Research Paper: Analysis of the transportation system sustainability and identification of itsspatial pattern in the villages of Tabriz County

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ABSTRACT

Purpose: Rural transportation plays an essential role in achieving and realizing more than half of the sustainable development goals. For decades, transportation policy programs have sought to create sustainable transportation in rural areas.The successful implementation of sustainable transportation in these regions helps to achieve goals such as the reduction of poverty, ensuring food security, promoting and growing inclusive economic opportunities, empowering women, providing employment, and eliminating restrictions on access to services in rural areas. This research attemptsto evaluate and rank the level of sustainability of the transportation system in the villages of Tabriz County.

Methods: This research is applied in terms of purpose and, based on nature, it is descriptive-analytical. The necessary data for this research werecollected by documentaryand survey methods,drawing from the f 2011 and 2016 censuses of Iran and a researcher-made questionnaire.The population of the research includes rural households in Tabriz County. Using Cochran's formula and with a 95% confidence interval, the sample size was determined to be 320 households, and a simple random sampling method was used for the selection of samples from villages.For data analysis, the Multi-Attribute Utility Theory (MAUT) ranking method was used, and Moran's I Index was used to analyze spatial autocorrelation.

Results: The ranking obtained from the MAUT method indicates that Bagh Yaqoub Village, located near Tabriz City, has the highest level of transportation sustainability in terms of the considered indicators, and GowarVillage has the lowest level.The results of spatial autocorrelation analysisindicatethe existence of a clustered pattern in the spatial distributionof transportation sustainability. Specifically, the villages with high transportation sustainability levels are more concentrated in certain parts of the studied area.

Conclusion: The research concludesthat the villages near Tabriz City, the county's center and well-connected by main roads, are more sustainable than the villages located farther away.

Keywords:

Sustainability, Transportation, MAUT, Moran I Index, Tabriz County

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1. Introduction

Mobility and movement are integral to human daily activities and essential for traffic studies. These activities play a crucial role in causing environmental pollution and the depletion of ecologicalresources (Taqvai & Sajjadi, 2015: 2), highlighting the need for sustainable transport development. Achieving sustainable transport requires planning, monitoring, and evaluating the current system. Local conditions and individual behavior patterns are vital considerations for a sustainable transport system, which is influenced by environmental policies that affect the behavior of the people involved. Consequently, sustainable transport policy relies on information and tools to guide informed decisions, aiming to meet transport needs while minimizing environmental impacts, promoting social equity, and reducing negative environmental effects (Tomej & Liburd, 2019: 2). The use of renewable fuels, reduced mobility, and sustainable transport modes such as public transport and cycling havebeen proposed by many researchers as the most practical methodsto enhance the sustainability of the transport system (Hall et al., 2017). Buses and rail are preferable alternatives to private cars, performing significantly better in terms of ecological footprint and causingfewer negative health consequences (Ming Wen & Rissel, 2007). Moreover, they are affordable and accessible to disadvantaged populations and rural areas.

The concept of sustainable transportation in rural areas differs from that in urban areas. In urban areas, sustainable transportation is associated with reducing reliance on cars and promoting walking and cycling. However, in rural areas, sustainable transportation is achieved by improving access to public transportation, using modern vehicles with clean or low-polluting energy, constructing suitable roads, and facilitating access to services. In rural contexts, walking and cycling to reach destinations are often considered indicators of weak mobility and instability (Rahimzadeh, 2020: 25). Rural areas are sparsely populated and often located at relatively long distances from each other, with limited access to various services. This affects trip lengths, travel behavior, and individual mobility. The lack of access to a car or public transport increases inequality in access to services and opportunities, putting people without cars at greater risk of social exclusion and preventing them from engaging in social and economic activities (Giulio, 2016: 119). Land use characteristics, environmental conditions (mountainous or plains), rural centrality, and road access also affect travel choices and limit travel options equally for everyone (Stanley & Stanley, 2017). This has heightened the need for car ownership among rural people, as rural roads with uneven surfaces and considerable lengths make it impractical to use bicycles to reach services, especially during cold seasons. Reliance on private cars, while increasing environmental, social, and economic concerns in rural areas, has also exacerbated inequality in access to resources, differences in health status, and variations among villages in terms of transport sustainability (Farrington & Farrington, 2005: 9).

