merely as technological upgrades, but as spatial and institutional design interventions that shape everyday urban experiences, access, and justice. Structural Equation Modeling (SEM) and Multi-Group Analysis (MGA) were employed to assess the relationships between six smart city dimensions and urban justice.Also Spatial dependencies were assessed with Global Moran's I.

Finding: The results reveal that Smart governance had the largest direct effect on spatial justice ($\beta = 0.33$, $t = 6.48$, $p < 0.001$), followed by smart people justice ($\beta = 0.30$, $t = 5.87$, $p < 0.001$) and smart living justice ($\beta = 0.28$, $t = 5.22$, $p < 0.001$). MGA revealed significant spatial inequalities: the effects of smart governance, smart living, and smart mobility were markedly stronger in affluent districts than in deprived ones, indicating persistent gaps in governance capacity, infrastructure provision, and spatial quality. Global Moran's I test show significant positive spatial clustering for Smart Governance ($I = 0.421$, $p = 0.003$), Smart People ($I = 0.312$, $p = 0.014$), and Smart Mobility ($I = 0.355$, $p = 0.007$).

Conclusion: These findings suggest that achieving justice-oriented smart cities requires moving beyond technology-centered approaches toward spatially sensitive governance, inclusive urban design, and equity-driven policy interventions. By empirically linking smart city dimensions with spatial justice outcomes, this study contributes to creative city design and planning debates and offers actionable insights for urban designers and policymakers seeking to reduce socio-spatial inequalities in smart city transformations.

Keywords: Smart City; Spatial Justice; Smart Governance; Structural Equation Modeling (SEM); Multi-Group Analysis (MGA); Mashhad City

Cite this article: Mohammadzadeh Allah Verdi Khani, J., Alizadeh, K., Jafari, H., (2026). Analyzing and Evaluating Smart City Indicators Toward Achieving a Justice-Oriented Smart City (Case Study: Mashhad City), *Journal of Creative City Design,* 09(02): 201-219.
https://doi.org/10.57647/ccd.2026.0902.12

1. Introduction

Urbanization has emerged as one of the most defining geographical, social, and economic phenomena of the contemporary world. According to the United Nations, only about 30% of the global population lived in cities in 1950, while this figure rose to over 57% in 2023 and is projected to exceed 70% by 2050 [1]. The accelerated pace of urbanization particularly in developing countries has generated multifaceted challenges, including population density, spatial inequality, environmental pollution, infrastructure deterioration, traffic congestion, and the digital divide [2]. In response to these challenges, the concept of the smart city has emerged as an innovative paradigm in urban planning and governance, aiming to leverage digital, data-driven, and intelligent technologies to enhance citizens' quality of life and improve urban management efficiency [3].

In response, the smart city paradigm has emerged as a prominent policy and planning framework aimed at enhancing urban efficiency through digital technologies, data-driven governance, and intelligent infrastructure. Initially rooted in Information and Communication Technologies (ICTs), the smart city concept has gradually evolved toward a more holistic and human-centered approach that emphasizes participatory governance, environmental sustainability, and quality of life. Contemporary smart city frameworks recognize that technological innovation alone is insufficient unless it is embedded within inclusive governance structures and equity-oriented planning strategies. Despite this conceptual shift, a growing body of critical scholarship highlights a fundamental paradox: smart city initiatives often reproduce or even exacerbate existing socio-spatial inequalities. Empirical evidence suggests that smart urban services, digital infrastructures, and data-driven decision-making processes tend to concentrate in affluent and central areas, while peripheral and deprived neighborhoods remain digitally marginalized. This phenomenon has raised critical concerns regarding spatial justice, digital equity, and the uneven distribution of the benefits of smart urbanization. This study is theoretically grounded in the intersection of smart city theory and spatial justice. While mainstream smart city literature emphasizes efficiency, innovation, and technological performance, critical urban theory highlights the importance of equity, inclusion, and justice in urban development processes. By integrating these perspectives, the study conceptualizes urban justice as equitable access to smart urban services, governance mechanisms, and socio-economic opportunities across different spatial and social groups. Spatial justice is considered both as a precondition and as an outcome of sustainable and inclusive smart city development. Urban justice has long been a central concern in sustainable urban planning and human geography. David Harvey (1973) defines justice as the fair distribution of urban resources, opportunities, and services, while Edward Soja (2010) conceptualizes spatial justice as a prerequisite for sustainable urbanism. Spatial justice thus refers to the equitable access of all citizens to facilities, services, and opportunities across the urban landscape [4]. In Iran, despite numerous smart city initiatives in major cities such as Tehran, Mashhad, Isfahan, and Shiraz most projects have faced significant challenges, including the absence of a justice-oriented framework, weak data governance, and uneven spatial distribution of smart infrastructures [5]. Although Mashhad has been recognized by the International Telecommunication Union (ITU) as the first smart city in Iran and the third in the Middle East, the city faces complex and multidimensional urban challenges.

Rapid urban growth, profound socio-economic and environmental transformations, and the presence of the Holy Shrine of Imam Reza which attracts millions of domestic and international pilgrims annually have imposed intense pressures on the city. These dynamics have contributed to population growth, large-scale migration, widening social and economic inequalities, uneven spatial and physical development, inefficient urban governance, depletion of natural resources, severe traffic congestion, air pollution, and pronounced disparities in the distribution of population, infrastructure, activities, and urban services. As a result, existing local capacities and conventional planning mechanisms are insufficient to guide Mashhad toward a justice-oriented and sustainable smart city model.

Achieving such a transformation requires coordinated engagement across multiple sectors, particularly in the fields of information and communication technologies, data-driven governance, and integrated urban management. Smart city–oriented policies, when strategically aligned with principles of spatial equity, have the potential to improve resource management efficiency, enhance quality of life, stimulate economic innovation, and foster entrepreneurship. Given that many of Mashhad's strategic urban challenges are approaching critical thresholds, addressing these issues is essential for achieving sustainable urban development goals. Within this context, smart urbanization can function as a key strategy for reshaping Mashhad's spatial structure toward a more balanced and polycentric development pattern. Such a shift may reduce excessive spatial concentration, promote more equitable access to urban services, and ultimately contribute to the realization of a smart and justice-oriented city. Despite extensive research on smart cities, four critical gaps remain: Limited attention to spatial justice outcomes within smart city evaluations. Insufficient empirical studies linking smart city dimensions to justice indicators using structural modeling approaches. A lack of intra-urban comparative analyses distinguishing between affluent, middle-income, and deprived areas. Scarcity of justice-oriented smart city research in Global South and Iranian metropolitan contexts. This study directly addresses these gaps through a spatially differentiated SEM–MGA framework applied to Mashhad, Iran, examining how six smart city dimensions smart governance, smart people, smart economy, smart environment, smart living, and smart mobility affect urban justice across socio-economic zones. Accordingly, the present study seeks to analyze the spatial distribution of smart city indicators in Mashhad and to provide evidence-based recommendations for future improvements. By addressing existing research gaps, this study aims to contribute to the development of equitable, sustainable, efficient, and livable urban environments. Moreover, the findings offer a transferable analytical framework that can inform justice-oriented smart city planning in other Iranian metropolises and in cities across the Global South, supporting the realization of data-driven, spatially informed, and equity-focused smart urban development.

2. Research significance and rationale

The digital transformation and the emergence of advanced Information and Communication Technologies (ICTs) have become fundamental drivers of change in urban management and planning in the twenty-first century [3]. Within this context, the concept of the smart city has emerged as an innovative paradigm in urban governance, aimed at enhancing quality of life, environmental sustainability, and social justice [6, 7]. However, global experience demonstrates that mere digitization of infrastructure without integrating spatial, social, and economic dimensions of justice often results in the formation of digitally unequal cities [8, 9].
Analyzing and evaluating smart city indicators serves multiple purposes. On the one hand, it enables the identification of spatial disparities, infrastructural deficiencies, and citizens' needs across different urban areas facilitating the design of targeted interventions to improve urban services and residents' satisfaction. On the other hand, it empowers urban managers to allocate resources more efficiently, reduce operational costs, and enhance the overall effectiveness of city governance. Moreover, this process contributes to environmental sustainability, hazard-risk assessment, and urban security planning, while also improving transportation systems, mitigating congestion, and strengthening public trust in municipal institutions. In essence, the analysis of smart city indicators requires the cooperation of multiple stakeholders including government agencies, the private sector, and citizens to ensure that technological innovations produce equitable and sustainable outcomes. Mashhad, as Iran's second-largest metropolis, faces numerous challenges concerning social and spatial justice. Rapid population growth, cultural and economic diversity, and widening spatial inequalities have complicated its urban dynamics. Since the early 2000s, Mashhad Municipality has pursued the establishment of an electronic city, drafting the first Strategic Plan for Mashhad's Electronic City in 2004 based on international experiences. Today, the Smart City Organization of Mashhad operates as a pioneering body, striving to promote spatial justice through digital infrastructure development and electronic service delivery [10]. The organization's Department of Planning and Smart City Services Development collaborates with universities and research institutions to identify urban needs, design strategic frameworks, and implement smart infrastructures often in partnership with the private sector. From a planning perspective, two key policy documents the Comprehensive ICT Plan and the Smart City Master Plan serve as the foundation for smart urban development in Mashhad. Nevertheless, significant gaps remain in applying advanced technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and Big Data analytics to address urban inequalities. Achieving a justice-oriented smart city requires not only upgrading physical infrastructures and urban services but also ensuring social inclusion, environmental resilience, and equitable access to technology. Through spatial data collection and analytical modeling, it is possible to identify the strengths and weaknesses of Mashhad as Iran's first officially recognized smart city and to design targeted interventions that enhance spatial justice.

