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Invisible Walls to Green Mobility: Barriers to Sustainable Transportation in Izmir

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ABSTRACT

The need for sustainable transportation has come to the forefront due to rapidly increasing population growth in metropolitan areas, increasing motor vehicle use, and deepening environmental problems. Izmir, the third-largest city in Turkey, has faced multidimensional transportation problems such as traffic congestion, air pollution, inadequate public transportation infrastructure, and social injustice in transportation. In order to solve these problems, it is necessary to systematically identify and prioritize the barriers to sustainable transportation throughout the city. In this study, the SWARA (Step-wise Weight Assessment Ratio Analysis) method, a popular Multi-Criteria Decision-Making (MCDM) method, was used to evaluate the barriers to sustainable transportation in Izmir under five different main dimensions: "environmentally friendly transportation," "inclusive and accessible transportation," "public transport quality," "governance and digitalization," and "safe urban mobility." This method was applied to evaluate barriers to sustainable transportation in Izmir. The findings revealed that geographical/topographical constraints, lack of funding for accessibility, lack of digital infrastructure, and lack of emergency notification systems are the most important barriers to the development of sustainable transportation. This study provides a quantitative prioritization framework for decision-makers in developing sustainable transportation strategies in Izmir and highlights the need for holistic, data-driven planning approaches. As a result, the prioritized barriers and constraints identified contribute to the strategic planning and roadmap development in sustainable transportation for relevant stakeholders, especially Izmir's transportation department.

1. Introduction

In addition to the conveniences brought by technological developments in transportation facilities and the benefits that transportation provides to people, the search for minimizing the inevitable negative effects has led to the development of sustainable transportation. Increasing use of motor vehicles has brought many problems such as air pollution, greenhouse gas emissions, noise pollution, traffic accidents, traffic congestion, energy consumption and excessive use of natural

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resources. Transportation is one of the largest contributors to air pollution problems, accounting for 24% of global CO_2 emissions and about 20% of total global energy consumption [1]. The resulting multidimensional negative impacts have made it necessary to consider transportation systems not only as a technical infrastructure service, but also as an area that needs to be managed in an integrated manner with the environment, society and economy.

Sustainable transport can be defined as an approach that aims to minimize the negative impacts of environmental and social problems caused by transport systems, while at the same time meeting the mobility needs of current and future generations by considering human health, social justice and economic development goals. Accordingly, transportation is not only a technical service, but also a social system that is compatible with the principles of environmental sustainability, social inclusion and economic accessibility [2].

There are many obstacles to the implementation of sustainable urban transportation policies, including environmental sensitivity, irregular urbanization, population, etc. In this context, Chun *et al*., [3] predicted that there are two obstacles to sustainable urban transportation: the first of these is the intensive use of automobiles as a result of the traditional urban and transportation planning that encourages the use of private vehicles, and the second is the inability to share the problems and costs created by the transportation system fairly on individuals; that is, the inability to ensure social justice.

Our study is applied in the province of Izmir. Izmir is the 3rd largest city in Turkey. Transportation problems in Izmir are increasing due to the city's rapid growth and population density. According to TurkStat data on the population growth of Izmir, the population of Izmir will reach 4 million 493 thousand by 2024 [4]. Throughout the world, there is a continuous flow of population from rural areas to cities for personal, economic, social and various other reasons. This flow increases the population in cities and increases population density. In Izmir, transportation problems arise due to increased migration. Improvements and innovations should be implemented in Izmir region in terms of transportation. Izmir is one of the most important nodes of the country with road, rail or air connections to all other major cities of the country. As a growing city, Izmir faces problems such as traffic congestion, increased commute times, lack of parking spaces, inadequate public transportation, incomplete infrastructure for bicycle traffic, and increased environmental pollution and energy consumption. Addressing these issues and promoting sustainable and people-centered development in the light of Turkey's national strategies/targets has become inevitable for Izmir. The key issue here is how to identify a green mobility development pathway that is appropriate to Izmir's urban structure [5].