Poor access also leads to socio-economic and demographic challenges, largely determining the quality of life in a region. This situation is evident in the rural areas of Iran. Villages in Iran are among the most deprived areas of the country. Despite significant efforts in recent decades, there are still relative deficienciesin services, transportation, road construction, etc., exacerbated by the low density and scattered nature of villages (Aghayari et al., 2022: 30). In Tabriz County, the rural transportation sector mainly involves road construction without providing transportation services. Except for a few villages near Tabriz City, no action has been taken to improve access to public transportation services, which play a crucial role in sustainable transportation development. Unplanned road construction, while destroying and fragmenting agricultural lands, has led to the loss of farmers' motivation to cultivate and increased the price of roadside land. On these roads, transportation is mainly by private vehicles, and public transportation is either non-existent or very poor. The growth of personal transportation has resulted in the spread of harmful gases, water and soil pollution, noise pollution in villages adjacent to main roads, and an increase in livestock and human accidents on rural roads. The lack of public transportation services has also affected trip lengths and times, as well asthe costs for individuals, leading to wastedtime and causingdestructive social (accessibility and safety) and economic impacts. Considering the positive and negative effects of transportation on social, economic, and environmental conditions, this article seeks to determine the sustainability of the rural transportation system and rankthe villages in Tabriz County accordingly.

2. Literature Review

Developing and creating an efficient transportation system is crucial for the survival and preservation of regions, playing a significant role in the socio-economic development of a society. Enhancing transportation systems strengthens connections between industries, fosters economic growth, and creates favorable conditions for the utilization of surrounding lands (Yancang et al., 2014: 5).

Transportation is also a fundamental pillar of sustainable development, aiming to prioritize affordable, accessible, healthier, and cleaner alternatives to current transportation methods (European Commission, 2019).To reduce greenhouse gas emissions, improve accessibility, and prevent social exclusion across various income classes, efforts have been made to shift from private cars to public transportation. This shift not only supports economic development and poverty reduction (Jiang et al., 2020) but also plays a crucial role in sustainable development. However, analyzing transport poverty without adequate data availabilityis complex, particularly in underdeveloped and developing countries, where rural areas dominate and data access is challenging.Additionally, there is no consensus on conceptualizing and measuring transport poverty, which is sometimes linked to energy poverty or the inability to travel due to transport costs or access issues (Metta, 2020). To address this, the concept of transport poverty and instability based on access and mobility has emerged (Lucas et al., 2016). An individual is considered transport-poor when they meet at least one of the following conditions: lacking an appropriate transportation option, facing difficulties in reaching destinations for daily activities such as education, health, and employment (Martens & Bastiaanssen, 2019), incurring transportation costs above the official poverty line, experiencing long travel times, or enduring unsafe, dangerous, or unhealthy travel conditions.Sustainable transport systems should be emphasized, as they provide significant opportunities for people by enabling access to schools, jobs, healthcare, and markets. This improves individuals' quality of life, reduces poverty levels, and contributes to economic, social, and environmental growth (Bergman & Bergman, 2019).

Transport poverty should not only be studied through the aforementioned approach but also from a mobility perspective, as access is not equally available to all groups, leading to inequality and social exclusion. This issue affects the most vulnerable individuals, particularly those in underdeveloped and developing countries who are anchored in poverty. They often reside in slums or rural areas and must travel long distances to access work, healthcare, education, and other essential services.Some individuals suffer from various diseases or conditions, such as pregnancies requiring constant medical care, which are practically impossible to manage due to economic, physical (inadequate infrastructure), and temporal barriers. Others may be unemployed, disabled, or elderly with low incomes, dependent on health services but facing limited access due to geographic distance and transportation issues.This problem is more pronounced in rural areas, where transportation deprivation impacts environmental, economic, and social sustainability. Rural transport plays an essential role in achieving over half of the Sustainable Development Goals and fulfilling the 2030 Agenda for Sustainable Development. Providing safe, reliable, and affordable rural transport infrastructure and services is crucial to facilitatingaccess to markets, services, employment, healthcare, and education, thereby increasing agricultural production, developing modern supply chains, and preventing food loss. Ultimately, this contributes to achieving zero hunger and reducing poverty (Cook et al., 2020: 2).

The distance to all-season roads and transport services primarily defines rural access. It includesthe distance to markets and basic services, as well as first/last-mile connectivity with appropriate services and infrastructure (Aghayari Hir et al., 2022: 75). In developing countries, rural communities are often isolated from main roads, railways, and public transport services, which are essential for accessing economic and social opportunities in cities. Therefore, improving rural accessibility is key to addressing the mobility problem, enabling the rural poor to rise out of poverty and overcome social exclusion by connecting their goods to markets and linking rural areas to towns, cities, and global markets.Although there is no specific Sustainable Development Goal (SDG) for rural accessibility, there are numerous linkages between rural accessibility and the SDGs. However, not much research has been conducted on the sustainability of rural transportation in Iran.

Foladchi et al. (2019), in their manuscriptentitled "The Role of Imam Khomeini Airport in the Sustainability of Rural Settlements in Robat Karim County," used the Morris Davis model to examine the airport's impact on village sustainability. Their results indicated that the villages of Hakimabad and Shatrakhand exhibited the highest sustainability compared to other villages. In contrast, the impact of Imam Khomeini Airport on the social development of the studied villages was minimal.