3. Literature review and theoretical background

3.1. The concept of the smart city

The concept of the smart city has evolved as a multidimensional and dynamic construct reflecting transformations in urban development paradigms. Given that the city itself is a complex system comprising economic, social, cultural, environmental, and spatial dimensions, definitions of the smart city have also varied according to theoretical perspectives and policy orientations [11]. Smart cities represent an emerging model of urban governance and planning that utilizes digital technologies, data-driven decision-making, and innovation ecosystems to enhance quality of life, promote social welfare, and improve the efficiency of urban management. Despite the proliferation of this concept in academic and policy discourses over the past two decades, one of its major challenges remains the absence of a unified and comprehensive definition [12]. Early conceptualizations emphasized the role of Information and Communication Technologies (ICTs) as the foundation of smart urbanism linking technological infrastructure with improved service delivery and participatory governance [13]. In this sense, the smart city can be interpreted as a strategic response to the pressing challenges of urbanization, such as population growth, traffic congestion, pollution, social inequality, and environmental crises [3]. The underlying assumption is that the integration of technology into urban systems enables more adaptive, efficient, and citizen-centered governance structures. According to the European Smart City Framework, six interrelated dimensions define the structure and functionality of a smart city [6]:

Smart Economy – based on innovation, competitiveness, productivity, and entrepreneurship;

Smart Governance – characterized by transparency, accountability, citizen participation, and evidence-based policymaking;

Smart People – emphasizing human capital, digital literacy, and lifelong learning;

Smart Environment – promoting sustainable resource management, renewable energy use, and environmental resilience;

Smart Living – enhancing quality of life, health, safety, and social well-being;

Smart Mobility – developing efficient, safe, and environmentally friendly transportation systems. Collectively, these six dimensions illustrate that a smart city is not solely a technological construct but a socio-technical system in which innovation serves human and ecological goals. As Albino et al. [7] note, the true value of a smart city lies in its capacity to integrate technology with social inclusion, sustainability, and spatial justice. In this regard, technology acts as an enabler rather than an end in itself facilitating the creation of more equitable, participatory, and sustainable urban futures. Recent studies extend this conceptualization by emphasizing the intersection of smart governance, data ethics, and urban justice. Scholars such as Kitchin and Angelidou [6] argue that the next generation of smart cities must transcend purely technocratic models and adopt frameworks that address issues of inequality, digital exclusion, and uneven spatial development. Hence, a justice-oriented smart city integrates technological innovation with inclusive governance and citizen empowerment, ensuring that digital transformation benefits all social groups and territories equally.

3.2. Spatial justice

Spatial justice is one of the fundamental concepts in human geography and urban planning, rooted in theories of social justice and sustainable development. It emphasizes the equitable and balanced spatial distribution of resources, services, opportunities, and amenities within urban areas [14]. In the context of smart cities, spatial justice extends beyond physical accessibility to encompass digital equity ensuring that all citizens and urban regions have fair access to technological infrastructures, open data, and smart urban services. When such access is uneven, smart urbanization can paradoxically exacerbate spatial inequality, resulting in what scholars call a “dual smart city,” where affluent, tech-enabled districts thrive while marginalized areas remain excluded from the benefits of digital transformation [15, 8]. Recent empirical research underscores this tension between technological advancement and spatial equity. Nurbatsin et al. [16], employing a spatial autoregressive model (SAR) across cities in Kazakhstan, found that variables such as electronic billing adoption had a significant positive effect on smart city development, whereas cloud service use and server density showed limited spatial spillover effects. This indicates that not all technological inputs contribute equally to spatially balanced smart growth. Similarly, Ullah et al. [15] highlighted that emerging technologies particularly the Internet of Things (IoT) and Machine Learning (ML) hold promise for fostering more sustainable, efficient, and livable smart cities. However, they also warned that challenges related to data security, privacy protection, and ethical governance continue to hinder the realization of spatially just smart cities. Building upon this Ye.X et al. [17] introduced the concept of urban artificial intelligence (Urban AI), positing that AI systems can enhance transparency, civic trust, and knowledge co-production between citizens and local governments. They argued that equitable data representation and algorithmic fairness are prerequisites for preventing spatial bias in smart governance. As such, AI-driven decision-making must integrate ethical frameworks to ensure justice-oriented outcomes in spatial planning. From a regional perspective, Iranian studies have contributed to understanding spatial disparities in urban contexts. Pourahmad et al. [18] analyzed spatial justice in Yasuj city using nearest neighbor index and network analysis in ArcGIS. Their findings revealed a clustered and unequal distribution of urban services central neighborhoods enjoyed higher accessibility, while eastern and southern zones remained underserved. In a similar vein, Rezapour Ghotbi et al. [19] assessed smart city indicators through structural equation modeling (SEM) using AMOS and found that “smart economy,” “smart governance,” and “smart living” were the most influential components of urban smartness. Their results demonstrated that more affluent areas, particularly in District 1 of Babol, exhibited higher levels of smart city development compared to less privileged districts. Additionally, Namdar Ardakani et al. [20] explored the interlinkages between spatial justice and sustainable urban development in Shiraz. Their study revealed significant inequalities in access to urban facilities, showing that central districts due to concentrated investments and service provision were better positioned than peripheral areas.

3.3. The relationship between smart cities and spatial justice

The concept of the smart city centers on the integration of advanced information, communication, and digital technologies to enhance quality of life, improve urban efficiency, and promote economic and environmental sustainability. However, a critical concern in the trajectory of smart city development is the issue of spatial and social justice. Technology alone does not guarantee equality; rather, without deliberate planning and inclusive governance, it may reinforce or even exacerbate existing spatial disparities [14, 6] Spatial justice within the smart city framework refers to the equitable distribution of technological benefits, infrastructures, and digital services across all urban spaces. When smart initiatives concentrate primarily in affluent or central districts, the outcome is the emergence of “smart islands” within an otherwise unequal urban fabric [9]. In this sense, spatial justice is not merely an outcome of smart urbanization but rather a strategic prerequisite for achieving truly inclusive and sustainable smart cities. From a theoretical standpoint, the nexus between smart cities and spatial justice can be conceptualized across three interrelated levels: Infrastructure Level – ensuring equitable access to digital technologies, high-speed connectivity, smart mobility systems, and urban data networks for all citizens, regardless of geographic location or socioeconomic status [21]. Social Level – fostering active civic participation, digital literacy, and co-production of knowledge between citizens and governance institutions to prevent technocratic dominance and promote inclusion. Governance Level – promoting balanced distribution of resources, data ownership, and decision-making power through transparent, participatory, and data-driven governance mechanisms [2]. Achieving a justice-oriented smart city thus requires the integration of three foundational dimensions: technological efficiency, participatory governance, and equity-centered policymaking. These dimensions are mutually reinforcing—technology provides the infrastructure for inclusivity, governance ensures accountability and transparency, and justice-oriented policy guarantees fair distribution of urban benefits. Recent urban scholarship increasingly recognizes that the success of smart cities must be evaluated not only by their technological sophistication but also by their contribution to social equity, spatial inclusivity, and democratic governance [21]. Therefore, smart urbanism must shift its focus from technological determinism toward human-centered digital justice, where innovation serves as a means to advance fairness, accessibility, and well-being across the entire urban spectrum. In summary, the relationship between smart cities and spatial justice underscores a paradigm shift in urban studies from viewing technology as a neutral tool to understanding it as a political and ethical instrument that shapes the spatial distribution of opportunities and power within the city. Only by embedding justice as a guiding principle in smart city governance can cities achieve sustainable, inclusive, and truly intelligent futures.

4. Research methodology

This study adopts an applied research orientation and employs a descriptive analytical mixed-methods design with an exploratory sequential logic. In the first phase, a systematic meta-synthesis of international and national studies published between 2000 and 2025 was conducted to identify the key dimensions and components of a justice-oriented smart city and to develop an initial conceptual framework. This framework was then refined through comparison with international smart city standards and widely used conceptual models, ensuring theoretical consistency and analytical coherence. Urban justice in this research is conceptualized as a perceived and experiential construct, reflecting residents’ lived experiences of fairness, inclusion, and equitable access to smart urban services across socio-spatial contexts. This conceptualization is grounded in critical urban theory, which emphasizes that justice and inequality are not only objective spatial conditions but are also socially experienced and interpreted by urban residents. Consequently, perception-based measures are particularly appropriate, as governance legitimacy, public trust, and policy effectiveness are strongly influenced by how citizens perceive access, participation, and fairness in urban systems. Based on the refined conceptual model, a structured questionnaire consisting of 46 items measured on a five-point Likert scale was developed. Face and content validity were assessed by five university faculty members and three experts in the field of smart cities, and the instrument was revised accordingly. Reliability and construct validity were confirmed through Cronbach's alpha (values above 0.88), composite reliability (CR>0.80), average variance extracted (AVE), and discriminant validity tests (Fornell–Larcker and HTMT), using SmartPLS 4.

