Smart City Insights

www.sci.reapress.com

Smart City Ins. Vol. 3, No. 1 (2026) 16–24.

Paper Type: Original Article

Application of Artificial Intelligence in Neighborhood-Based Planning: A Case Study of Marvdasht City Neighborhoods

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Citation:

Received: 14 January 2025 *Revised: 8 February 2025* *Accepted: 13 June 2025*	Sharafi, H., Ahmadi, M., & Ghanezadeh, H. (2026). Application of artificial intelligence in neighborhood-based planning: A case study of Marvdasht city neighborhoods. *Smart City Insights, 3*(1), 16-24.

Abstract

The escalating growth of urbanization and the increasing complexity of urban issues have made the utilization of novel analytical tools in the urban planning process inevitable. Among these, Artificial Intelligence (AI), as an emerging paradigm, possesses remarkable capabilities in analyzing complex spatial patterns and identifying inequalities in the distribution of urban services. This study aims to investigate these capacities in neighborhood-based planning, focusing on the neighborhoods of Marvdasht city. The core issue is the inefficiency of traditional methods in analyzing the imbalance between population density and service accessibility. The research employs a descriptive-analytical approach based on intelligent modeling (the K-Means++algorithm). Findings indicate a significant gap between high population density in peripheral neighborhoods and the level of provided services. The results of AI optimization models suggest the potential to reduce this gap by 45% over a five-year period. This study concludes that AI is not merely a tool for analyzing the status quo; rather, through scenario planning and intervention prioritization, it provides an efficient platform for transitioning from static to dynamic and justice-oriented planning. Utilizing such systems is a fundamental strategy for enhancing spatial justice in the neighborhood-based management of Marvdasht.

Keywords: Artificial intelligence, Spatial inequality, Urban justice, Marvdasht, Neighborhood-based planning, Intelligent modeling.

1 | Introduction

In recent decades, the rapid growth of urbanization and the increasing complexity of urban issues have heightened the necessity of utilizing novel analytical tools in urban planning. One of the most significant emerging approaches in this field is the use of Artificial Intelligence (AI) to analyze spatial patterns, identify

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inequalities in the distribution of urban services, and support neighborhood-based decision-making. The application of AI in urban analyses has opened new horizons for neighborhood-based planning and the equitable assessment of urban service distribution. By processing massive volumes of spatial and social data, this technology enables the identification of spatial inequality patterns at the neighborhood level, helping urban planners more accurately detect existing gaps in service access. In cities like Marvdasht, where spatial disparities among neighborhoods can significantly impact residents' quality of life, leveraging AI can provide a scientific basis for targeted decision-making, a more balanced distribution of facilities, and the promotion of spatial justice in urban development.

Urban planning has undergone significant transformations under the influence of technological innovations, becoming heavily reliant on data-driven strategies. As an advanced technology, AI has the capacity to drive profound changes in the realm of urban planning. Today, this technology enables urban planners to identify patterns and trends in citizens' behavior and the urban development process using big data [1]. With the aid of AI, societal needs and desires can be better understood, allowing for the formulation of programs that align with citizens' expectations. AI can enhance transparency, accountability, and public trust in urban decision-making, ultimately leading to smarter and more sustainable cities [2].

The city, as a complex system, comprises various elements and is in constant interaction with them. This system is subdivided into smaller units known as neighborhoods. In the current paradigm of urban planning and management, participatory strategies and bottom-up planning approaches have gradually gained consensus among urban planners and managers [3]. A neighborhood, as a physical and social entity, possesses the capacity for collective action and social organization, providing suitable conditions to enhance public participation and harness collective power [4]. The rapid acceleration of urbanization in recent decades has created numerous challenges in urban management and planning. One of these fundamental challenges is the unequal distribution of urban services at various levels, particularly at the neighborhood scale. This spatial inequality can lead to socio-economic divides, reduced quality of life for residents in deprived areas, and an intensified sense of injustice. Marvdasht, as a developing city, faces this phenomenon, with observable disparities in access to essential services such as healthcare, education, transportation, green spaces, and cultural-recreational facilities across its different neighborhoods. Traditional approaches in urban planning have often been limited in accurately identifying and quantifying these inequalities and providing effective, neighborhood-based solutions. However, the emergence and development of new technologies, particularly AI, have opened new horizons in this regard. With its ability to analyze massive volumes of spatial, demographic, economic, and social data, AI can identify and predict complex patterns of spatial inequality with unprecedented accuracy.