The SWARA method used in the study is a multi-criteria decision-making method that helps experts to determine criteria weights based on ranking and relative comparisons of criteria in decision-making problems and is realized in 6 steps. In the application of the developed method, it is important to select experts on the subject. The method gains a more objective quality with the ranking made by experts in criteria evaluation. The main advantages of the method are the ease of application of mathematical operations as well as the use of expert opinions in the calculation of criteria weights [6-9].

2. Literature Review

Urban transportation systems involve complex decision-making processes with a large number of conflicting criteria. In this context, CRM methods are widely used in areas such as transportation strategy evaluation, policy prioritization and infrastructure planning. SWARA, which is one of the CRM methods, provides a systematic clarity to the decision-making process in environments with multidimensional and conflicting criteria such as urban transportation. In this context, in the literature, Radović and Stević [8] selected 20 of the 62 performance indicators related to transportation and weighted them with SWARA and found that transportation distance and vehicle utilization are the prominent criteria. Erturgut and Koç [10] evaluated the performance of urban transportation lines in the case of Ankara by integrating SWARA and ARAS methods and defined the maximum passenger capacity as the most important criterion. In the study conducted by [11], the choice of transportation mode in the trade of logistics companies with Western European countries was evaluated with SWARA and MARCOS methods and road transportation was determined as the most suitable option. Stević *et al.,* [12] addressed the limitations of fuzzy SWARA and proposed an improved version of IMF SWARA. Keshavarz-Ghorabaee [13] evaluated transportation emission reduction policies using the SWARA II method and found that active public transportation is an important policy for reducing carbon emissions. Bouraima *et al.,* [14] analyzed sustainable railway systems in West Africa with IRN (Improved Rough Number) SWARA and CoCoSo (Combined Compromise Solution) model. Moslem *et al.,* [15] evaluated public transportation service quality in Mersin with the integration of Imf SWARA using fuzzy Bonferroni operator. Traceability factor was found to be an important factor in Mersin transportation. Kabakuş and Eyüboğlu [16] evaluated the factors affecting pedestrian safety with SWARA method.

A summary of the literature review on the use of SWARA method, one of the multi-criteria decision-making approaches, in the transportation sector is given in Table 1. When the studies within the scope of the research are examined, it is seen that the application area of the SWARA method in the transportation sector has a wide scope and the frequency of use has increased in recent years.

Table 1
Literature review

Authors	Method	Implementation Area	Region
Radović and Stević [8]	SWARA	Evaluation of performance indicators in transportation	Bosnia and Herzegovina and Serbia
Erturgut and Koç Ustalı [10]	SWARA ve ARAS	Urban rail transportation performance evaluation	Ankara
Pajić *et al.,* [11]	MCDM methods, SWARA, MARCOS	Sustainable logistics	Transportation from Serbia to Germany
Stević *et al.,* [12]	Improved fuzzy SWARA	Logistics	
Keshavarz-Ghorabaee *et al.,* [13]	SWARA II f	Transportation emission policies	
Bouraima *et al.,* [14]	an integrated IRN SWARA, IRN CoCoSo method	Sustainable railway systems	West Africa
Moslem *et al.,* [15]	An integrated IMF SWARA and Fuzzy Bonferroni operator	Urban bus transportation (Mersin case study)	Mersin
Kabakuş and Eyüboğlu[16]	SWARA	Traffic safety	Turkey

3. Methodology

The SWARA method was developed to be used in determining criteria weights in multi-criteria decision-making problems [17]. The main advantages of choosing the SWARA method are as follows: (1) SWARA method has a simple and understandable mathematical structure. Therefore, it can be used effectively in group decision-making processes where experts can exchange views; (2) The complexity of the mathematical structure does not increase even if the number of criteria increases. This makes it suitable for complex models with a large number of decision attributes; and (3) SWARA method allows the processing of data based on different evaluation scales. This flexibility allows the method to be easily adapted to specific situations [18-23].

The application steps used to determine the criteria weights in the SWARA method are as follows [19]:

Step 1: The criteria are ranked in descending order of importance.

Step 2: Starting from the second criterion, the participant expresses the relative importance of criterion j with respect to the previous (j-1) criterion for each criterion. This ratio is called the comparative importance of the average value, s_j [17].

Step 3: The coefficient kj is calculated according to the following equation.

