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Evaluation of urban transportation preferences with analytical hierarchy process method

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Abstract

This study aims to analyze the inner-city transportation modes and rank them according to some predetermined criteria for the city of Bursa. The Analytical Hierarchical Process (AHP) method, a Multiple Criteria Decision Making (MCDM) method, was used to create a general ranking for the modes of vehicles operating within the city. A total of seven criteria that affect the choice of transportation type were considered in this study. These are price, prestige, comfort, timely arrival, safety, ease of payment, and courtesy. A group of experts was consulted to determine the importance of these criteria. Safety, on-time arrival, and courtesy were the most critical factors for this analysis. Four modes, UBER, taxi, minibus, and bus, were used as alternative transportation modes. The AHP method was used to estimate weighted average scores of seven criteria for four-mode alternatives. The AHP analysis results indicate that the most preferred inner-city transportation alternative is UBER, followed by taxi, bus, and minibus.

Keywords Transportation · AHP · Transportation modes

JEL Classification C02 · C11 · C45 · C46 · C63

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1 Introduction

Urban transportation is related to the movement of people and goods within a populated area. People move around for different purposes within the city where they live. In addition to routinely using transportation modes between home and work, they travel within the city for leisure. Individuals have alternatives to transportation systems based on the level of infrastructure development in their town. Therefore, as a city's socioeconomic development level increases, the quality of transportation systems and the number of alternatives are expected to increase.

Transportation actively improves the economy by providing access to trade and services in various sectors. The transportation system impacts population dynamics, urbanization, urban planning, economic growth, and environmental quality. Besides, the development of transportation systems in major cities has contributed positively to the economy (Buwana et al. 2016). Transport mobility is critical for livable communities and facilitates social participation, communication and information sharing, and civil participation (Fields et al. 2020). People's preferences and selection criteria for urban transportation systems vary at different times and occasions. Thus, individuals can levy different degrees of importance on these criteria. For this reason, it will be possible to determine the decisions to be made on a numerical scale (Görçün, 2018; Wolnowska and Konicki 2019).

Multi-Criteria Decision Making (MCDM) methods are used to determine preferences for urban transportation systems and to support the decision-making process in complex decision-making systems where there are many factor variants in quantity and quality (Trzaskalik 2014; Papapostolou et al. 2020). In this respect, the AHP, one of the most frequently applied methods in solving general decision problems and determining the priority/weights of selection alternatives, was used (Lyu et al. 2020). The AHP is a structured method to analyze and solve complex decision problems by separating them and synthesizing comparative judgments and priorities (Saaty 1980; Achu et al. 2020). The AHP decomposition of a problem captures the essential elements of the problem and develops a hierarchical structure by organizing goals, objectives, features, and alternatives (Achu et al. 2020; Chen 2020). Accordingly, MCDM methods can determine preferences for urban transportation systems. The AHP method is used to simplify complex decision problems. The decision maker develops an understanding of the definition and elements of the problem. AHP allows decision problems to include both objective and subjective thoughts in the decision process. The AHP method is more suitable for group decisions compared to other multi-criteria decision-making methods (Ömürbek and Şimşek 2014). AHP can make pairwise comparisons between criteria using the eigenvalue approach and is the best multi-criteria decision-making method that calibrates the numerical scale used in measuring quantitative and qualitative performance (Vaidya and Kumar 2006).

In this study, the AHP has been selected to evaluate individuals' preferences and selection criteria for urban transportation systems.

This paper is organized as follows: Sect. 2 presents the literature review; Sect. 3 presents the methodology and discusses the study's results for evaluating transportation modes using seven pre-selected criteria. Finally, Sect. 4 offers the conclusion and recommendations for further research.

2 Literature review

Transportation creates economic value and is closely related to other sectors. Therefore, it is an essential intermediate service and one of the most critical elements of economic life. Various applications and decision processes are presented in transportation decision systems. Transportation mode selection requires a multi-criterion decision-making method since several choices and criteria sometimes contradict each other.