Zahri et al. (2017), in their article titled "Evaluating the Impact of Transportation on Various Aspects of Rural Development in the Central District of Tabriz County," analyzed the role of transportation in the development of 19 villages in the county. The study revealed a significant and positive relationship between rural transportation, rural population, and structural changes in villages, including employment and economic prosperity, education, health, and social welfare.

Pourtaheri et al. (2017) explored the economic effects of access to transportation in their study, "The Role of

Rural Transportation System in Economic Development of Rural Areas (Case Study of North Taghenkoh Rural District)." The study found that reducing production costs and saving costs had the greatest impact on the rural transportation system while increasing urban-based investment had the least impact.

Aghayari Hir et al. (2017), in their study,entitled "Factors Affecting the Network Process of Mobility of Rural Areas in the Central District of Tabriz County," concluded that distance was more effective than other factors in the mobility of rural settlements.

Aghayari Hir and Rahimzadeh (2016), in their article entitled"Solutions to Control the Adverse Effects of Rural Transportation on the Environment," investigated and identified the adverse effects of rural transportation on the environment. Their research shows that numerous adverse effects are imposed on the environment due to the lack of comprehensive studies related to road construction operations and vehicle production, as well as insufficient monitoring of their effects to assess direct, indirect, and cumulative impacts. Therefore, the main solution is to focus on sustainable rural transportation.

Sajjadi (2014) studied the impact of transportation infrastructure on sustainable rural development and highlighted the existence of roads as an effective factor in sustainability. Pourtaheri et al. (2012), in their article "Assessment of Accessibility to the Transportation System and Its Role in the Development of Rural Settlements" in the villages of the southern countryside of Dehgolan County, concluded that accessibility to transportation has been effective in the organic changes of rural areas in this region, with transportation structures having the greatest impact on these changes.

Rezvani et al. (2012), in their study "Evaluating the Impact of Transportation on Social Development of Rural Areas (Case Study: Villages on the Margins of the Sanandaj-Divandareh Communication Axis)," concluded that there is an inverse and significant relationship between the level of social development indicators of villages located on the periphery of this axis and villages located 10 kilometers awayfrom this axis.

Porter et al. (2013), in their study "Transportation and Mobility Limitations in Older People: References to Livelihoods and Health in Rural Tanzania," examined the mobility of older people in the Kibaha region of Tanzania regardingthe relationship between transportation, health, and livelihoods. The research results show the growing importance of motorcycle taxi services in people's access to services and how the relationship between older people and the younger generation influences the formation of movement patterns.

Strakey and Hein (2014), in their book "Poverty and Sustainable Transport Development," review the literature on sustainable transport development and how transport affects the lives of poor people. They propose policies to reduce poverty by improving transport, considering the experience of some European Countries. They suggest investing in roads to improve transport, pointing out that improving roads will remove poor people, who mostly live in rural areas, from isolation and increase their access to transportation, services, and economic opportunities. This investment can lead to increased agricultural production due to lower travel costs for delivering products to the market, thereby improving economic opportunities in rural areas.

Adedeji et al. (2014), in their manuscript titled "Assessing the Impact of Road Transport on Rural Development: A Case Study of Obokun Local Government Area of Osun State, Nigeria," concluded that the provision and improvement of road infrastructure in the area, have led to differences in the level of rural development. The weakness of road infrastructure in the region has negative effects on agricultural activities and contributes to poverty. The study emphasizes that improving existing roads encourages public-private partnerships in transportation development and suggests adopting a self-reliance approach.

Miral Gash et al. (2016), in their study "Gender Analysis of Everyday Mobility in Urban and Rural Areas: From Challenges to Sustainability," found that women travel more than men for various reasons and use sustainable transport modes. They argue that gender is a fundamental variable in the sustainability of transport, particularly in terms of energy consumption and greenhouse gas emissions. They advocate for considering women's knowledge and mobility practices as valuable factors that can effectively guide public policies towardpromoting more sustainable mobility patterns.

López-Iglesias et al. (2018), in their article "Mobility Innovations for Sustainability and Cohesion in Rural Areas: Transport Model and Public Investment Analysis for Valdeorras (Galicia, Spain)," concluded that these innovations have reduced the environmental cost of sustainable mobility, increased socio-economic integration, and improved the quality of economic and demographic policies.

Tomej and Liburd (2021), in their manuscript entitled "Sustainable Accessibility in Rural Destinations: A Public Transport Network Approach," concluded that public transport connectivity and usability play a decisive role in the level of access to services for different groups. They highlight that public policies and their orientations and arrangements can lead to positive changes in sustainability.

3. Methodology

The present study is applied in terms of purpose and, based on nature, is descriptive-analytical, with data collected through documentary and survey methods. In the documentary section, some of the data were obtained from the census of 2011 and 2016, while in the survey section, additional data were collected using a questionnaire. The study population was comprised of rural households in Tabriz County, and a researcher-made questionnaire was used to collect the necessary data. Tabriz County includes six districts, including Aji-Chay, Espiran, Meydan-Chay, Sard-Sahra, Lahijan, and Taze-Kand, encompassing 72 villages, eight of which are uninhabited and 64 are inhabited. The total number of households in the villages of Tabriz County is 33,379. A sample size of 320 households was used to collect household data using the Cochran formula.