4.1. Population and sampling

The statistical population of the study comprised all residents of Mashhad City, Iran. According to the latest national census (Statistical Center of Iran, 2016), the total population of Mashhad was estimated at 3,057,679 individuals. To determine the sample size, Cochran's formula was applied, assuming a confidence level of 95% and a margin of error of 5%, resulting in a required sample of 384 respondents. The sampling method followed a multi-stage cluster random sampling technique. Initially, the urban districts of Mashhad were stratified according to population size. Subsequently, a proportional allocation method was employed to ensure that the number of respondents selected from each district accurately reflected its share in the total population.

Random selection within each cluster guaranteed representativeness across the city's diverse spatial and socioeconomic contexts.

A summary of the sample distribution across Mashhad's municipal districts, proportionate to their population ratios, is presented in Table 1. Figure 1. Location of the Study Area: Showing the Thirteen Municipal Districts of Mashhad City within the Maps of Iran, Khorasan Razavi Province, and the County.

Table 1. Demographic characteristics of respondents

Sample Size	Percentage	Population	Mashhad's Regions
21	5.4%	167008	Region 1
65	16.8%	514411	Region 2
52	13.6%	417950	Region 3
33	8.6%	261938	Region 4
22	5.7%	175844	Region 5
29	7.6%	232609	Region 6
32	8.4%	256563	Region 7
11	2.9%	89216	Region 8
41	10.7%	327001	Region 9
37	9.7%	296832	Region 10
25	6.5%	200161	Region 11
14	3.6%	108869	Region 12
22	0.5%	13849	Region Samen
384	100%	3062242	Total

Source: Mashhad City Statistics, 2016 and author's calculations

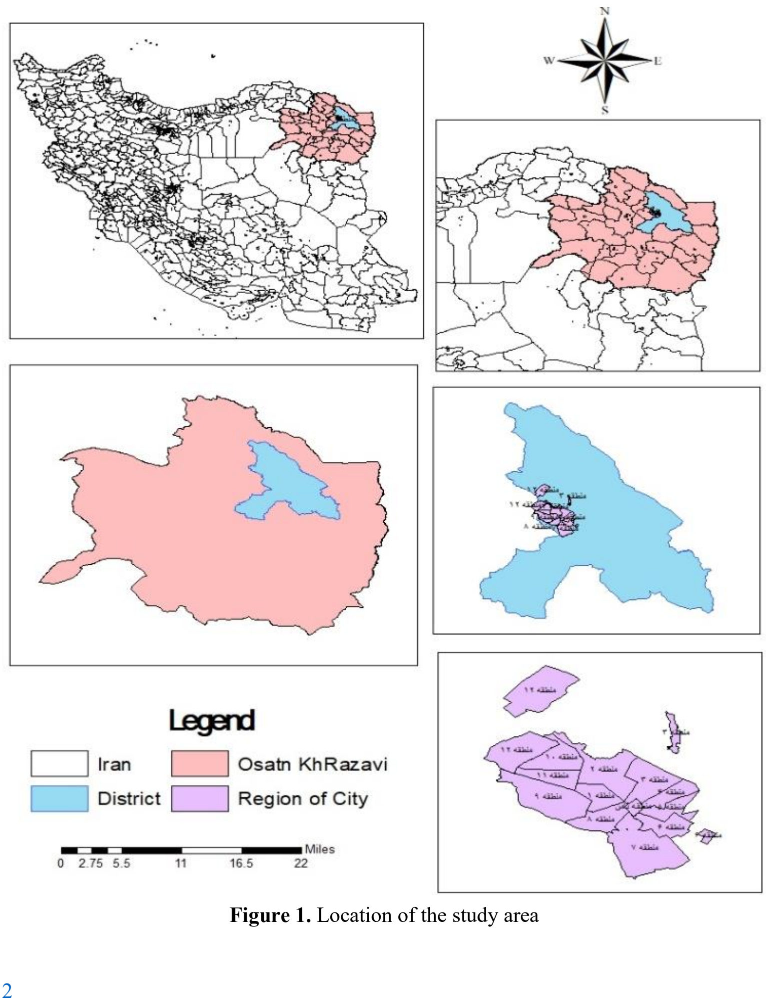

Figure 1. Location of the study area

10.57647/ccd.2026.0902.12

4.2. Structural and multi-Group analytical approach

To empirically test the conceptual model, Structural Equation Modeling (SEM) was employed to examine the relationships between six smart city dimensions smart governance, smart people, smart economy, smart environment, smart living, and smart mobility and multiple dimensions of urban justice (distributive, procedural, interactional, cognitive, and data justice). In addition, Multi-Group Analysis (MGA) was applied to compare these relationships across socio-spatial zones of Mashhad, categorized as affluent, middle-income, and deprived areas. In the absence of fine-grained objective spatial datasets (accessibility indicators),(Global Moran's I) was used as an analytical proxy to capture spatial differentiation and inequality patterns across urban areas. This approach allows for the identification of systematic differences in how smart city dimensions affect perceived urban justice among distinct socio-spatial groups, thereby providing meaningful spatial insight from a perception-based dataset.

4.3. Limitations and future research directions

While this study provides a robust perception-based analysis of the relationship between smart city development and urban justice, certain limitations should be acknowledged. The reliance on self-reported survey data may introduce subjective bias; however, this approach is theoretically justified given the study's focus on lived experiences of justice and inequality. Moreover, the use of advanced statistical techniques and multi-group comparisons enhances internal consistency and analytical rigor. Future research could strengthen and extend the present findings by integrating objective spatial indicators such as GIS-based accessibility measures, infrastructure distribution data, municipal performance indicators, or remote sensing data with perception-based models. Such mixed-data approaches would enable more comprehensive validation of justice-oriented smart city frameworks and support evidence-based urban policy-making in diverse socio-spatial contexts.

5. Findings

The demographic characteristics of the respondents are summarized in Table 1. Out of a total of 384 participants, 233 (60.7%) were male and 151 (39.3%) were female. The largest proportion of respondents belonged to the 28–32 age group (13.8%), while the lowest proportion was observed among individuals aged 62 years and above (5.2%). Overall, younger age groups (18–37 years) accounted for more than half of all participants, indicating that the sample mainly represents the views of younger citizens who are more engaged with technology and digital services. Regarding educational level, the majority of respondents held a bachelor's degree (35.2%), followed by master's degree holders (20.1%) and associate degree holders (15.9%). Only 4.7% of the participants had an education level below high school. In terms of employment, 239 respondents (62.2%) were employed in the private sector, while 145 respondents (37.8%) worked in the public sector. Concerning the length of residence, the largest share of respondents had lived in their current area for 10–15 years (29.9%), followed by those with 15–20 years (25%) and 5–10 years (24.7%) of residence. Additionally, 20.3% of participants had resided in their neighborhood for more than 20 years. This distribution indicates that a significant portion of respondents have long-term residence in their districts, suggesting that their perceptions of smart city and spatial justice indicators are grounded in a deep understanding of local urban dynamics and long-term changes (Table 2). The KMO value was 0.912, which, according to Kaiser's (1974) interpretation, indicates excellent sampling adequacy for factor analysis (KMO > 0.9 = excellent, 0.8–0.9 = good, < 0.5 = unacceptable). Bartlett's test of sphericity yielded $\chi^2 = 3845.27$, $p < 0.001$, indicating that the null hypothesis of equal correlation matrices is rejected. This confirms that there are sufficient correlations among variables to perform factor analysis and spatial clustering. Therefore, the data obtained from the questionnaire are suitable for further analysis.The reliability of the questionnaire was assessed using Cronbach's alpha, which yielded a value of 0.88 for the overall instrument, indicating high internal consistency. For content validity, the questionnaire was evaluated by experts in the field of urban geography and planning. To examine construct validity, exploratory factor analysis (EFA) was conducted to identify latent dimensions and extract the main components using Principal Component Analysis (PCA) with Varimax rotation. Six factors were extracted, explaining 72.4% of the total variance, indicating strong construct validity. For confirmatory factor analysis (CFA), the conceptual model fit and indicator validity were assessed using SmartPLS software.

Convergent validity was evaluated using Average Variance Extracted (AVE), Composite Reliability (CR), and Heterotrait-Monotrait ratio (HTMT). All indicators showed factor loadings above 0.8, and the model exhibited adequate goodness-of-fit, To assess the presence of common method bias, the full collinearity variance inflation factor (VIF) approach was employed. All VIF values are below the conservative threshold of 3.3, indicating that common method bias and multicollinearity are not critical concerns in this study. Therefore, the structural model results can be interpreted with confidence confirming the robustness and validity of the proposed measurement model (Table 4).Based on the values presented in Table 3, all indicators demonstrated adequate internal reliability and convergent validity, and therefore, no items were removed.

Figure 2 illustrates the measurement model of the study, which was generated using SmartPLS software.

