Sustainable Urban & Regional Development Studies Quarterly

Volume 6, Issue 4 - Serial Number 22, Winter 2025 **Online ISSN: 2783-0764**
Journal Hompage https://www.srds.ir/
https://www.srds.ir/article_221214.html?lang=en

Evaluation of the spatial distribution pattern of bus stops in Mashhad city

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Received Date: 25 January 2025 **Accepted Date:** 18 May 2025

Abstract

Background and Objective: Paying attention to public transportation is one of the most important issues in sustainable development. Access to bus stops is one of the implementation of a successful transportation system. Considering that the city of Mashhad has religious tourism, many pilgrims from all over the world travel to this city every year. Therefore, the purpose of the research is to evaluate the spatial distribution pattern of bus stops in the city of Mashhad.

Methodology: The present study is applied in nature and descriptive-analytic in method. GIS software (nearest neighbor average, low and high clustering, Moran's spatial autocorrelation, network analysis) has been used to analyze the data and research findings..

Findings and Results: The results of the research findings showed that the average ratio of the nearest neighbor indicates a clustering state and the value of G is equal to zero, therefore suggesting a high clustering pattern. Given that the value of the Moran index is 0.65 and the z-score is high and the P-value is small, the data has spatial autocorrelation. Finally, the output from the network analysis and service access showed that in most cases, bus stops in the city of Mashhad are located at a distance of 400 meters and are located at a standard distance in terms of user location (in the administrative-commercial area and the urban core).

Keywords: Spatial distribution, bus stations, network analysis, Mashhad city.

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Cite this article: Ghahri, S. , Yazdani, M. H. and Jafariyan, H. (2026). Evaluation of the spatial distribution pattern of bus stops in Mashhad city. Journal of Sustainable Urban & Regional Development Studies (JSURDS), 6(4), 222-235.

Extended Abstract

Introduction:

The transportation sector has an impact on many economic, social and environmental areas. Today, the unresolved problem of traffic in cities and the pollution caused by it has serious consequences for people's health and vitality and causes the death of many pulmonary and heart patients. The urban bus system is one of the types of public intra-city transportation systems that is of great importance due to its high flexibility compared to the subway, its relatively low cost, and its great impact on the movement of mass urban passengers, especially in metropolises. In addition, the high costs of building equipment and facilities for other types of urban transportation have made this vehicle the best option for people to travel in different urban areas (Jalilvand and Azar, 88:1402). Paying attention to public transportation is one of the most important issues in sustainable development. In addition to sustainable development, Mashhad has religious tourism, with many pilgrims from all over the world traveling to this city every year. The history of using buses in Mashhad's inner-city transportation dates back to 1318, when the private sector provided service using 2 buses on the route of the Holy Shrine and Arg Street (currently Imam Khomeini). After 26 years, in 1344, the Bus Unit Company was established using 13 buses and was registered on 07/27/1353 under the name of Mashhad Municipality Bus Organization. Currently, the Bus Organization serves the pilgrims and residents of the shrine of the Eighth Imam (AS) and the public by using about 1720 vehicles of various types and having 2829 bus stops on 167 private and organizational lines. For this purpose, the present study aims to investigate the spatial distribution of bus stops in Mashhad.

Methodology:

The research method of the present study is descriptive-analytical and in order to collect the data required for the research, documentary and field methods have been used simultaneously and according to the research needs. GIS software (average nearest neighbor, low and high clustering, Moran's spatial autocorrelation, network analysis) has been used to analyze the data and research findings. In such a way that the final map obtained from this process will indicate the spatial distribution of bus stops in the city of Mashhad.

• Average nearest neighbor:

The average nearest neighbor distance first measures the distance between the center point of each feature and the center point of its nearest neighbor, then calculates the average of all these nearest neighbors. If the average calculated distance is less than the average spatial distribution, then it can be concluded that the distribution of the phenomenon under study in space is clustered. If the average distance calculated is greater than the average of the assumed random distribution, then it can be concluded that the features are distributed sparsely in space.