To operationalize the study's concept, which is the sustainability of the rural transportation system, an extensive review of sources was conducted. Several studies have been performed on the sustainability assessment of human systems, including works by Bossel (1999), Rokneddin Eftekhari and Aghayari Hir (2007), and Rokneddin Eftekhari and Badri (2012), and other sources. These studies suggest 8 main criteria for assessing the sustainability of human systems: 1) existence; 2) effectiveness; 3) diversity; 4) security; 5) compatibility; 6) equality; 7) responsibility; and 8) satisfaction. Despite numerous studies on the sustainability assessment of human settlements, the sustainability of rural transportation has rarely been considered. Rahimzadeh (2022) addressed this category, and the indexing framework presented by this research, with some modifications, was considered in the present study. Table 1 shows its general format.

The indexes of the present study consist of 72 items, each including multiple indicators and measures whose data have been collected and analyzed. To avoid lengthening the manuscript with extensive data details, this section presents only the calculated values for the eight-criteria for the 64 inhabited villages in Tabriz County, shown in Figure 1.

After operationalizing the research concepts and criteria, validity was assessed using the opinions of experts

Table 1. Structural matrix for assessing the sustainable development of the transportation system

	Main systems / Subsystems	Network/Physical Elements • Infrastructure (1) • Vehicles (2) • Control and communication tools (3)			Stakeholders/Human Factors • Public and Private Management (4) • Passengers and Cargo Owners (5) • Drivers (6)			Plementation Mechanisms • Planning (7) • Resource and Facility Allocation (8) • Executive Models (9)			Total average
Features of the sustainability system	Existence (a)	a1	a2	a3	a4	a5	a6	a7	a8	a9	a
	Effectiveness (b)	b1	b2	b3	b4	b5	b6	b7	b8	b9	b
	Diversity ©	c1	c2	c3	c4	c5	c6	c7	c8	c9	c
	Security (d)	d1	d2	d3	d4	d5	d6	d7	d8	d9	d
	Compatibility (e)	e1	e2	e3	e4	e5	e6	e7	e8	e9	e
	Equality (f)	f1	f2	f3	f4	f5	f6	f7	f8	f9	f
	Responsibility (g)	g1	g2	g3	g4	g5	g6	g7	g8	g9	g
	Satisfaction (h)	h1	h2	h3	h4	h5	h6	h7	h8	h9	h

JSRD

related to the research topic. Ten transportation engineering experts confirmed the validity of the framework. Following this validation, a questionnaire was designed to collect the data. To ensure reliability, Cronbach's Alpha Coefficient was calculated, yielding a value of 0.955, which demonstrates a high level ofreliability. The finalized questionnaire was then distributed randomly among the samples for data collection.

The data analysis technique used in this study includes theMulti-Attribute Utility Theory (MAUT) ranking model and spatial autocorrelation analysis with the Moran I Technique. Initially, the focuswas on data processing and performing necessary calculations to determine the sustainability score of the studied villages using the aforementioned eightcriteria. These calculations helped determine the final score of the villages in terms of the sustainability of the transportation system, and the villages of Tabriz County were classified into fivegroups based on their transportation system sustainabilitylevel.

The MAUT method involves creating a model that prioritizes available alternatives and assigns them relative weights (Zebua & Hondro, 2021: 30). This model, a classical multi-criteria ranking and decision-making method from the American school, defines desirability as the degree to which each decision-maker desires to achieve a particular option. The method was first introduced by Raifa and Kenny in 1976.

MAUT is a quantitative comparison method in which the final utility of each alternative is usually obtained from the weighted combination of the values of utility functions (Sadeghi Roshe & Jabalbarzi, 2017: 104). The advantage of the MAUT method is its efficiency, as it can directly calculate the final evaluation value without needing to compare the weight values of the criteria. The method aims to rank and select an option from a set of alternatives.

In this model, a real-valued utility function UU is defined over a set of feasible alternatives, and the decision-maker selects thealternative with the highest utility (Alp et al., 2015). This method is used to find the most suitable alternative based on both quantitative and qualitative criteria, with the goal of making subjective data computable to determine the most beneficial alternative.