Table 2. Demographic Characteristics of Respondents

Percentage Frequency	Frequency	Descriptive Characteristics		Percentage Frequency	Frequency	Descriptive Characteristics	
4.7%	18	Undergraduate		60.7%	333	Male	
15.1%	58	Diploma		39.3%	151	Female	Gender
15.9%	61	Associate Diploma		100%	384	Total	
35.2%	135	Bachelor's Degree	Education level	Percentage Frequency	Frequency	Descriptive Characteristics	
20.1%	77	Master's Degree		10.02%	39	18 to 22 years	
9.1%	35	Doctorate		12.2%	47	23 to 27 years	
100%	384	Total		13.8%	53	28 to 32 years	
Percentage Frequency	Frequency	Descriptive Characteristics		12.0%	46	33 to 37 years	
24.7%	95	5 to 10 years		10.7%	41	38 to 42 years	
29.9%	115	10 to 15 years		10.4%	40	43 to 47 years	Age
25.0%	96	15 to 20 years	Length of residence in the area	9.9%	38	48 to 52 years	
20.3%	78	More than 20 years		8.6%	33	53 to 57 years	
100%	384	Total		7.0%	27	58 to 62 years	
62.2%	239	Government	Employment status	5.2%	20	62 years and above	
37.8%	145	Free		100%	384	Total	

Table 3. Results of the KMO index and Bartlett test to ensure data adequacy

Interpretation	Significance level	Statistical value	Statistical indicator
High sample adequacy for factor analysis and cluster analysis	---	0.912	KMO Indicator
Significance of correlation between items (acceptability of analyses)	0.000	$\chi^2 = 3845.27$	Bartlett Test

Table 4. Convergent reliability results (CR and AVE)

Result	Average variance extracted (AVE)	Composite reliability (CR)	Factor loadings	Cronbach's alpha(α)	Number of items	Smart City Indicators
Stable and reliable	0.97	0.997	0.996-0.983	0.89	9	Smart Governance
Stable and reliable	0.83	0.973	0.965-0.875	0.87	8	Smart People
Stable and reliable	0.97	0.996	0.996-0.976	0.89	8	Smart Living
Stable and reliable	0.98	0.997	0.999-0.991	0.89	7	Smart Economy
Stable and reliable	0.98	0.998	0.998-0.991	0.88	8	Smart Environment
Stable and reliable	0.98	0.998	0.998-0.981	0.99	6	Smart Transportation
Stable and reliable	0.97	0.993	0.992-0.973	0.99	5 Justice dimension	Justice

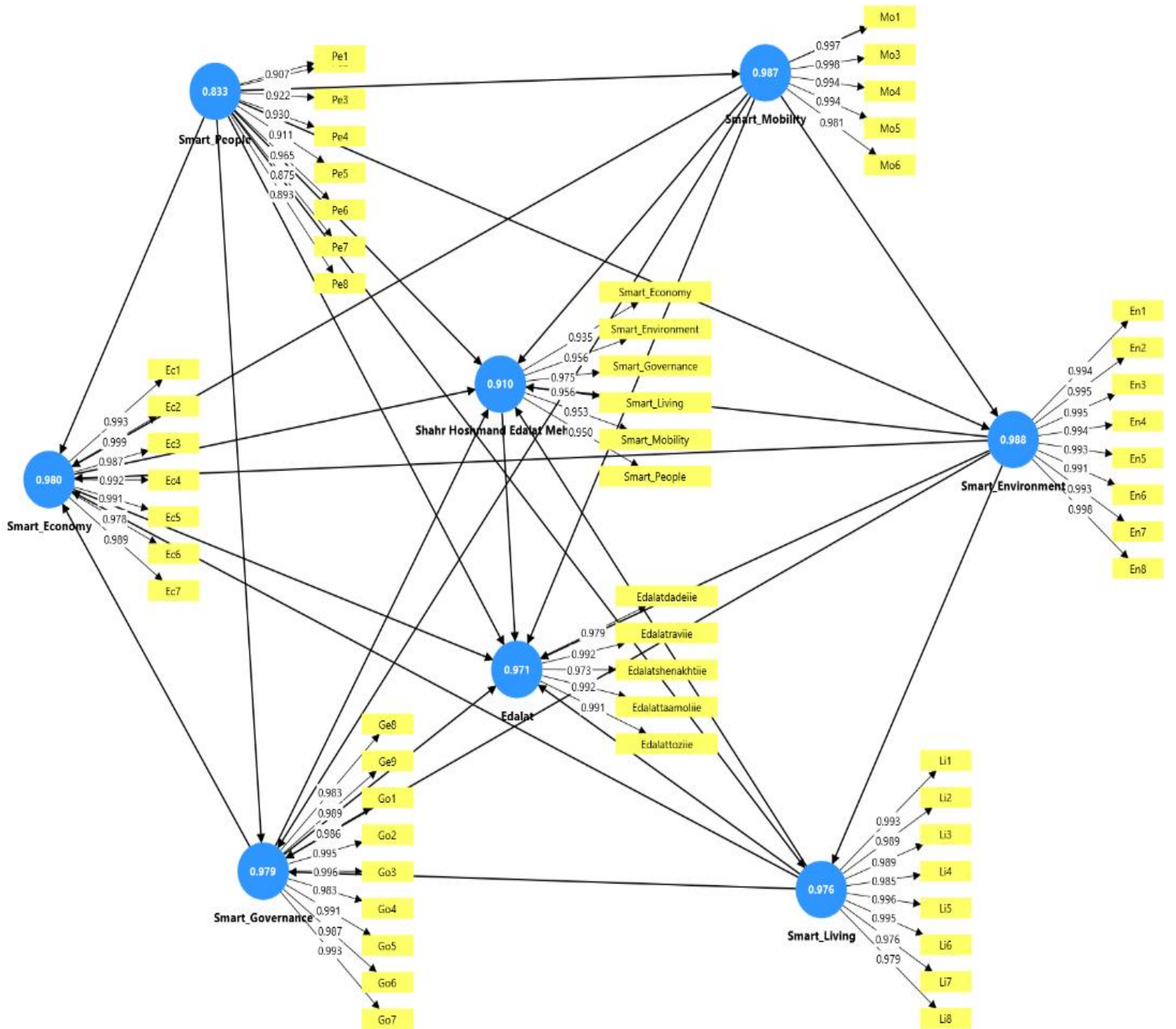

Figure 2. Research measurement model with factor loadings for each item using SmartPLS software

Discriminant validity assesses the degree to which constructs are distinct from one another and ensures that each indicator measures its intended construct rather than other constructs in the model. In the present study, discriminant validity was evaluated using two primary methods within SmartPLS:

(A): Fornell-Larcker Criterion: According to this approach, the square root of the Average Variance Extracted (AVE) for each construct should be greater than its correlations with other constructs. In the current measurement model, all diagonal values in the Fornell-Larcker matrix (i.e., the square roots of AVE) were greater than the corresponding inter-construct correlations, indicating satisfactory discriminant validity.

The results are presented in Table 5. These findings confirm that the measurement model is robust, and the constructs are adequately distinct, providing a strong foundation for subsequent structural equation modeling (SEM) and multi-group analysis (MGA).

(B): Discriminant Validity Using HTMT:In addition to the Fornell–Larcker criterion, Heterotrait–Monotrait (HTMT) ratio of correlations was employed to assess discriminant validity.

The HTMT values for all constructs were below 0.85, indicating adequate discriminant validity. Since both the Fornell–Larcker criterion and HTMT ratio
satisfy the required thresholds, it can be concluded that the designed questionnaire reliably and validly measures each construct, and no items need to be removed. Therefore, the discriminant validity of the measurement model in this study is confirmed, as shown in Table 6.

(C): Examining the absence of common method bias using the Full Collinearity VIF method, the value of this index for all research indicators is less than 3.3, indicating that common method bias and multiple collinearity in the model are at an acceptable level and the results of structural analyses have the necessary validity, the results of which are presented in the Table 7.

Table 5. Results of the Fresnel-Larker matrix for measuring the divergent validity of smart city indicators

Smart Transportation	Smart Environment	Smart Economy	Smart Living	Smart People	Smart Governance	Smart City Indicators
0.54	0.59	0.63	0.62	0.61	0.83	Smart Governance
0.52	0.57	0.65	0.59	0.80	0.61	Smart People
0.52	0.56	0.57	0.82	0.59	0.62	Smart Living
0.53	0.55	0.81	0.57	0.65	0.63	Smart Economy
0.51	0.80	0.55	0.56	0.57	0.59	Smart Environment
0.78	0.51	0.53	0.52	0.52	0.54	Smart Transportation

Table 6. Results of the heteromonocrite-monocrite correlation ratio index for measuring

Smart Transportation	Smart Environment	Smart Economy	Smart Living	Smart People	Smart Governance	Smart City Indicators
0.65	0.67	0.72	0.69	0.69	---	Smart Governance
0.63	0.66	0.74	0.68	---	0.69	Smart People
0.60	0.65	0.67	---	0.68	0.69	Smart Living
0.61	0.64	---	0.68	0.74	0.72	Smart Economy
0.59	---	0.64	0.65	0.66	0.67	Smart Environment
---	0.59	0.61	0.60	0.63	0.65	Smart Transportation

Table 7. Common Method Unbiased Results Using the VIF Method

Full Collinearity VIF	Smart City Indicators
2.67	Smart Governance
2.41	Smart People
2.36	Smart Living
1.98	Smart Economy
2.12	Smart Environment
1.74	Smart Transportation

After confirming the measurement model, the structural model was estimated to test the hypotheses and examine the relationships among latent variables using SmartPLS version 4.