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \tag{1}$$

Step 4: The variable qj is calculated according to the following equation.

$$q_j = \begin{cases} 1 & j = 1 \\ (q_j - 1)/k_j & j > 1 \end{cases} \tag{2}$$

Step 5: The relative weights of the evaluation criteria are calculated as follows. Where w_j denotes the relative weight of the j^{th} criterion.

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{3}$$

4. Identification of Sustainable Transportation Barriers

The barriers to transportation in Izmir were assessed in 5 main dimensions (Sustainable and environmentally friendly transportation, inclusive and accessible transportation, improving the quality of public transport, governance and digitalization, safe urban mobility) and 25 sub-dimensions, considering environmental, economic and social dimensions. Existing barriers were obtained from Izmir ESHOT transportation department and literature research and are given in Figure 1.

i. Sustainable and environmentally friendly transportation: environmentally friendly, cleaner, greener transportation. It minimizes negative impacts on the environment and human health.
ii. Inclusive and accessible transportation means that everyone can access and use any place and any service independently and safely at any time.
iii. Improving the quality of public transport aims to increase users' use of public transport by improving service quality, timeliness and safety.
iv. Governance and digitalization aim for open, transparent and integrated systems in management. Increasing digitalization in transportation management with smart systems.
v. Safe urban mobility is a movement that aims to make communities healthier, safer, more livable and sustainable.

Fig. 1. Five main dimensions and 25 sub-dimensions

5. Results

Step 1: Five experts from the Izmir Municipality General Directorate of Electricity, Water, Gas, Bus and Trolleybus (ESHOT) were consulted. Information about the decision makers is given in Table 2. A questionnaire on obstacles to the application of the criteria was administered to the decision makers. 5 decision makers participated in the questionnaire. Decision makers (DMs) ranked the evaluation criteria from 5 to 1 from the most important to the least important for them. Sustainable and environmentally friendly transportation criterion was evaluated by decision maker-1 and the criteria ranking is given in Table 2. This study was conducted within the Department of Transportation and Directorate General of ESHOT in Izmir, Turkey. To apply the SWARA method, a survey was administered to a total of five ESHOT employees on two separate occasions, specifically on May 5 - 20, 2025.

Table 2
Criteria ranking according to decision makers

Criteria	DM1	DM2	DM3	DM4	DM5
C1.1	5	4	3	5	5
C1.2	4	3	1	2	2
C1.3	2	2	4	1	1
C1.4	1	1	2	3	4
C1.4	3	5	5	4	3

Step 2: The s_j value was determined by comparing the criteria with each other (Table 3). Decision makers rated the importance of the first criterion over the second criterion, the second criterion over the third criterion, the third criterion over the fourth criterion, and the fourth criterion over the fifth criterion, starting with the second criterion.

Table 3
Comparative importance of criteria at the level of decision makers

	DM1		DM2		DM3		DM4		DM5	
	Criteria	s_j	Criteria	s_j	Criteria	s_j	Criteria	s_j	Criteria	s_j
1	C1.1		C5		C5		C1		C1	
2	C1.2	0.3	C1	0.7	C3	0.8	C5	0.1	C4	0.2
3	C1.5	0.3	C2	0.9	C1	0.6	C4	0.3	C5	0.2
4	C1.3	0.2	C3	0.5	C4	0.5	C2	0.1	C2	0.4
5	C1.4	0.2	C4	0.8	C2	0.3	C3	0.1	C3	0.2

Step 3: The kj coefficient for each decision maker was calculated. For this purpose, for example, in the criteria ranking of the first decision maker, the first ranked criterion was given a value of one, and for the other criteria, a value of one was assigned to the criterion determined in the previous step.

One was added to the sj value. This process was repeated for all criteria and decision makers. Then, the value of qj was found with the help of equation (2) and the value of w_j was found with the help of equation (3). The results are given in Table 4.