Statistical principles:

Statistically, the average nearest neighbor distance is estimated as follows:

The average distance observed between the feature in question and its nearest neighbors is calculated as follows:

The average distance between the feature and its nearest neighbors if the distribution in this feature formula is random and is explained as follows:

In the above relationship, $_i$ is the distance between the feature under study and its nearest neighbor, the total number of phenomena, and also the area of the entire area under study.

The standard score ANN is also estimated as follows:

and is equal to

The p. value will be an approximation of the area under the curve of the given distribution direction, which is limited by a statistical test (ibid.).

• Low and High Clustering

High and low clustering analysis measures the degree of density and clustering of high or low values in a variable under study. This analysis, which is also known as the general G statistic, is the second item in pattern analysis after the nearest neighbor mean tool and the result is graphically shown in the image below. In the analysis of variables in this statistic, the null hypothesis means that there is no spatial clustering, whether high or low. The condition for rejecting the null hypothesis for this statistic is that the Zscore value is very large and the Pvalue is very small and close to zero, so the Z value is positive, meaning that high or high values of the variable are clustered. If the calculated Z is negative, then we conclude that low or low values are clustered.

• Spatial autocorrelation

Spatial autocorrelation is related to the relationship between the residual values along the regression line. Strong autocorrelation occurs when the residuals are related along the regression line. Strong autocorrelation occurs when the residuals are strongly related to each other. In other words, their changes occur systematically. Spatial autocorrelation is a relatively simple concept and is in fact an extension of the same concept in classical statistics. If the features or values of the variables related to them are randomly distributed in space, there should apparently be no relationship between them. Network Analysis: The process of network analysis is one of the most important capabilities and facilities that are available to users in the geographic information system through software such as ArcGIS. In ArcGIS, an extension that is built into ArcGIS by default and called Network Analyst is used to perform network analysis. Network analysis is a useful tool in analyzing water distribution, river flow, and traffic flow, and is part of it. In finding the service area of the network, Network Analyst draws a polygon around specific services (such as bus stops, parks, educational spaces, etc.) and determines its service area based on the defined time and access restrictions. In fact, the result of this analysis is a linear layer (streets) and a polygonal layer (service area).

Results and Discussion:

Access to the bus station is one of the implementations of a successful transportation system. Urban development has increased travel demand. The studies conducted show that the existing public transportation is not able to meet this demand. On the other hand, it is observed that the increasing trend of travel demand in the future justifies the use of public transportation systems more than before. In this regard, this study aims to spatially analyze the bus stations in Mashhad to determine their physical accessibility with respect to the connected passages around the bus stations by network analysis and service provision. The results of the study showed that the average ratio of the nearest neighbor is 0.3209610, indicating a clustering state. The value of the G index is zero, indicating a high clustering pattern and a high number of bus stations in Mashhad. The next analysis used in the present study was Moran's spatial autocorrelation analysis. In this regard, considering that the value of the Moran index is 0.65 and its value is positive and close to one. Therefore, the data has spatial self-correlation. Also, considering the high Z score and the very small p-value, the hypothesis of no spatial correlation between the data can be rejected. After analyzing and determining the type of spatial distribution pattern of bus stations in Mashhad, the network and access to services were analyzed based on the criteria related to public transportation stations. The output in this regard showed that in most cases, bus stations are located at a distance of 400 meters and in terms of user location (within the administrative-commercial area and urban core), which is a standard distance. The findings of the present study are inconsistent with the results of the study by Rahnama and Sabbaghi-Abkouh (2015), on the

one hand, that the level of access is generally minimal for hospitals and parks. On the other hand, it is consistent with the fact that access is more balanced for libraries. Since in the present study, urban uses (developed and densely residential) are located at a distance of 600 to 1000 meters. Therefore, to improve the public transportation system, especially the bus system, it can play an important role. This improvement is possible in two ways: one is to upgrade the system by changing the bus network in terms of routes, number of lines, and designing a new network, and the other is to improve the performance of the lines.

Declarations

•**Funding**: There is no funding support for this study.

•**Authors' Contributions**: All authors contributed equally to the conceptualization and writing of the article. The authors approved the manuscript's content and agreed on all aspects of the work.

•**Conflict of Interest:** The authors declare no conflict of interest.

•**Acknowledgments**: The authors extend their gratitude to all scientific consultants who provided invaluable insights during this research.

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