Figure 3 illustrates the designed structural model along with the standardized path coefficients. In this model, the "Justice-Oriented Smart City" construct was considered as the dependent variable, while its six main dimensions Smart People, Smart Economy, Smart Governance, Smart Mobility, Smart Environment, and Smart Living along with their associated indicators, were treated as independent variables. The primary objective of this analysis was to assess the strength and direction of the effects of each smart city dimension in explaining the overall concept of a justice-oriented smart city in Mashhad and its contribution to achieving urban equity.

In SmartPLS, the bootstrapping method with 5,000 resamples was employed to estimate the significance of the path coefficients.

The path coefficients (β), t-statistics, and p-values were calculated to determine the impact of each smart city dimension on the overall model. The results are presented in Table 8.

The results indicated that among the six main smart city dimensions, "Smart Governance" had the highest direct effect on the realization of a justice-oriented smart city in Mashhad, with a path coefficient (β) = 0.33, t-value = 6.48, and p-value = 0.000.

This finding highlights that enhancing transparency, accountability, citizen participation, and the provision of e-services in urban management plays the most significant role in promoting spatial and social justice in the city.

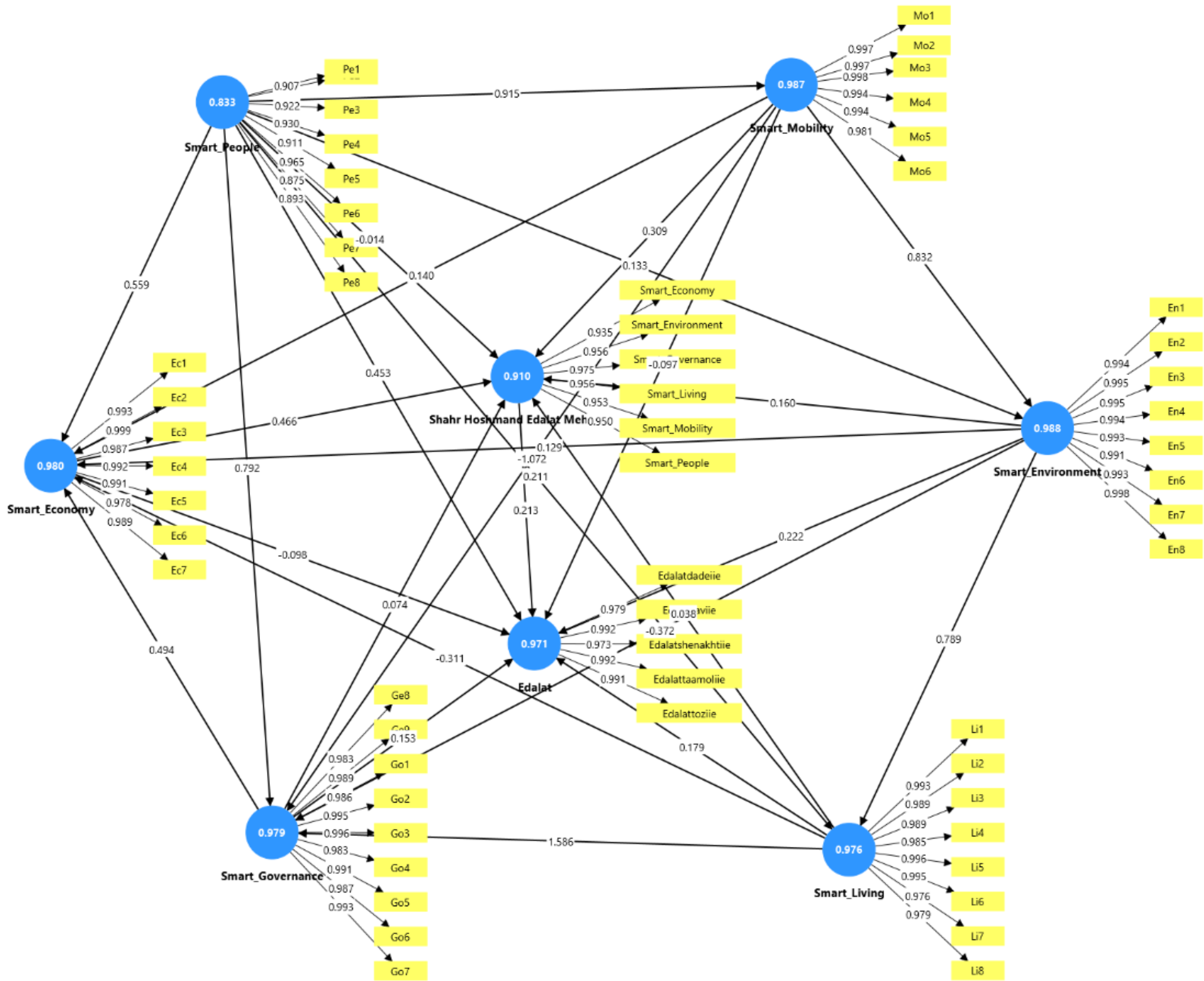

Figure 3. Structural model of the research with standardized path coefficients using SmartPLS software

Table 8. Estimation of significance of path coefficients (β) in Smart PLS software

Result	Significance Level (P-value)	Statistic Value (T)	Path Coefficient (β)	Path of Effect
Strongly significant	0.000	6.48	0.33	Governance → Overall Justice-Based Smart City Index
Strongly significant	0.000	5.87	0.30	People → Overall Justice-Based Smart City Index
Strongly significant	0.000	5.22	0.28	Life → Overall Justice-Based Smart City Index
Significant	0.000	4.91	0.24	Economy → Overall Justice-Based Smart City Index
Weakly significant	0.001	3.31	0.16	Environment → Overall Justice-Based Smart City Index
Weakly significant	0.016	2.42	0.12	Transportation → Overall Justice-Based Smart City Index

The second most influential dimension was "Smart People" with a path coefficient (β) = 0.30, indicating the importance of digital skills, civic education, cultural acceptance, and access to knowledge infrastructure in creating a just urban environment. This result aligns with the theories of Griffin (2022) and Cohen (2020), which emphasize the role of human capital and digital literacy in achieving urban justice.

The third influential component was “Smart Living” (β = 0.28), followed by “Smart Economy” (β = 0.24) and “Smart Environment” (β = 0.16), reflecting the positive impact of welfare services, social amenities, health, and urban environmental quality on citizen satisfaction and social justice. Finally, “Smart Mobility” had the lowest path coefficient (β = 0.12), but remained statistically significant ($p < 0.05$) (Table 9). This suggests that despite ongoing efforts in public transport development and traffic smartification in Mashhad, this sector has not yet reached full maturity and requires further investment to achieve equitable access and mobility justice.

The structural model fit indices were computed as follows:

Table 9. Model Fit Indices using SmartPLS

Result	Optimal Limit	Obtained Value	Fit Index
Good fit	≥0.08	0.048	Standardized root mean square residual SRMR
Excellent fit	≤0.90	0.93	Normalized fit index NFI
Strong model	≤0.5	0.72	Coefficient of determination of the model R2
Decent/adequate prediction	>0	0.41	Predictive validity index Q2
Strong overall model fit	>0.36	0.59	Goodness of fit index GOF
Moderate to large effect	≤0.02	0.38-0.15	Effect size f2

The results of the structural model analysis indicated that all causal paths between variables were statistically significant, and the path coefficients were positive. This implies that strengthening each dimension of the smart city contributes to the enhancement of urban justice. From a statistical perspective, the coefficient of determination (R^2) for the justice-oriented smart city variable was calculated as 0.72, indicating that approximately 72% of the variance in the dependent variable is explained by the six main dimensions of the smart city. This value demonstrates a strong fit of the structural model. Moreover, the Standardized Root Mean Square Residual (SRMR = 0.048) fell within the acceptable range (less than 0.08), confirming the overall goodness-of-fit of the model. Overall , the SmartPLS structural model results reveal that: Smart Governance has the highest impact on urban justice. Human capital and the competencies of smart citizens play a complementary role in enhancing justice. Other dimensions, such as Smart Economy, Smart Living, and Smart Environment, also contribute to improving quality of life and spatial justice at varying levels. The final research model, validated with strong fit indices, provides a reliable basis for urban policy-making and can guide the roadmap for developing a justice-oriented smart city.

5.1. Multi-group analysis (MGA) in smartPLS

After validating the measurement and structural models using Smart PLS 4, Multi-Group Analysis (MGA) was conducted to examine whether significant differences exist in the relationships between the six dimensions of smart cities and urban justice across different regions of Mashhad. This method is employed when the researcher seeks to assess the stability of the structural model among different subgroups. In other words, the purpose of the MGA in this study was to evaluate differences in the relationships between smart city dimensions and urban justice across three levels of regional development within Mashhad.