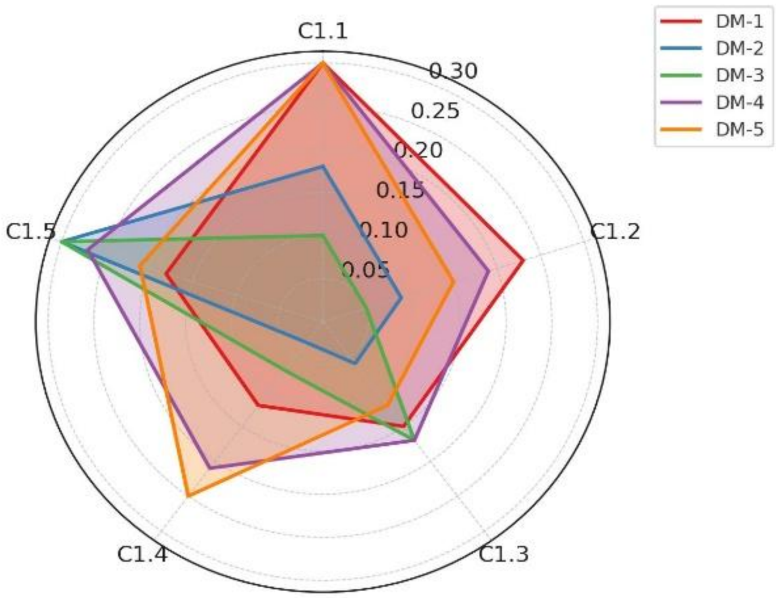
Table 4
Values of the first decision maker

Row	DM1				
	Criteria	s_j	k_j	q_j	w_j
1	C1.1		1	1	0.306
2	C1.2	0.3	1.3	0.769	0.235
3	C1.5	0.3	1.3	0.591	0.181
4	C1.3	0.2	1.2	0.493	0.151
5	C1.4	0.2	1.2	0.410	0.125

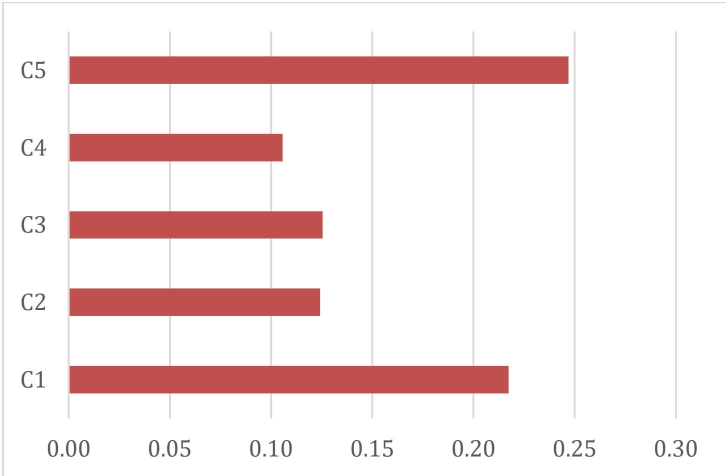
Step 4: In the last step, the geometric mean of the criteria weights calculated for all decision makers was taken and thus the common criteria weights were calculated (Tables 5-9). The results are presented in Table 5 and Figure 2.

Table 5
Weights of criteria (1) calculated on the basis of decision makers

Criteria	DM-1	DM-2	DM-3	DM-4	DM-5	G. O	Ranking
C1.1	0.31	0.18	0.11	0.31	0.31	0.22	2
C1.2	0.24	0.09	0.05	0.19	0.15	0.13	4
C1.3	0.15	0.06	0.17	0.18	0.13	0.13	3
C1.4	0.13	0.04	0.07	0.21	0.26	0.11	5
C1.5	0.18	0.31	0.31	0.28	0.21	0.25	1