The AHP method has effectively selected many transportation methods for the last 25 years. Figure 1 shows how transportation selection studies use the AHP method. In this context, the AHP method is better for determining the best transportation mode choice.

Görçün (2018) has tried to determine the best preference factors for urban transportation systems by using the AHP method with nine factors and five decision choices. Eren et al. (2018) studied alternative tram vehicles for urban transportation using the AHP and fuzzy AHP methods.

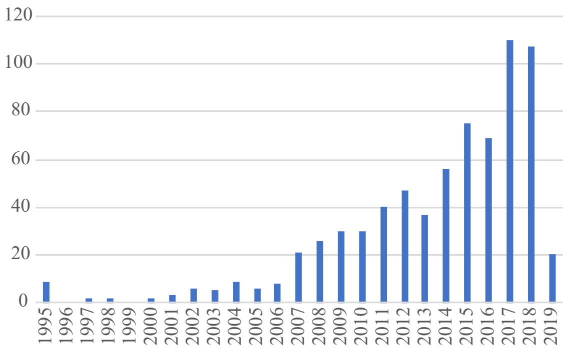
Özbek and Demirkol (2018) evaluated the economic performance of logistics companies with Step-Wise Weight Assessment Ratio Analysis (SWARA), a multi-criteria decision-making method, and they considered the economic performance of the options using the Gray Relational Analysis (IGO) method.

Günay and Ünal (2016) used the AHP-TOPSIS method to choose a telecommunications company's suppliers. Achu et al. (2020) used the GIS and AHP method, multi-criterion decision analysis, to identify potential groundwater regions in a tropical river basin by remote detection.

Dağdeviren and Yüksel (2008) used the AHP method, and they concluded that the detection and correction of misbehavior in the workplace were very important both for employees and companies.

Radivojević and Gajović (2013) determined their share of supply chain risk categories using the AHP and fuzzy AHP methods in supply chain risk modeling. Singh et al. (2018) used a fuzzy AHP and TOPSIS approach to select the cold chain's third-party logistics (3PL). Ding et al. (2008) used the fuzzy AHP approach for the Performance Assessment Model for a Transportation Corridor. Wang et al. (2016) evaluated three alternative modes of transportation for Kinmen military logistics for four primary and 13 sub-criteria with the fuzzy AHP method.

Fig. 1 Site selection studies using the AHP method for the last 25 years (Web of Science)



3 Methodology

The AHP method used in the study is discussed in this section. AHP is one of the most frequently used methods in the literature because of its computability, flexibility in terms of better understanding by administrators and practitioners, and allowing solutions in different computer programs (Lyu et al. 2020). The AHP is primarily used in problems where the options are known, but the decision-making conditions cannot be expressed mathematically (Geng et al. 2020). The aim here is to determine the most suitable criteria and alternatives according to the determined criteria. In other words, we try to determine the option that contributes the most to the defined criteria (Benitez et al. 2020).

The analytical hierarchy process is the Multi-Criterion Decision-Making method, which allows decision-makers to model a complex problem in a hierarchical structure of goals, criteria, sub-criteria, and alternatives (Wolnowska and Konicki 2019). The AHP combines the importance of criteria and alternative preference metrics with a single overall score to sort decision alternatives based on binary comparison matrices (Carra et al. 2019; Ulloa et al. 2018). The AHP consists of three principles: separation, comparative judgment, and priority synthesis. Separation is related to the construction of the hierarchical structure of the model to reveal the problem (Hillerman et al. 2017; Kumar et al. 2019). The highest level represents the overall goal, the mid-level shows evaluation criteria, and the lowest level demonstrates decision alternatives. Figure 2 displays a three-level AHP structure. A comparative decision is a two-way comparison of factors of the same level to measure their contribution to the overall goal. A comparison matrix has been developed by comparing benchmark pairs or alternatives. Finally, compounded weight is calculated for each alternative based on preferences defined by prioritization and comparison matrices. Depending on the compound weight's value, each alternative's relative priority can be obtained, and the consistency of the results is measured using the consistency rate. As stated by Lee and Kozar (2012), a consistency rate smaller than 10% is considered sufficient to interpret the results.