In this study, to conduct Multi-Group Analysis (MGA), the urban districts of Mashhad were classified into three groups Well advantaged, moderately-advantaged, and Less-advantaged based on a composite smart city justice-oriented index. This index was calculated by aggregating the mean scores of the six core dimensions of the smart city framework. Subsequently, using the statistical distribution of the composite index values and applying a tertile-based classification approach, the districts were systematically categorized into three levels of urban advantage. This data-driven and distribution-based grouping strategy enabled a meaningful comparison of structural relationships among smart city dimensions across different levels of spatial advantage. To perform the analysis, the regions of Mashhad were categorized based on their development levels according to the six smart city dimensions and the results obtained from previous analyses into three groups:

- Well - advantaged regions: 5, 9, 10
- Moderately-advantaged regions: 1, 2, 4, 6, 11, 12
- Less-advantaged regions: 3, 7, 8, Samen

The results of the MGA, showing potential differences in path relationships among the three levels of regional development, are presented in Table 10. Figures 4 through 9 illustrate the status analysis of the thirteen regions of Mashhad city in terms of the Smart City indicators, based on the Multiple Group Analysis (MGA).

Table10. Results of multi-group analysis (MGA) between the three levels of wealth in Mashhad city regions

Result	Moderate-Less-advantaged	Well-advantaged-moderate difference	Well-advantaged - Less-advantaged	Less-advantaged (β)	Moderate (β)	Well-advantaged (β)	Structural Path
The difference between all regions is highly significant	0.13 *(p=0.02)	0.09 *(p=0.04)	0.22 *(p=0.001)	0.23	0.36	0.45	Governance → Urban Justice
The difference between the rich and the poor is significant	0.08 (Ns)	0.05 (Ns)	0.13 *(p=0.02)	0.25	0.33	0.38	Individuals → Urban Justice
The difference between the rich and the poor is significant	0.06 (Ns)	0.04 (Ns)	0.10 *(p=0.04)	0.27	0.33	0.37	Life → Urban Justice
The difference is not significant	0.03 (Ns)	0.05 (Ns)	0.08 (Ns)	0.26	0.29	0.34	Economy → Urban Justice
The difference is not significant	0.04 (Ns)	0.03 (Ns)	0.07 (Ns)	0.23	0.27	0.30	Environment → Urban Justice
The difference between all regions is highly significant	0.14 *(p=0.04)	0.08 *(p=0.05)	0.22 *(p=0.003)	0.17	0.31	0.39	Transportation → Urban Justice

*Significant at the P-value level of 0.05, Ns=no significance

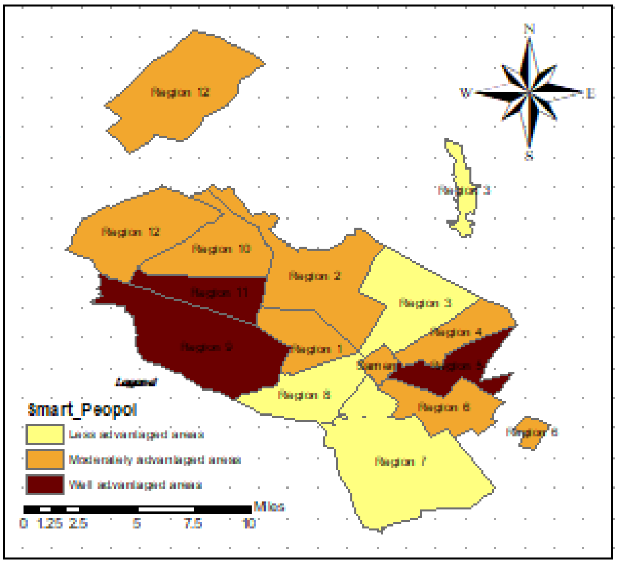

Figure 4. Analysis of the status of the thirteen regions of Mashhad city in terms of Smart People Indicators

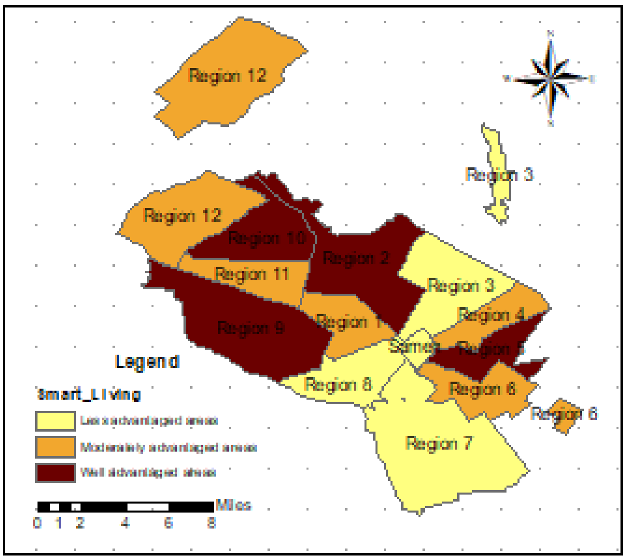

Figure 5. Analysis of the status of the thirteen regions of Mashhad city in terms of Smart Living Indicators

10.57647/ccd.2026.0902.12

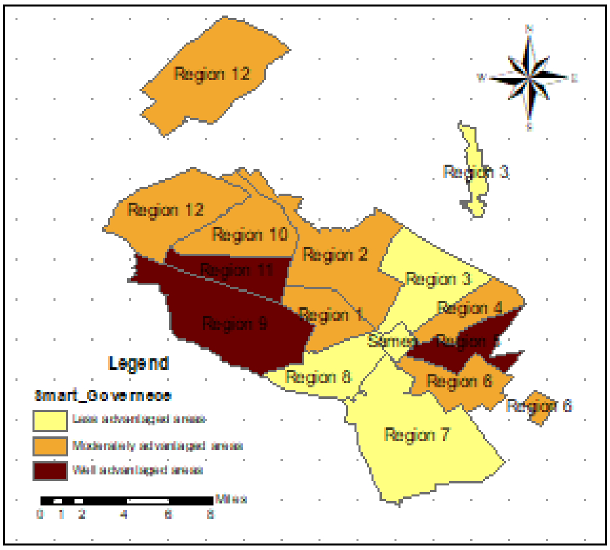

Figure 6. Analysis of the status of the thirteen regions of Mashhad city in terms of Smart Governece Indicators

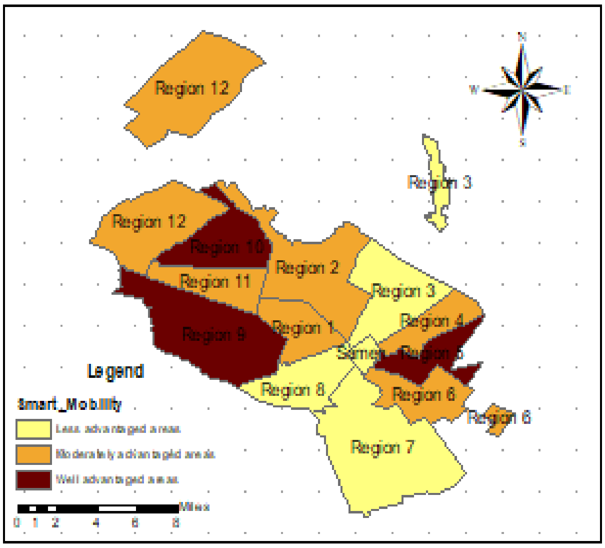

Figure 7. Analysis of the status of the thirteen regions of Mashhad city in terms of Smart Mobility Indicators

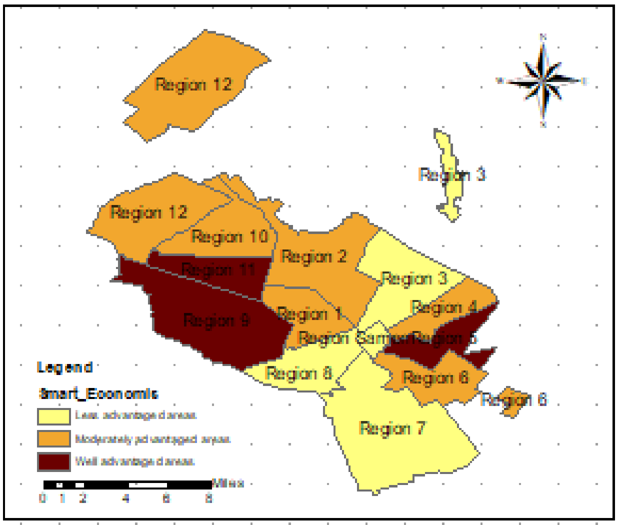

Figure 8. Analysis of the status of the thirteen regions of Mashhad city in terms of Smart Economic Indicators

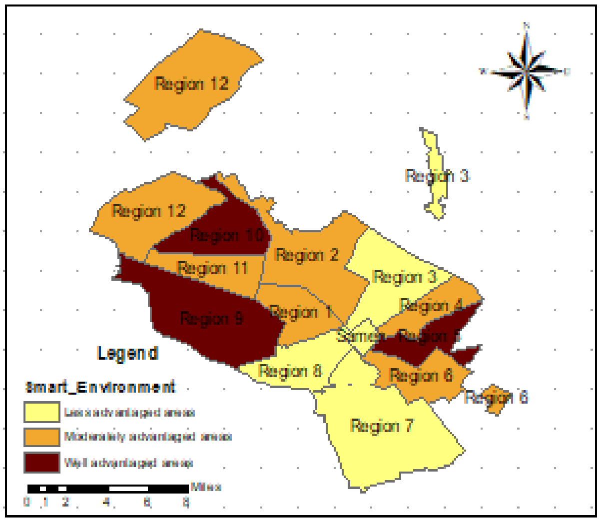

Figure 9. Analysis of the status of the thirteen regions of Mashhad city in terms of Smart Environment Indicators

The results of the Multi-Group Analysis (MGA) indicated that the pattern of the effects of smart city dimensions on urban justice significantly differed across highly advantaged, moderately advantaged, and underprivileged areas of Mashhad. Specifically, three dimensions, namely "Smart Governance," "Smart Mobility," and "Smart Living," exhibited significant differences between the three levels of area affluence, whereas the dimensions "Smart Economy" and "Smart Environment" showed no significant variation across groups. Additionally, the "Smart People" dimension demonstrated a significant difference between highly advantaged and underprivileged areas, while no notable difference was observed in other groups.