The Moran I method is another technique used in this manuscript. This method considers the spatial relationships between the location of points and the desired index score, referred to as spatial autocorrelation analysis, which usesMoran's I technique to identify the spatial pattern of point distribution. In the present study, this technique was utilized due to the point-based nature of the sustainability scores of the transportation system in the studied villages (Aghayari Hir et al., 2022). Based on the study by Vitale Brovarone et al. (2020), the relationships used in this technique shown inEq. 1:

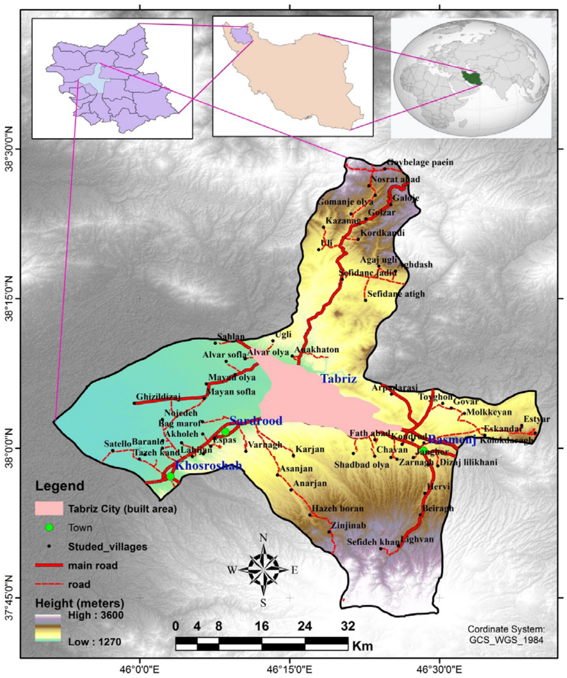

Figure 1. Location of the county in East Azerbaijan province and distribution of villages in the studied area JSRD

Eq. 1. $$I \equiv \frac{n}{S_o} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{i,j,z_iz_j}}{\sum_{i=1}^{n} Z_i^2}$$

Here, Zi is the difference between the value of feature i and its mean (xi-X). Wij is the spatial weight between features i and j, n is the total number of geographic features in the layer used, and So is the sum of the total spatial weights (Eq. 2).

Eq. 2. $$S_o \equiv \sum_{i=1}^{n}\sum_{j=1}^{n} W_{i,j}$$

The standard Zi score for Moran's statistic is calculated as Eq. 3:

Eq. 3. $$Z_I \equiv \frac{I - E[I]}{\sqrt{V[I]}}$$

$$E[I] = -1/(n - 1V[I] = E[I^2] - E[I]^2$$

The research methodology is shown in Figure 2.

4. Findings

After processing the data and performing initial calculations, a research decision matrix consisting of 8 criteria was created for the 64 studied villages. This matrix was normalized to enable the comparison of values, and the resulting data arepresented in Table 2.

In the next step, the Shannon Entropy Model was used to determine the weight of the criteria. The calculated weights are presented in Table 3. Based on these weights, the existence criterion, with a weight of 0.2047, obtained the highest weight, and the compatibility criterion, with a weight of 0.0633, wasfound to have the lowest weight in assessing the sustainability of the rural transportation system.

Then, the values from the utility matrix were multiplied by the weights derived from the Entropy Model, resulting in the final utility coefficients for each village's sustainability indicator. These coefficients were then used to rank the villages in terms of the sustainability of their transportation systems, as shown in Table 4.

The scores obtained from the MAUT technique were entered into software and classified into five classes using the Natural Breaks function. The range of these classes is presented in Table 5.

Subsequently, the sustainability classification of the rural transportation system in Tabriz County was performed, and the results are depictedin a map (Figure 3). As seen from the map, the level of sustainability is higher in villages adjacent to the main communication axes, particularly in areas close to Tabriz City.

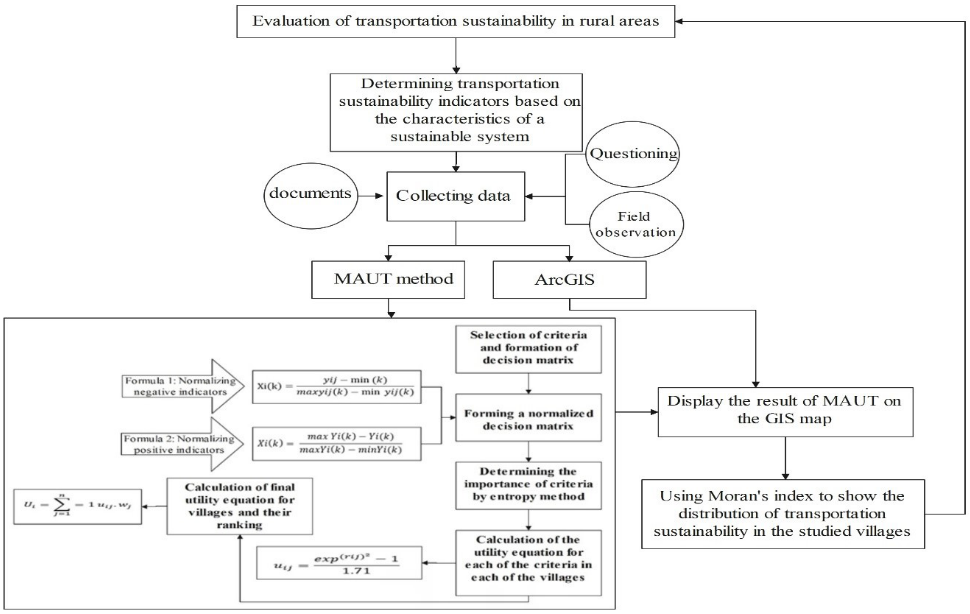

Figure 2. Steps of conducting research using the MAUT and spatial autocorrelation analysis