(a) Radar Chart



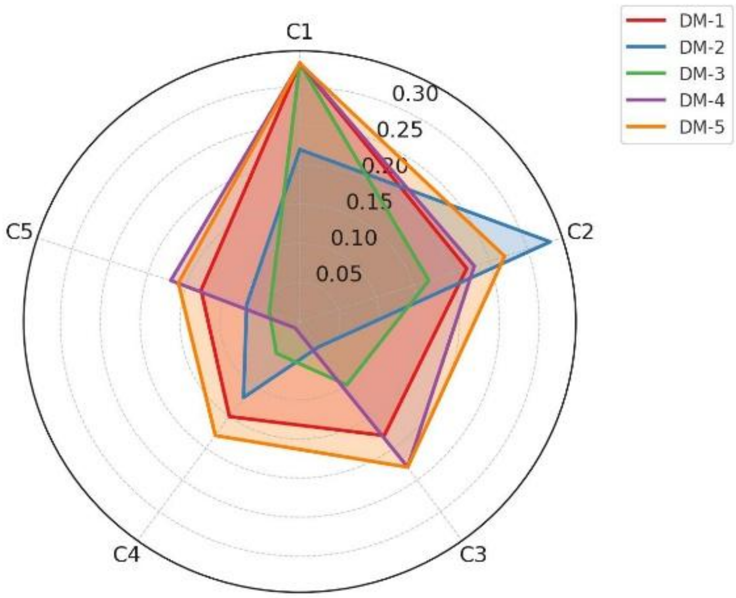
(b) Clustered horizontal bar chart

Fig. 2. Result graphs 1 (a) Radar Chart Based on Criteria and Decision Makers (b) Clustered horizontal bar chart (1) based on geometric mean

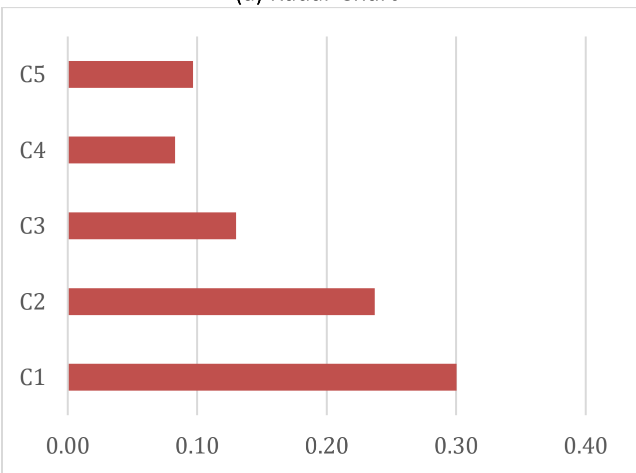
According to the obtained criteria weights, the most important transportation barrier in the first main criterion of sustainable and environmentally friendly was found to be geographical or topographical constraints (e.g. hills, narrow streets) with the number (1.5). The least important criterion was found to be the inaccessibility of green technology suppliers criterion (1.4).

Table 6
Weights of criteria (2) calculated on the basis of decision makers

Criteria	DM-1	DM-2	DM-3	DM-4	DM-5	G. O	Ranking
C2.1	0.33	0.22	0.33	0.33	0.33	0.30	1
C2.2	0.22	0.33	0.17	0.23	0.27	0.23	2
C2.3	0.18	0.04	0.10	0.23	0.23	0.12	3
C2.4	0.15	0.12	0.06	0.02	0.19	0.08	5
C2.5	0.13	0.07	0.04	0.17	0.16	0.09	4



(a) Radar Chart



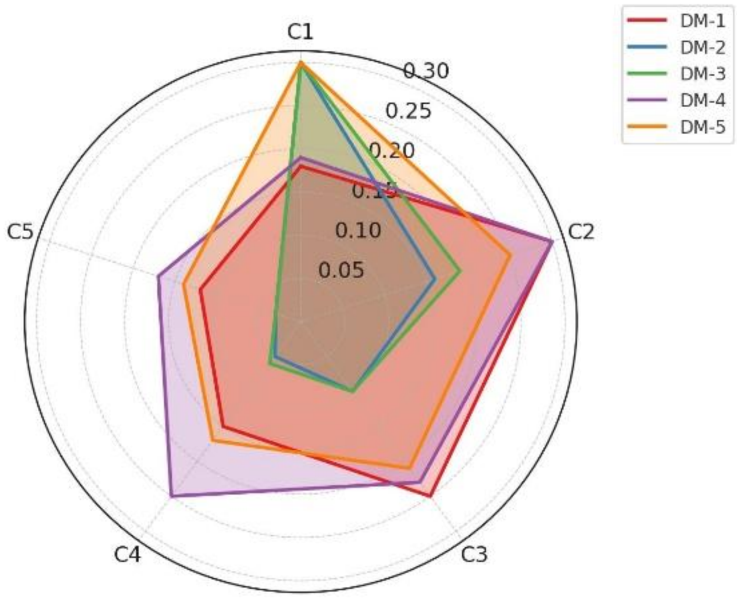
(b) Clustered horizontal bar chart

Fig. 3. Result graphs -2 (a) Radar Chart Based on Criteria and Decision Makers (b) Clustered horizontal bar chart (2) based on geometric mean