The most pronounced variation among the three groups was observed in Smart Governance. In highly advantaged areas, Smart Governance had a substantial effect on achieving urban justice (β = 0.45), whereas this effect decreased to β = 0.23 in underprivileged areas. This indicates inequities in the distribution of citizen participation opportunities, administrative transparency, and institutional accountability, highlighting that more effective municipal performance in advantaged areas enhances citizens' satisfaction and perceived justice. The significance levels across all comparisons ($P<0.05$) confirm these differences.

The Smart People dimension also exerted a stronger influence on urban justice in advantaged areas (β = 0.38) compared to underprivileged areas (β = 0.25). This finding underscores the critical role of educated human capital, digital skills, and social awareness in promoting urban justice in advantaged districts. In other words, enhancing education, access to technology, and social participation in these areas facilitates socio-cultural equity.The Smart Living dimension, encompassing quality of services, security, health, and citizens' welfare, showed higher influence on urban justice in advantaged areas (β = 0.37) compared to underprivileged areas (β = 0.27). This suggests that residents in advantaged areas enjoy higher levels of social welfare, healthcare services, and public facilities, contributing to a greater sense of spatial justice.

The Smart Economy dimension did not exhibit significant differences across the three area groups, indicating that economic policies in Mashhad such as support for startups, access to financing, and promotion of technology-driven employment are implemented relatively uniformly citywide. Nevertheless, higher path coefficients in advantaged areas (β = 0.34) reflect better economic infrastructure in these districts.

The Smart Mobility dimension showed notable disparities between areas, with path coefficients of β = 0.39 in advantaged areas and β = 0.17 in underprivileged areas. This result demonstrates that access to public transport infrastructure and intelligent traffic management systems is significantly weaker in underprivileged districts, whereas in advantaged areas, such services contribute to enhanced spatial justice.

Finally, the Smart Environment dimension did not show significant differences across any of the groups ($P > 0.05$), indicating that environmental policies in Mashhad such as waste management, green space development, and air pollution control are implemented relatively evenly across all areas.

5.2. Global Moran's I spatial autocorrelation analysis

In urban studies particularly in the assessment of smart city indicators understanding the spatial structure and distributional patterns of these indicators across urban areas is essential. Smart city dimensions such as smart economy, smart people, smart governance, smart mobility, smart environment, and smart living are rarely distributed evenly in space; instead, they exhibit significant spatial disparities driven by socioeconomic, infrastructural, and institutional conditions.

To capture and quantify these spatial dependencies, the Global Moran's I spatial autocorrelation statistic serves as a fundamental analytical tool. It measures the degree to which similar or dissimilar values of a given variable are clustered or dispersed across neighboring spatial units. In other words, it evaluates whether high or low values of an indicator tend to occur near each other, thereby revealing spatial clustering, randomness, or dispersion patterns.

The use of Global Moran's I in this research is justified on several methodological and conceptual grounds:

1. Detection of spatial patterns:

Global Moran's I enables the identification of spatial clusters or outliers of smart city indicators, providing insights into whether urban smartness exhibits localized concentrations or random distributions.

2. Assessment of spatial inequality and justice:

As spatial justice represents a core dimension of equitable smart cities, Global Moran's I helps to reveal areas of spatial concentration or deprivation in smartness levels, thereby linking spatial analytics to distributive urban equity.

3. Evidence-based policy formulation:

Employing Global Moran's I allows urban decision-makers to ground their interpretations and policy responses in empirical spatial evidence, enhancing the precision and legitimacy of spatially targeted interventions.

Accordingly, Global Moran's I is applied in this study not merely as a descriptive measure, but as an inferential tool to examine the spatial interrelationships among the aggregated smart city indicators across Mashhad's administrative districts.

By detecting the existence and strength of spatial autocorrelation, this analysis provides a basis for identifying spatial inequalities, guiding resource allocation, and promoting balanced smart urban development toward spatial justice. The results of Moran's autocorrelation analysis are presented in Table 11.

The results of the Global Moran's I spatial autocorrelation test indicate that the Smart Governance indicator, with a Global Moran's I value of 0.421 and a significance level of 0.003, follows a statistically significant clustered spatial pattern. Similarly, the Smart People indicator (Global Moran's I = 0.312, p = 0.014) and the Smart Mobility indicator (Global Moran's I = 0.355, p = 0.007) also exhibit positive and statistically significant spatial clustering across the urban districts of Mashhad.

Table 11. Results of Global Moran's I Spatial Autocorrelation Analysis

Type	P-value	Z-Score	Morans I	Smart City Indicators
Clusterd	0.003	3.02	0.421	Smart Governance
Clusterd	0.014	2.45	0.312	Smart People
Clusterd	0.052*	1.95	0.189	Smart Living
Random	0.261	1.12	0.098	Smart Economy
Dispersed	0.041	2.05-	0.215-	Smart Environment
Clusterd	0.007	2.73	0.355	Smart Transportation

* Almost significant

In contrast, the Smart Environment indicator shows a negative and statistically significant Global Moran's I value (−0.215, $p = 0.041$), indicating a spatially dispersed and heterogeneous pattern. This suggests that districts with high and low environmental performance are located in close proximity, and no coherent clustered spatial structure is observed. Overall, these findings demonstrate that the different dimensions of smart urban development in Mashhad do not follow uniform spatial patterns. Rather, they reveal the presence of statistically significant spatial inequalities in the distribution of smart city indicators across urban districts. This underscores the necessity of explicitly incorporating spatial justice considerations into smart city policies and urban planning strategies.

6. General conclusion

The results of this study indicate that the achievement of spatial justice in smart cities is not a purely technological outcome but a complex, multidimensional, and context-sensitive process shaped by institutional arrangements, social capacities, and spatial structures. The empirical findings derived from structural equation modeling reveal that »smart governance« constitutes the most influential dimension in promoting spatial justice in Mashhad. This finding can be theoretically grounded in Harvey's conception of spatial justice, which emphasizes that urban justice emerges primarily through the redistribution of power, transparency in decision-making, and equitable access to institutional resources rather than through technological provision alone. In this regard, smart governance through improved data transparency, institutional accountability, and participatory digital mechanisms functions as a corrective instrument for historically embedded spatial inequalities. The multi-group analysis further demonstrates that the effects of smart city dimensions on spatial justice are spatially differentiated across Mashhad's urban fabric. In relatively affluent districts, smart governance, smart mobility, and smart living exhibit stronger and more consistent relationships with justice-oriented outcomes. Conversely, in less privileged areas, infrastructural inadequacies, limited digital access, and weaker local governance capacities substantially attenuate these relationships. These findings resonate with Soja's notion of spatial justice as an evolving socio-spatial process, wherein contemporary inequalities are deeply rooted in long-standing patterns of uneven development and institutional asymmetry. The significance of the «smart people» dimension underscores the central role of human capital in justice-oriented smart city development. Beyond technical skills, this dimension reflects citizens' digital literacy, data awareness, and capacity to actively participate in data-driven urban governance. From a data justice perspective, the results indicate that digital inequality in Mashhad extends beyond disparities in technological access to include unequal opportunities for data production, interpretation, and utilization. Such inequalities, particularly pronounced in disadvantaged neighborhoods, contribute to the reproduction of socio-spatial injustice within smart urban systems.

In contrast, the relatively weaker impact of the «smart environment» dimension reveals a critical gap in the alignment of environmental sustainability with spatial justice objectives.

When environmental smartness is implemented without explicit attention to equity, it risks reinforcing uneven urban development and excluding marginalized areas from the benefits of sustainable urban transformation. Accordingly, environmental initiatives can contribute to spatial justice only when they are deliberately designed to enhance environmental quality and urban livability in underprivileged districts.

Overall, this study demonstrates that a justice-oriented smart city is not the outcome of technological advancement alone, but the product of an integrated interplay between smart governance, empowered human capital, equitable service provision, and spatially sensitive policymaking.

The findings provide empirical support for critical theories of spatial and data justice and highlight that smart city initiatives, if detached from distributive, procedural, and data equity considerations, may inadvertently reproduce existing urban inequalities. The smart urban transformation of Mashhad thus remains incomplete, underscoring the necessity of targeted, inclusive, and data-driven policy interventions, particularly in less advantaged areas. Beyond the local context, this research offers a transferable analytical framework for metropolitan regions in developing countries seeking to reconcile smart city development with the principles of spatial justice and sustainable urban governance.