Table 2. Normalized matrix of considered criteria for assessing rural transportation sustainability

Village Name	Existence (a)	Effectiveness (b)	Diversity ©	Security (d)	Compatibility (e)	Equality (f)	Responsibility (g)	Satisfaction (h)
Baghmaroof	0.67	0.21	.021	0.04	0.21	0.19	0.09	0.48
Esfahlan	0.52	0.48	0.19	0.18	0.21	0.37	010	0.40
Anakhatoon	0.73	0.75	0.47	0.21	0.48	0.53	0.17	0.42
Mayan Sofla	1	0.89	0.89	0.31	0.69	1	0.46	1
Qizil data	0.30	0.35	0.31	0.15	0.45	0.28	0.42	0.35
Mayan Olya	0.60	0.44	0.15	0.88	0.21	0.67	0.51	0.44
Sahlan	0.30	0.35	0.26	0.18	0.27	0.22	0.29	0.05
Alvare sofa	0.44	1	1	0.50	0.64	0.67	0.63	1
Khajedizaj	0.30	0.35	0.26	0.18	0.31	0.04	0.11	0.35
Alvare Olya	0.44	1	1	0.50	0.64	0.67	0.63	1
Oghly	0.23	0.17	0.22	0.04	0.51	0.22	0.23	0.35
Aghajoghli	0.12	0.14	0.10	0.15	0.15	0.00	0.00	0.00
Aghdash	0.03	0.03	0.01	0.00	0.15	0.00	0.00	0.00
Sefidan Atiq	0.12	0.14	0.10	0.00	0.15	0.00	0.00	0.00
YenigiEspiran	0.19	0.22	0.15	0.07	005	0.28	0.09	0.12
QmanjSofla	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.00
Ovli	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Kazang	0.00	0.00	0.13	0.00	0.03	0.00	0.00	0.00
Gomanj Olya	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.00
Goy bolaghpain	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00
Mashirabad	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Nosrat abad	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.00
Kord Kandi	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.00
Goloje	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00
Golzar	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00
Sefidehkhan	0.03	0.00	0.36	0.00	0.01	0.04	0.00	0.00
Ligvan	0.44	0.55	0.87	0.58	0.72	0.89	0.23	0.61
Beyrag	0.44	0.55	0.82	1	0.49	0.55	0.91	0.67
Hervi	0.90	0.55	0.67	0.64	0.72	0.55	0.86	0.68
Chavan	0.64	0.82	0.89	0.88	0.90	0.44	0.85	0.75
Shabadmashayekh	1	0.61	0.87	0.66	0.72	0.44	0.72	0.75
Fathabad	0.64	0.82	0.91	0.88	0.90	0.44	1	0.67
ShadabadOlya	0.50	0.61	0.42	0.88	0.81	0.44	0.19	0.17
Zarang	0.90	0.55	0.57	0.22	0.31	0.28	0.35	0.40
Bagh yaghoob	1	1	1	0.88	0.57	0.89	1	1
Jangoor	0.71	0.75	0.87	0.50	0.21	0.67	1	0.91
Hajabdal	0.64	0.67	0.57	1	1	0.17	0.04	0.31
DizajeLeylikhani	0.50	0.82	0.66	0.88	0.40	0.22	0.42	0.28
Kondrood	0.80	0.82	0.87	1	0.35	0.67	0.19	0.40
Nematabad	0.90	0.75	0.22	0.026	0.27	0.28	0.04	0.40

Table 2. Normalized matrix of considered criteria for assessing rural transportation sustainability