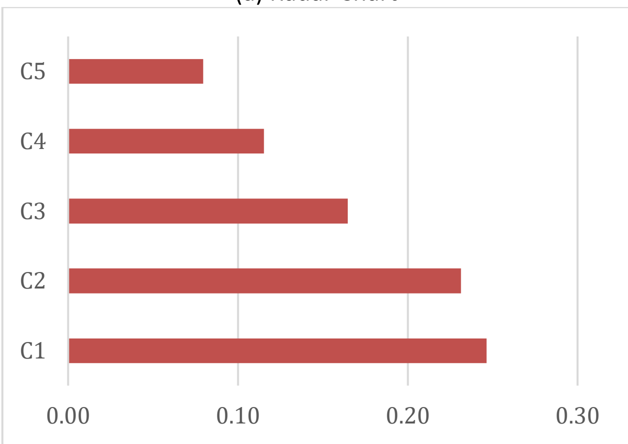
According to the criteria weights obtained (Table 6 and Figure 3), the most important transportation barrier in the second main criterion of inclusive and accessible transportation was found to be (2.1) insufficient funding for accessibility improvements. The most important criterion was found to be the criterion (2.4) of resistance to the redesign of urban space.

Table 7
Weights of criteria (3) calculated on the basis of decision makers

Criteria	DM-1	DM-2	DM-3	DM-4	DM-5	G. O	Ranking
C3.1	0.18	0.30	0.30	0.19	0.30	0.24	1
C3.2	0.30	0.16	0.19	0.30	0.25	0.23	2
C3.3	0.25	0.10	0.10	0.23	0.21	0.16	3
C3.4	0.15	0.05	0.06	0.25	0.17	0.11	4
C3.5	0.12	0.03	0.03	0.17	0.14	0.07	5



(a) Radar Chart



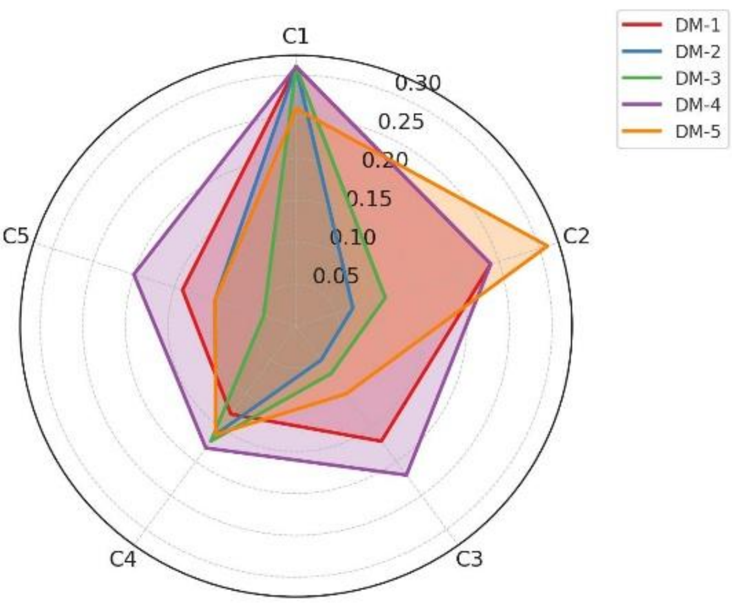
(b) Clustered horizontal bar chart

Fig. 4. Result graphs-3 (a) Radar Chart Based on Criteria and Decision makers (b) Clustered horizontal bar chart (3) based on geometric mean