AI refers to the intelligence demonstrated by machines, in contrast to natural intelligence, which is exhibited by humans and other animals. AI is executed using an intelligent agent, which refers to any device or algorithm that perceives its environment and takes actions that maximize its chances of achieving its goals [2]. AI is the intelligence manifested by machines, as opposed to the natural intelligence displayed by humans [5]. This capability provides urban planners with a powerful tool to better understand the actual needs of neighborhoods, design and implement more targeted interventions, and ultimately advance toward spatial justice and sustainable urban development. This research aims to focus on the application of AI in analyzing spatial inequality in urban services within the neighborhoods of Marvdasht, seeking a deeper understanding of this phenomenon and proposing technology-based solutions to improve the current situation. The unequal distribution of urban services not only directly affects citizens' welfare and quality of life but can also pave the way for social, economic, and security issues in less privileged areas. In growing cities like Marvdasht, these gaps can widen, posing serious challenges to the urban development process. The necessity of this research can be examined from several perspectives:

Impact on quality of life: Unequal access to urban services directly affects the health, education, employment opportunities, and overall life satisfaction of residents in different neighborhoods. Identifying these inequalities is vital for addressing shortcomings and improving living standards.

Promoting spatial justice: Achieving spatial justice is a key objective of sustainable urban planning. By providing tools to measure and analyze inequalities, this research helps planners realize a fairer distribution of resources and services across the city.

Application of modern approaches: Given the increasing complexity of urban issues, relying solely on traditional methods is no longer sufficient. Utilizing AI as an advanced technology offers an innovative approach to tackling these challenges, holding high potential for enhancing the effectiveness of urban planning.

Providing neighborhood-based solutions: Focusing on the neighborhood level allows for more precise solutions tailored to the specific needs of each area. AI can contribute to a deeper understanding of each neighborhood's needs by analyzing micro-scale data.

Optimal resource management: By accurately identifying areas in need, limited urban resources can be allocated more optimally, preventing the waste of capital in areas with lower service demands. Assisting Urban Managers in Decision-Making: The findings of this research can serve as a scientific, data-driven foundation for managers and planners in Marvdasht to prioritize projects and allocate budgets. The overarching goal of the present research is to investigate the role and function of AI in identifying and analyzing spatial inequality in the distribution of urban services in the neighborhoods of Marvdasht. This study seeks to explore the dimensions of this inequality and pave the way for providing solutions based on new technologies and intelligent analyses. In this regard, the main hypothesis of the research is based on the premise that utilizing AI algorithms in analyzing spatial and social data provides the possibility of more accurate, in-depth, and comprehensive identification of spatial inequality in the distribution of urban services in Marvdasht's neighborhoods compared to traditional methods. Accordingly, the main research question is: How can the capacities of AI be leveraged to precisely analyze spatial inequality in urban services and provide effective solutions to promote urban justice in the neighborhoods of Marvdasht?

2 | Theoretical Framework

A neighborhood or district refers to a part of a city or village that has its own name, boundaries, and characteristics [6]. Just as there is a wide variety of definitions for a city—mostly stemming from the efforts of different disciplines to define it—neighborhoods have also been defined from the perspectives of various fields related to this urban concept. In other words, specialists in fields such as geography, sociology, architecture and urban design, and housing planning have provided different definitions of a neighborhood based on their areas of expertise. "The concept of a neighborhood has a specific definition in every country. For instance, in Morocco, the neighborhood has less of an administrative and commercial concept and carries a more symbolic meaning" [7]. The phenomenological approach, despite its similarities to humanistic discussions, views the neighborhood as a social construct and a cultural phenomenon, linking the sense of place to the collective memory of the city [8]. From the perspective of urban geographers, who are pioneers and founders of spatial planning, a set of connections between a place, its people, and their activities within a shared territory creates a social realm in the sense of neighborhood and co-residency. In this shared territory, the sense of neighborhood, identity, and belonging transcends the commonalities formed out of mere necessity. From the viewpoint of urban spatial planning, a neighborhood is a geographical territory comprising various urban land uses that fulfill the essential needs of its residents. Today, researchers consider a neighborhood or neighborhood unit as a space for human interaction aimed at achieving a healthier quality of life, asserting that a neighborhood requires a society whose members are constantly interacting and engaging with one another, looking out for each other, and cooperating. Social participation is a variable that indicates the overall interaction of individuals within a neighborhood unit [9]. In its early stages, AI was a novel topic in studies, but over time, and due to existing urban problems, this approach evolved into a method for solving urban issues. Today, many AI systems are utilized within the framework of smart city initiatives. Automated decision-making, infrastructure management, error minimization, data analysis, service delivery, and efficiency improvement are among the core applications of AI in cities and urban planning. Implementing