A total of 63 comparative questionnaire questions were used in this study. AHP is evaluated independently of the criteria options since the AHP method requires familiarity and experience, knowing the criteria, sub-criteria, and alternatives specific to the study.

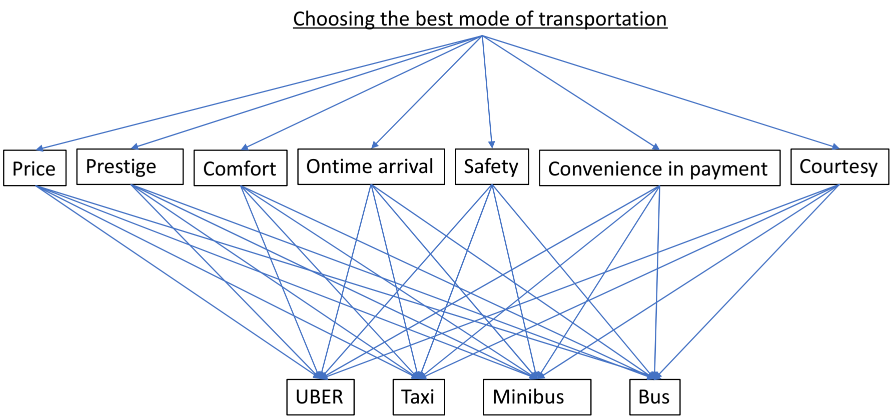


Fig. 2 Building hierarchy

An intensive literature review and expert opinions determined the criteria and the alternatives. The criteria include price (Alejandro et al., 2020), prestige, comfort, timely arrival (Żak and Kruszyński, 2015; Chen et al. 2020), security (Żak and Kruszyński, 2015), convenience and courtesy in payment (Alejandro et al., 2020; Reul et al. 2021). Mode alternatives are Uber, Taxi, Minibus and Bus (Görçün, 2018; Żak and Kruszyński, 2015; Jiao et al. 2021).

3.1 Basic scale usage

Step 1 Building the Hierarchy: Building the hierarchy to solve the problem requires care and precision. The hierarchy must show the most appropriate structure for solving the problem.

Step 2 Building of binary decision matrix: After building a decision hierarchy in the AHP, binary decision matrices are created so that the impact of the elements can be estimated on each other. The AHP method converts impact differences in decision points to percentage distributions using a predefined comparison scale. At this stage, the primary purpose is to determine the relative importance of the main criteria and sub-criteria and the effect of this importance on the overall goal (target). A 1–9 scale suggested by Saaty is used in comparisons (Aytürk 2006). A matrix of binary comparisons is created by using this scale.

Table 1 shows that the intermediate values are 2, 4, 6, and 8. The model uses a value of 4 if it stays undecided between 3 and 5 when making comparisons.

The AHP is limited to 9 criteria, as shown in Table 1. There are several reasons for this (Saaty and Vargas 2000; Forman and Peniwati 1998):

1. Saaty and Vargas suggested having less than ten criteria; the best results are obtained with seven. In other words, significant inconsistencies may occur if the number of criteria is greater than nine when solving multi-criterion decision-making problems with the AHP method.
2. If there are many elements in a matrix, this can cause more significant inconsistencies.

Step 3 Pair-wise comparison matrix: Binary comparisons are the most critical stage of the AHP. Relative and absolute measurements are used to obtain binary comparisons. By taking advantage of these comparisons, judgments at the AHP are converted into a matrix. The binary comparison matrix, n x n, is square; a_{ij} property i with j shows the binary comparison value of the property. The value of a_{ji} is the comparison value of the jth and ith criterion. If a_{ij} value has been given, this value is obtained from $a_{ji} = 1/a_{ij}$ equality. Saaty and Vargas (2000), Dyer (1990), and Saaty (1994) called this property the corresponding feature.