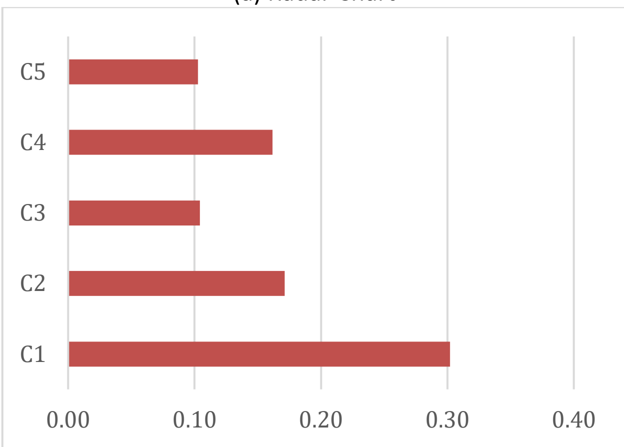
According to the obtained criteria weights (Table 7 and Figure 4), the most important transportation barrier in the third main criterion of improving the quality of public transport is the lack of data systems for real-time service adjustments (3.1). The least important criterion was found to be the criterion (3.5) of poor public perception of public transportation reliability.

Table 8
Weights of criteria (4) calculated based on decision makers

Criteria	DM-1	DM-2	DM-3	DM-4	DM-5	G. O	Ranking
C4.1	0.31	0.31	0.31	0.31	0.26	0.30	1
C4.2	0.24	0.07	0.11	0.24	0.31	0.17	2
C4.3	0.17	0.05	0.07	0.22	0.10	0.10	4
C4.4	0.13	0.16	0.17	0.18	0.16	0.16	3
C4.5	0.14	0.10	0.04	0.20	0.10	0.10	5



(a) Radar Chart



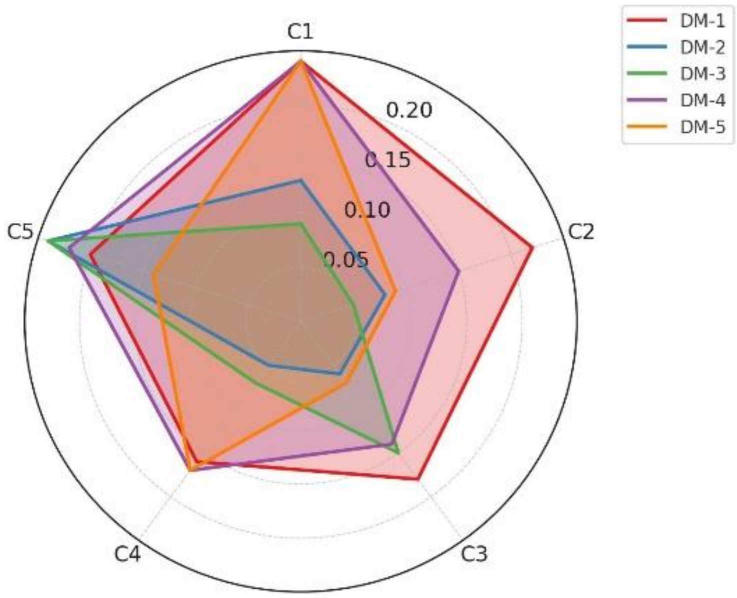
b) Clustered horizontal bar chart

Fig. 5. Result graphs-4 (a) Radar Chart Based on Criteria and Decision Makers (b) Clustered horizontal bar chart (4) based on geometric mean

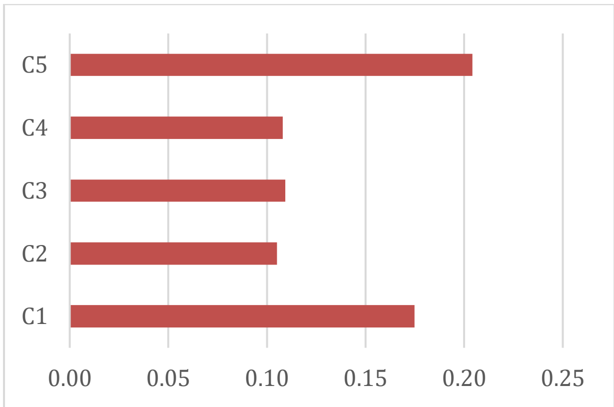
According to the criteria weights obtained (Table 8 and Figure 5), the most important transportation barrier in the fourth main criterion of governance and digitalization was found to be the lack of integrated digital infrastructure (4.1). The least important criterion was found to be the resistance to adopt smart systems criterion (4.5).