AI in urban environments and planning leads to systemic maturity in the city's decision-making and executive organizations. On the other hand, the diversity of AI's goals and applications necessitates that the city and its institutions create the necessary conditions for the successful adoption of AI. Although AI provides opportunities for organizations and their stakeholders to interact with technology, greater attention must be paid to the ethical implications, knowledge and experience acquisition, and system management of healthy AI applications. In the development of smart cities, AI can play a significant role in urban planning, development, and management through advanced security programs, traffic monitoring, and waste management, thereby enhancing community security and livability. A key application of AI in traffic management is traffic prediction. By analyzing traffic data, weather conditions, and other relevant factors, AI algorithms can generate accurate forecasts regarding future traffic conditions, such as congestion levels, travel times, and accident probabilities. AI can also play a crucial role in the development of good urban governance [10].

3 | Literature Review

Ebrahimi and Ehsan Bakhsh [1], in a study titled "The Application of Artificial Intelligence in Participatory Urban Planning: Emphasizing Natural Language Processing (NLP)," utilized content analysis and machine learning algorithms to analyze opinions collected from social platforms. They found that NLP can identify sentiments, main topics, and patterns in citizens' opinions with acceptable accuracy. These findings indicate that NLP can be used as a powerful tool to improve the decision-making process in urban planning.

Hosseini et al. [11], in a study analyzing the factors explaining the role of AI in urban planning and city development, examined the relationship between the most important thematic areas of various articles published around the concept of AI and its role in urban planning. The analysis of data from the mentioned articles showed that 6 thematic clusters had a direct impact on the role of AI in urban planning. Furthermore, in recent years, concepts related to the research approach have shifted from focusing on the initial examination of AI concepts and their functioning to novel methods for solving urban problems. The articles in the first cluster, with the most frequently reviewed keywords, examined important current urban issues such as air pollution, transportation, resilience, economy, etc., and the application of AI in solving them. The goal in the studies of this cluster was to create major transformations in the digital industry and cities using AI.

Khosravani et al. [12], in a study titled "Smart and Sustainable Urban Growth Through the Use of Artificial Intelligence Technologies in Urban Planning and Management," found that the use of AI in urban planning and management is considered a relatively new field. This study is a literature review of the fields of urban planning and management where AI can be applied to support smart and sustainable development in cities. The results emphasize that expanding the research areas of AI in urban planning paves the way for the actual and broader acceptance and use of this technology by urban managers. It must be considered that preparing fundamental and reliable data is an important element for the effective use of AI in urban planning and management. Also, the alignment of AI and humans is very important for properly managing urban challenges and achieving smart and sustainable development. These items further reveal the necessity of cooperation between key stakeholders in cities, specifically in order to achieve greater AI adoption.

Behzadi Nejad [10], in a study titled "Application of Artificial Intelligence in Urban Planning," concluded that AI in the development of smart cities can play an important role in urban planning, development, and management with advanced security programs, traffic monitoring, and waste management, thereby providing communities with greater security and livability through access to and control over their homes and other life activities. One of the key applications of AI in traffic management is traffic prediction. By analyzing historical traffic data, weather conditions, and other relevant factors, AI algorithms can create accurate predictions about future traffic conditions, such as congestion levels, travel times, and accident probabilities. AI can play an important role in the development of good urban governance. This is achieved by influencing smart decision-making in a large city or by monitoring and controlling, including traffic, waste management, air and

water pollution control, and urban security monitoring, performing these activities automatically and more accurately.

4 | Study Area

Marvdasht is located in the north of Fars Province, geographically positioned between 51°44' to 53°30' East longitude and 29°15' to 30°59' North latitude, at an altitude of 1600 meters above sea level. In terms of political divisions, this county is bordered by Eghlid and Khorrambid counties to the north, Arsanjan county to the east, Shiraz County to the south, and Sepidan county to the west. The center of the county is Marvdasht city, which is located 45 kilometers northwest of Shiraz. Over 43% of the county's total area consists of mountainous and hilly regions, while the rest comprises plains and lowlands. Based on the 2016 census, the population of Marvdasht is 148,858. Marvdasht is currently the second most populous and the fourth largest city in Fars Province [13].