7. Policy implications and practical recommendations

Based on the empirical results derived from the structural equation modeling, multi-group analysis, and Global Moran's I Spatial Autocorrelation Analysis, the following evidence-based recommendations are proposed for urban managers, planners, and policymakers in Mashhad.

These recommendations are explicitly grounded in the statistically significant relationships identified in the model and aim to translate quantitative findings into actionable urban policies.

- Prioritizing Smart Governance as a Justice-Oriented Policy Lever

The SEM results demonstrated that smart governance exerts the strongest and most consistent effect on spatial justice across all urban zones. This finding empirically confirms that governance-related mechanisms rather than purely technological factors play a decisive role in reducing spatial inequalities.

Accordingly, urban policy interventions in Mashhad should prioritize governance reforms that enhance institutional transparency, data openness, and citizen participation, particularly through digital governance platforms. Strengthening accountability mechanisms and participatory decision-making processes is likely to generate the greatest marginal gains in spatial justice outcomes.

- Targeted Interventions in Less-Advantaged Districts Based on MGA Findings

The multi-group analysis revealed statistically significant differences in the effects of smart city dimensions between affluent, middle-income, and deprived areas. Specifically, the influence of smart governance and smart living on spatial justice was substantially weaker in less-advantaged districts. This empirical asymmetry indicates that uniform smart city policies may unintentionally reinforce existing inequalities. Therefore, policymakers should adopt spatially differentiated strategies, allocating greater institutional, digital, and infrastructural resources to peripheral neighborhoods where governance capacity and service accessibility are structurally constrained.

- Reframing Smart Environment Policies Through a Justice Lens

The smart environment dimension exhibited the weakest direct effect on spatial justice in the SEM results, suggesting that environmental smartness alone does not automatically translate into equitable urban outcomes. This finding implies that environmental initiatives in Mashhad may currently be implemented without sufficient attention to distributive equity. Urban managers should therefore redesign smart environmental policies such as green infrastructure, intelligent energy systems, and environmental monitoring technologies by explicitly targeting underserved areas.

Aligning environmental sustainability initiatives with spatial justice objectives can prevent the selective concentration of environmental benefits in already advantaged districts.

- Evidence-Based Urban Data Governance Linked to Governance Effects

Although urban data platforms were not modeled as an independent construct, the strong effect of smart governance on spatial justice indirectly underscores the importance of data transparency and evidence-based decision-making.

The results suggest that governance effectiveness is enhanced when reliable, accessible, and interpretable data support policy formulation. Consequently, developing integrated urban data systems should be viewed not as a generic smart city aspiration but as a functional mechanism for strengthening governance capacity, reducing informational asymmetries, and improving justice-oriented outcomes.

- Strengthening Institutional Coordination to Reduce Governance Asymmetries

The observed spatial unevenness in governance effects highlights disparities not only in physical infrastructure but also in institutional coordination and administrative capacity across Mashhad. This finding implies that fragmented governance structures weaken the justice potential of smart city initiatives. Therefore, fostering cross-sectoral coordination among municipal departments, technology providers, and community-based organizations is essential to translating smart city investments into equitable outcomes. Institutional integration should be prioritized in districts where governance-related effects were empirically shown to be weakest.

Authors Contribution

All authors contributed to the conceptualization and design of the study. Dr. K. Alizadeh and H. Jafari were primarily involved in the interpretation of the results and the critical review of the intellectual content of the paper. J. Mohammadzadeh Alavardikhani was responsible for data collection, data analysis, and drafting the initial and final versions of the manuscript. Finally, all authors reviewed, revised, and approved the final version of the manuscript for submission.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of interests

The author states that there is no conflict of interest.

References

[1] United Nations Department of Economic and Social Affairs, Goal 11 Make Cities and Human Settlements Inclusive, Safe, Resilient and Sustainable.(2022). https://sdgs.un.org/goals/goal11

[2] Bibri SE, Krogstie J. Smart sustainable cities of the future: An extensive interdisciplinary literature

review. Sustainable cities and society. 2017 May 1;31:183-212. https://doi.org/10.1016/j.scs.2017.02.016#

[3] Komninos N. Smart Cities and Connected Intelligence: Platforms, ecosystems and network effects. Routledge; 2019 Dec 5. https://doi.org/10.4324/9780429268197#

[4] Taylor L. What is data justice? The case for connecting digital rights and freedoms globally. Big Data & Society. 2017 Oct;4(2):2053951717736335. https://doi.org/10.1177/2053951717736335#

[5] Dadashpour, H., & Alvandi-Pour, N. Review of research related to spatial justice in Iran at the urban scale (2004–2015). Urban Ecology Research Journal, (2018). 9(2), 61–86. https://grup.journals.pnu.ac.ir/article_4456.htm#

[6] Dadashpour, H., & Alvandi-Pour, N. Spatial justice at the urban scale in Iran: A meta-study of theoretical frameworks in the existing literature. Journal of Fine Arts: Architecture and Urbanism, (2016). 21(3), 67–80. https://doi.org/10.22059/jfaup.2016.61103#

[7] Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanović, N., & Meijers, E. Smart cities – Ranking of European medium-sized cities (Final report). Centre of Regional Science, Vienna University of Technology (2007). http://www.smartcities.eu/download/city_ranking_final.pdf#

[8] Albino, V., Berardi, U., & Dangelico, R. M. Smart cities: Definitions, dimensions, performance, and initiatives. Journal of Urban Technology, (2015). 22(1), 3–21. https://doi.org/10.1080/10630732.2014.942092#

[9] Kitchin, R. The real-time city? Big data and smart urbanism. GeoJournal, (2014).79(1), 1–14. https://doi.org/10.1007/s10708-013-9516-8#

[10] Shelton, T., Zook, M., & Wiig, AThe “actually existing smart city”. Cambridge Journal of Regions, Economy and Society, . (2015). 8(1), 13–25. https://doi.org/10.1093/cjres/rsu026#

[11] Gracias, J. S., Parnell, G. S., Specking, E., Pohl, E. A., & Buchanan, R. Smart cities—a structured literature review. Smart Cities, . (2023). 6(4), 1719-1743. https://doi.org/10.3390/smartcities6040080#

[12] Khamsi, A. Green book: A practical guide for municipalities, smart cities. Center for Urban and Rural Planning Studies. (2021). https://urbanism.blogsky.com/1392/02/24/post-83/#

[13] Caragliu, A., Del Bo, C., & Nijkamp, P. Smart cities in Europe. Journal of Urban Technology, (2011). 18(2), 65–82. https://doi.org/10.1080/10630732.2011.601117#

[14] Soja, E. W. Seeking spatial justice. University of Minnesota Press. Yigitcanlar, T., & Kamruzzaman, M. (2018). Does smart city policy lead to sustainability of cities? Land Use Policy, (2018). 73, 49-58. https://doi.org/10.1016/j.landusepol.2018.01.034#

[15] Ullah, A., Anwar, S. M., Li, J., Nadeem, L., Mahmood, T., Rehman, A., & Saba, T. Smart cities: The role of Internet of Things and machine learning in realizing a data-centric smart environment. Complex & Intelligent Systems, . (2024). 10(1), 1607-1637. https://doi.org/10.1007/s40747-023-01175-4#

[16] Nurbatsin, A., Kireyeva, A., Gamidullaeva, L. & Abdykadyr, T. Spatial analysis and technological influences on smart city development in Kazakhstan. Journal of Infrastructure, Policy and Development, (2024). 8(2), 3012-3124. https://doi.org/10.24294/jipd.v8i2.3012#

[17] Ye, X., Newman, G., Lee, C., Van Zandt, S., & Jourdan, D. (2023). Toward Urban artificial intelligence for developing justice-oriented smart cities. Journal of Planning Education and Research, 43(1), 6-7. https://theses.lib.polyu.edu.hk/handle/200/11165

[18] Pourahmad, A., Zangeneh-Sagharaki, S., & Saberi, A. Spatial justice analysis in access to urban services: A case study of Yasuj city. Geography & Development, (2023). 21(71), 1–32. https://doi.org/10.22111/GDIJ.2023.7588#

[19] Rezapour Ghatbi, K., Ezzatpanah, B., & Bigh Babaei, B. Assessing the feasibility of smart city indicators in accordance with contemporary urban fabric in Iranian cities: A case study of Babol. Geographical Spatial Planning, (2022). 13(2), 71–90. https://doi.org/10.30488/GPS.2023.375355.3602#

[20] Namdar Ardakani, M. J., Shokoor, K., & Bakht, A. A. City and spatial justice: An analysis of the distribution of sustainable development indicators in the spatial justice of Shiraz city. Geography and Urban & Regional Studies, (2022). 11(43), 142–160. https://doi.org/10.1001.1.20087845.1401.11.43.9#

[21] Harvey, D. Social justice and the city. Johns Hopkins University Press. Hosseini(2009). https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Social+justice+and+the+city.+Johns+Hopkins+University+Press.+Hosseini+&btnG=#