Village Name	Existence (a)	Effectiveness (b)	Diversity ©	Security (d)	Compatibility (e)	Equality (f)	Responsibility (g)	Satisfaction (h)
Arpadarasi	0.64	0.91	0.15	0.31	0.45	0.22	0.35	0.31
Malekkian	0.04	0.00	0.31	0.03	0.00	0.00	0.00	0.00
Toygon	0.05	0.00	0.26	0.03	0.00	0.00	0.00	0.00
Estiar	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00
Eskandar	0.00	0.00	0.26	0.03	0.00	0.00	0.00	0.00
Kolokdarag	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Varang	0.23	0.35	0.76	0.36	0.45	0.04	0.00	1
Karjan	0.39	1	0.22	0.43	0.00	0.00	0.00	1
Asanjan	0.00	0.01	0.31	0.43	0.00	0.00	0.00	0.01
Anarjan	0.00	0.01	0.31	0.43	0.01	0.00	0.00	0.01
Hazabooran	0.05	0.01	0.31	0.43	0.01	0.00	0.00	0.01
Zinjanab	0.00	0.01	0.31	0.43	0.03	0.00	0.00	0.01
Qaratapeh	0.26	0.01	0.18	0.22	0.31	0.04	0.00	0.28
Satllo	0.30	0.09	0.18	0.22	0.31	0.04	0.00	0.28
Nojehdeh	0.30	0.01	0.18	0.22	0.31	0.04	0.00	0.28
Akholeh	0.26	0.01	0.18	0.22	0.31	0.04	0.00	0.28
Baranlo	0.30	0.01	0.18	0.22	0.31	0.04	0.00	0.28
Tazehkand	0.30	0.03	0.18	0.22	0.31	0.04	0.00	0.28
Yengikandi	0.26	0.04	0.18	0.22	0.31	0.04	0.00	0.28
Lahijan	0.71	0.67	0.57	0.18	0.21	0.52	0.19	0.75
Esps	0.19	0.22	0.18	0.22	0.31	0.04	0.00	0.28
Qalacheh	0.23	0.25	0.18	0.22	0.31	0.04	0.00	0.28
Sheykhhasan	0.26	0.22	0.18	0.22	0.31	0.04	0.00	0.28

JSRD

Table 3. Results of weighting criteria based on the Shannon Entropy Model

	Existence	Effectiveness	Diversity	Security	Compatibility	Equality	Responsibility	Satisfaction
W	0.2047	0.1419	0.1836	0.1697	0.0785	0.1590	0.1157	0.0633

JSRD

Table 4. Ranking of villages in terms of sustainability of the transportation system

Rank	Village Name	Score	Rank	Village Name	Score	Rank	Village Name	Score
1	Baghyaghoob	0.938	23	Esfahlan	0.305	45	Aghajoghly	0.065
2	Fathabad	0.773	24	Baghmaroof	0.255	46	Sefidaneatiq	0.049
3	Mayansofla	0.766	25	Oghli	0.229	47	Seefidehkhan	0.034
4	Chavan	0.751	26	Khajedizaj	0.220	48	Malekkian	0.027
5	Jangoor	0.745	27	Varnag	0.200	49	Toygon	0.025
6	Alvare Olya	0.725	28	Sahlan	0.197	50	Estiar	0.023
7	Hervi	0.704	29	Sheykhhasan	0.164	51	Eskandar	0.020
8	ShadadMashyekh	0.700	30	Qalacheh	0.163	52	Aghdash	0.019
9	Beyrag	0.690	31	Espes	0.156	53	Kazang	0.010
10	Konndrood	0.589	32	Sattlo	0.152	54	GomanjSofla	0.006
11	Ligvan	0.571	33	Yeniespiran	0.150	55	Gomanjolya	0.006
12	MayanOlya	0.521	34	Tazekand	0.145	56	Nosratabad	0.006
13	Dizajelelikhani	0.490	35	Nojedeh	0.143	57	Kordkandi	0.006
14	Lahijan	0.468	36	Baranloo	0.143	58	Goybolaghpaiin	0.005
15	Alvare sofla	0.463	37	Yengikandi	0.142	59	Golojeh	0.005
16	HajAbdal	0.462	38	Garatapeh	0.138	60	Golzar	0.005
17	Shadbadolya	0.451	39	Akhole	0.138	61	Kolokdaraq	0.002
18	Anakhatoon	0.446	40	Karjan	0.109	62	Ovli	0.002
19	Zarnag	0.429	41	Hazabooran	0.074	63	Mashirabad	0.002
20	Arpadarasi	0.416	42	Zinjnab	0.071	64	Govar	0.002
21	Nematabad	0.370	43	Anarjan	0.069			
22	Qizildizaj	0.332	44	Asanjan	0.069			

JSRD

Table 5. Determining the range of sustainability classes of the rural transportation system

Sustainability level	Range of score
Very low stability	0.002- 0.074
Low stability	0.075-0.229
Medium stability	0.230-0.370
High level of stability	0.371-0.589
Very high level of stability	0.590-0.938

JSRD

The result of the analysis of the spatial pattern of rural transport sustainability in Tabriz County is shown in Figure 4. The value of Moran's index is 0.609251, indicating that the rural transport sustainability pattern in Tabriz County has spatial autocorrelation and tends toward a clustered pattern. This suggests that transport services in villages are unevenly distributed. The P-value obtained is zero, indicating that the observed results are statistically significant and did not occur by chance. Additionally, the high z-value (8.287202) also indicates a high level of spatial clustering and its significance.