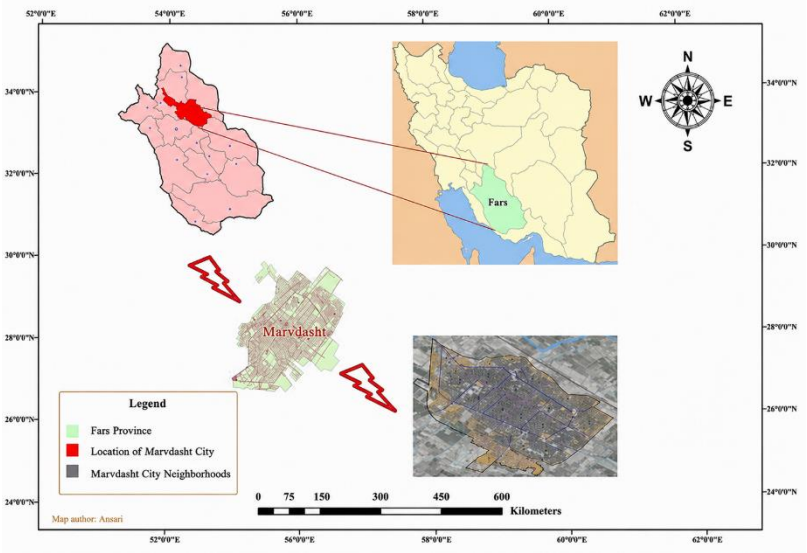

Fig. 1. Geographical location of the study area.

5 | Research Methodology

In terms of purpose, this research is applied, and in terms of nature and execution method, it is descriptive-analytical with a quantitative approach. Its main objective is to analyze and identify spatial inequality in the distribution of urban services in the neighborhoods of Marvdasht by leveraging the analytical capacities of AI. To this end, the required data is first collected from valid and official sources. This data includes spatial and descriptive information of urban services in various fields, including educational, healthcare, cultural, welfare, recreational, transportation, and green spaces across the neighborhoods of Marvdasht.

Additionally, demographic data such as population size, population density, and, where accessible, certain socio-economic characteristics of the neighborhoods' residents, along with physical and spatial data such as neighborhood boundaries, land use patterns, and the geographical location of services, are extracted from institutions such as the Municipality, the Statistical Center of Iran, and mapping organizations, and organized in a Geographic Information System (GIS) environment.

In the analysis phase, AI and data processing tools are used to identify hidden patterns and relationships between spatial and demographic variables. For this purpose, the data is processed in a Python environment utilizing libraries such as Pandas for data cleaning and organization, GeoPandas for spatial analysis, Scikit-learn for implementing machine learning algorithms, and Matplotlib and Seaborn for drawing charts and visualizing analysis results. In the first step, descriptive-spatial indicators such as per capita services, distance to the nearest service, and the accessibility level of each neighborhood are calculated to reveal the overall status of service distribution. Then, using clustering algorithms such as K-Means or Density-Based Spatial Clustering of Applications with Noise (DBSCAN), neighborhoods are classified into homogeneous groups

based on similarities in their level of service access and demographic characteristics. This classification enables the identification of privileged, semi-privileged, and deprived neighborhoods. Subsequently, to measure the intensity of spatial inequality and examine the factors affecting it, analytical and machine learning models are utilized to determine the share of variables such as population density, distance from the city center, and land use type in shaping unequal patterns of urban services.

6 | Research Findings

In this section, the results obtained from the analysis of spatial, statistical, and economic data of Marvdasht's neighborhoods, with a special emphasis on the application of AI technology—particularly machine learning and optimization algorithms—are presented in detail. The main objective is to provide a more accurate and multi-level picture of the status of spatial justice, access to urban services, and the prioritization of interventions. Neighborhood Clustering using the K-Means Algorithm and Neighborhood Typology: The clustering process was based on a feature vector of indicators including: per capita healthcare services, education, green space, transportation, population density, and socio-economic indicators (income level and household economic power). The output was categorized into three distinct clusters as follows:

Table 1. Clustering of sample neighborhoods in Marvdasht city.

Cluster	Sample Neighborhoods	Population Density	Service Access Level	Economic Power	Deprivation Index (0-10)
Cluster 1 (privileged)	Moallem-Saipa	120	0.85	0.80	0.25
Cluster 2 (medium)	Zhian-Baharestan	180	0.55	0.45	2.00
Cluster 3 (deprived)	Pashmazani-Ferdowsi	250	0.20	0.30	5.00

This clustering indicates a significant inequality and population concentration in deprived neighborhoods. The multi-fold population pressure in Cluster 3 neighborhoods is accompanied by a severe lack of services, which can create a cycle of deprivation and accumulation of social problems.