Table 9
Weights of criteria (5) calculated on the basis of decision makers

Criteria	DM-1	DM-2	DM-3	DM-4	DM-5	G. O	Ranking
C5.1	0.24	0.13	0.09	0.24	0.24	0.17	2
C5.2	0.22	0.08	0.05	0.15	0.09	0.11	5
C5.3	0.18	0.06	0.15	0.14	0.07	0.11	3
C5.4	0.16	0.05	0.07	0.17	0.17	0.11	4
C5.5	0.20	0.24	0.24	0.22	0.14	0.20	1



Radar Chart



(b) Clustered horizontal bar chart

Fig. 6. Result graphs-5 (a) Radar Chart Based on Criteria and Decision Makers (b) Clustered horizontal bar chart (5) based on geometric mean

According to the obtained criteria weights (Table 9 and Figure 6), the most important transportation barrier in the fifth main criterion of safe urban mobility was found to be (5.5) no public emergency reporting system (e.g. panic button). The least important criterion was found to be (5.2) inadequate driver training programs.

6. Conclusions

In this study, a decision support system has been developed to identify the obstacles and constraints to sustainable transportation in Izmir, the 3rd largest city in Turkey, which is constantly receiving migration due to its high number of job opportunities, location and social structure. Five main criteria (environmentally friendly transportation, inclusive and accessible transportation, quality of public transportation, governance and digitalization, safe urban mobility) and 25 sub-criteria (environmentally friendly transportation, inclusive and accessible transportation, quality of public transportation, governance and digitalization, safe urban mobility) were analyzed based on expert opinions. A hierarchical structure was created under the assumption that the five different main criteria are independent among themselves. The obstacles under the main problems were weighted and ranked according to their importance using the SWARA method. Through this method, the barriers are compared with each other in a ranked manner and expert opinions are also taken into account. According to the results, under the main dimension of sustainable and environmentally friendly transportation, geographical and topological constraints are the most important obstacles, and the natural structure of the province, being a city built on hilly terrain and a historical city of 5000 years, causes great difficulties in the creation of narrow historical roads, especially bicycle paths, electric vehicle infrastructure. These physical barriers are a problem that requires intervention as a priority. Within the scope of Inclusive and Accessible transportation, “Inadequate financial support for accessibility improvement” is seen as the most important barrier. Improving transportation infrastructure for people with disabilities, the elderly and people with limited mobility are public investments and costly projects. Their delay and lack of financial support directly affect the social justice dimension of sustainable transportation. Under the main dimension of improving the quality of public transportation, “Lack of data systems for real-time service adjustments” prevents instant monitoring of passenger density and necessary interventions (preventing bus/metro congestion, rescheduling frequencies, etc.). This reduces the reliability and efficiency of public transportation. This situation leads individuals to use private vehicles and increases the traffic problem. 4. The biggest obstacle under the main dimension of Management and Digitalization is “Lack of integrated digital infrastructure” The fact that the systems used in transportation management are not integrated with each other (ticketing, traffic control, mobile applications, etc.) makes it difficult for decision makers to make data-based management. This both reduces service quality and causes difficulties in strategic planning. Finally, “Lack of public emergency reporting system” is the most important constraint under the Safe urban mobility dimension. The inadequacy of the system that allows public transportation users to notify the authorities immediately in case of emergencies constitutes an important obstacle in sustainable transportation. This situation may reduce the confidence of women, children and elderly people in the transportation system. These results provide a concrete roadmap for decision makers in the process of implementing sustainable transportation policies. Interventions in line with the prioritized criteria will ensure more effective use of limited public resources and make significant contributions to achieving sustainability goals. In addition, although this study was developed specifically for Izmir, it can be considered as a decision support tool that can be taken as a model for cities of similar sizes. In the future study, it is aimed to create visual decision support systems by mapping the spatial distribution of the identified obstacles, neighborhoods with low accessibility, and regions with lack of digital infrastructure with Geographic Information Systems (GIS).

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Conflicts of Interest
The authors declare no conflicts of interest.

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