5. Discussion

In the present study, the MAUT ranking method was used to assess the sustainability of transportation in the villages of Tabriz County, and spatial autocorrelation analysis using Moran's I technique was employed to analyze its spatial pattern. Eight criteria were considered in forming the decision matrix for this study, derived from the data collected for 72 indexes. During the research stages, after forming and standardizing the decision matrix, the criteria were weighted using the Shannon Entropy Method, withthe existence criteria gaining

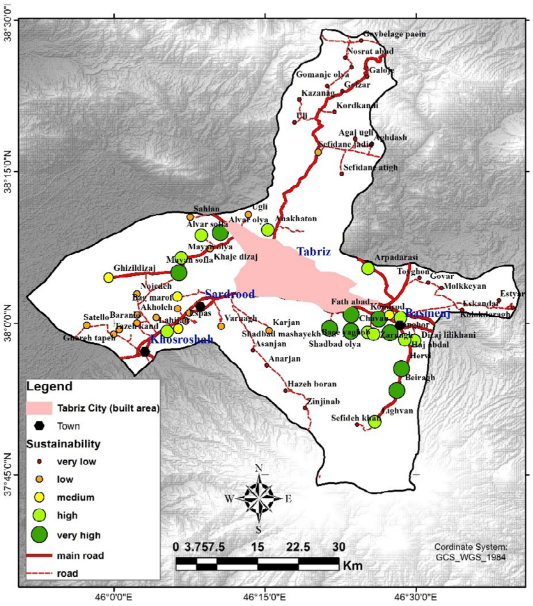

Figure 3. The level of transportation system sustainability in villages of Tabriz County

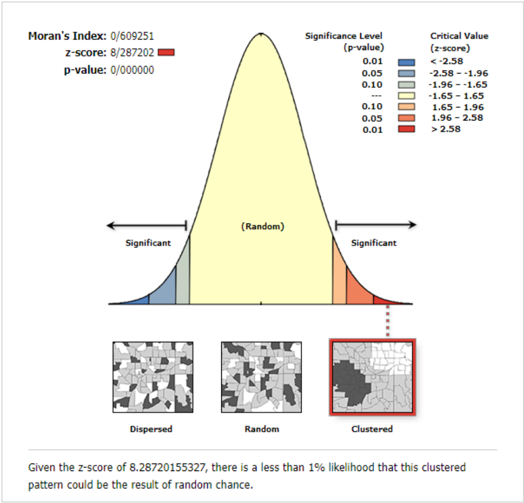

Figure 4. Graph of spatial autocorrelation test of rural transportation system sustainability in Tabriz County

the highest weight.Thus, it can be concluded that the existence of various elements of the rural transportation system has the greatest impact on its sustainability. This finding aligns with studies indicating that the availability of various services and easy access to these services, especially transportation, positively influences the sustainability of the social, political, and environmental aspects of societies. Moreover, it also causes the sustainability of transportation in villages, which is also confirmed by the results of the research of Sarkar (2010), Tomej and Libard (2019), and Vaishar and Stytena (2021).

The results of the MAUT method indicated that the sustainability score of the transportation system is higher in villages closer to Tabriz City, especially those near main roads, than in remote villages. Access to public transportation plays a fundamental role in the sustainability of these villages, providing access to various services, increasing service diversity, and enhancing resident satisfaction. This finding aligns with the research of Rezvani et al. (2012), Zahri et al. (2017), Gholami et al. (2017), Eftekhari et al. (2018), Wolny et al. (2019), and Zhu et al. (2022), which confirm a direct relationship between infrastructure, suitable roads, public transportation services, and development in various social and economic dimensions of villages. This development, in turn, positively impacts the sustainability of transportation and reduces poverty in the villages.

Furthermore, this accessibility has led to villages moving away from geographical isolation toward an open economy. The existence of tourist villages and second homes in many villages of Espiran District has also contributed to the improvement of roads leading to these villages, increased road safety, and the formation of public transportation. The acceptance of population overflow from the Tabriz metropolis into neighboring villages, both in Espiran and Aji-Chay Districts, has enhanced transportation services in these villages. This includes the allocation of public transportation lines, increased diversity and security on village roads, and an overall increase in their sustainability scores.

This sustainability, while facilitating travel, has reduced environmental impacts and fuel consumption levels and has increased integration among villages, which is consistent with the research of Miralles-Guasch et al. (2015), Camarero et al. (2016), and Lopez Iglesias et al. (2018). The livelihoods and employment of villagers in these areas have also been greatly affected, from facilitating access to markets to employing more people in Tabriz City or nearby factories. These results align with the research of Kaiser et al. (2022), Prus and Sikora (2021), and Kristof and Janne (2019).

According to various studies, improving and developing rural transport infrastructure is crucial for enhancing the sustainability of rural transport, passenger traffic, and goods exchange. Interventions such as institutionalization and the expansion of support services are appropriate strategies to increase sustainability and improve rural transportation.

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Conflict of Interest

The authors declared no conflicts of interest.

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