Correlation analysis of indicators and the service-economic power gap: By applying statistical analysis to the correlation matrix of development indicators, the following relationships were obtained:

I. Population density – access to healthcare services: -0.48.

II. Population density – access to green space: -0.55.

III. Economic power – urban service utilization: +0.73.

Table 2. Correlation matrix of development indicators.

Indicators	Correlation Coefficient
Population density – access to healthcare services	-0.48
Population density – access to green spaces	-0.55
Economic capacity – utilization of urban services	+0.73

Prioritization of interventions using AI optimization models:

Advanced location-allocation models and AI-based predictive analyses provide the following recommendations based on constructed deprivation factors.

Table 3. AI-based recommendations according to deprivation factors.

Priority	Neighborhood	Proposed Intervention Type	Deprivation Index	Predicted Impact	Timeline
1	Pashmazani	Development of healthcare, educational, and green space infrastructure	0.85	45% gap reduction in 5 years	Short-term
2	Ferdowsi	Completion of public transport network, economic training	0.50	30% increase in productivity	Medium-term
3	Saipa	Land use optimization and cultural service development	0.35	Service balance across the city	Long-term
4	Moallem	Demand management, upgrading existing service quality	0.25	Maintaining desirable level	Long-term

6.1 | Simulated Scenarios and Future Prediction

Based on the AI simulation model, two key scenarios were identified:

Scenario 1. Uniform distribution of resources based solely on population. This approach will exacerbate inequality in the Shast-metri and Pashmazani neighborhoods over the next 5 years, increasing the service gap by up to 20%.

Scenario 2. Targeted distribution based on neighborhood deprivation index using the AI model. Targeted allocation to deprived neighborhoods (Cluster 3) will lead to a 45% reduction in the disparity of access to services and increase the share of services for these neighborhoods out of the total city-wide services.

AI as a Key Tool for Neighborhood-Based Planning. The findings of this study emphasize the following:

High population density in peripheral neighborhoods, without proportional development of infrastructure and services, has turned into a trap of multidimensional deprivation. AI is capable of revealing the existing gap between physical access and actual service utilization by analyzing complex, multi-purpose data. This technology has not only performed beyond traditional methods in identifying critical points but also in precise prioritization and optimal resource allocation. Shifting the approach from static to dynamic planning, relying on AI models, can significantly improve spatial and economic justice in Marvdasht.

7 | Conclusion

The obtained results indicate that utilizing AI algorithms, particularly in the form of clustering, correlation analysis, and spatial optimization models, has been able to reveal the hidden and obvious dimensions of spatial inequality with an accuracy far beyond conventional methods. Accordingly, the main hypothesis of the research—that AI provides the possibility of more accurate, in-depth, and comprehensive identification of spatial inequality in the distribution of urban services in Marvdasht's neighborhoods compared to traditional methods—is confirmed. The findings showed that neighborhoods such as Pashmazani and Shast-metri are in a critical situation; high population density, low service levels, and weak economic power of residents have trapped these neighborhoods in a cycle of spatial and social deprivation. In contrast, neighborhoods like Moallem and, to some extent, Posht-e Saipa enjoy a more desirable level of services and access; however, even in these neighborhoods, the distribution of services does not necessarily mean complete spatial justice, and a distinction must be made between physical access, utilization capacity, and the actual needs of residents. The Ferdowsi neighborhood is also an example of hidden inequality; although it is in a middle position in

terms of some indicators, the gap between access and economic power prevents the full utilization of urban services.

AI can operate beyond merely describing the status quo and, by combining spatial and social data, help predict critical areas, prioritize interventions, and suggest targeted solutions. Such a capability is highly valuable in neighborhood-based planning, as it allows urban managers to direct limited resources toward areas that have the greatest need and the lowest level of access. In other words, in this research, AI has been not only an analytical tool but also a tool for making urban decision-making justice-oriented. In response to the main research question, it can be said that the capacities of AI, through multi-layered analysis of demographic, economic, physical, and service indicators, provide the possibility of accurately identifying spatial inequality and offering effective intervention models. This is especially important in cities like Marvdasht, where the distribution of urban services is simultaneously affected by demographic, economic, and physical factors. Therefore, the use of AI can serve as a basis for transitioning from traditional, holistic, and static planning toward smart, precise, and flexible planning. Ultimately, this research shows that realizing urban justice in the neighborhoods of Marvdasht requires urban decisions to be based on intelligent, data-driven analyses grounded in spatial realities. Hence, the development of AI-based decision-support systems, the application of predictive models in service allocation, and the revision of traditional patterns of facility distribution can be considered the main pathways for promoting spatial justice in neighborhood-based planning.

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