$A = \left(a_{ij}\right), i, j = 1, 2, 3, 4, \ldots \ldots \ldots n$ A is the judgement matrix

$$A = \begin{vmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \ldots & \vdots \\ a_{n1} & a_{n2} & \ldots & a_{11} \end{vmatrix} = \begin{vmatrix} 1 & a_{12} & \ldots & a_{1n} \\ 1/a_{12} & 1 & \ldots & a_{2n} \\ \vdots & \vdots & \ldots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \ldots & 1 \end{vmatrix} \tag{1}$$

Step 4 Binary Comparison Matrix in the AHP: The next step is normalizing the comparison matrix. To create a normalized comparison matrix (B), each A matrix element must be divided into the column total. Formula (1) is used for this purpose.

Table 1 Decision scale

Points	Definition	Explanation
1	Equally important	Both options contribute equally
3	A little more important	Experience and judgment make one criterion a little superior to another
5	Strongly important	Experience and judgment make one criterion superior to another
7	Very strongly important	One criterion is considered superior to the other, and this superiority is noticeable in practice
9	Extremely important	One criterion is decisively superior to the other
2, 4, 6, 8	Intermediate values	Values between two successive jurisdictions to be used when compromise is required

$$bij = \frac{a_{ij}}{\sum_{i=1}^{n} a_{iJ}}, i,j = 1, 2, \dots, n \tag{2}$$

Step 5 Determining criterion weights: This is an average of each row of the B matrix. Formula (2) is used to determine criteria weights (w).

$$Wi = \frac{\sum_{j=1}^{n} bij}{n} i,j = 1, 2, 3, \dots, \mathrm{n} \tag{3}$$

Step 6 **Measuring the consistency of the results:** The sixth and final stage of the AHP process is to measure the consistency of the results. The weights of the criterion obtained are based on the objective judgments of the decision-makers. The consistency of these objective judgments is calculated using formula (3) (Saaty 1980).

$$T_i = \frac{1}{n} \sum_{i=1}^{n} \left[\frac{\sum_{j=1}^{n} \left(a_{ij}\right)\left(w_{ij}\right)}{w_i} \right] \tag{4}$$

$$\mathrm{A} * \mathrm{W} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} * \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ \vdots \\ X_n \end{bmatrix} \tag{5}$$

$$\frac{t_i}{w_i} \forall_i \in n \, for \, \lambda_{\max=} \frac{\sum_{i=1}^{n} \frac{t_i}{w_i}}{n} \tag{6}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{7}$$

$$CR = \frac{CI}{RI} \tag{8}$$

The random index (RI) values in the equation are presented in Table 2.

If the consistency rate is above 0,10, the matrix is inconsistent. In this case, comparisons need to be reviewed. However, even if the consistency rate exceeds 0,10, the problem will be addressed and re-evaluated. The total weights of alternatives can be estimated based on the weights obtained. The decision-makers make their decision based on the weights. (Aytürk 2006).

Paired comparison matrices obtained from the survey were evaluated, those with a consistency ratio (CR) above 10% were repeated, and the average pairwise comparison matrices were obtained by taking the geometric mean of 25 results. According to Aczel and Saaty (1983), the geometric mean method is the best and only method for combining judgments.

This study used judgmental sampling. The sample population includes subject matter experts who used all four alternatives in the hierarchical model of the study. These experts participated in the questionnaires.

The UBER system was used in Turkey for a short time recently, but since it is not used now, the number of experts is limited, so it is thought that 25 people selected by the judgmental sampling method reflect the universe. AHP can be done by taking the geometric averages of one or more people's evaluations (Saaty and Vargas 2006).

3.1.1 The AHP application

A literature survey and expert opinions were used to determine criteria and alternatives. In this study, the criteria selected are price, prestige, comfort, timely arrival, safety, convenience in the payment, and courtesy. The criteria and alternatives are as follows:

Price: the amount of money required to purchase goods or services that a seller is willing to relinquish his right to the goods or services (Encyclopedia of Banking and Finance, 1962).
Prestige: reputation (Dutton & Dukerich 1991)
Comfort: physical and material well-being in travel (Siefert 2002)
On-time arrival: arriving at a destination at the scheduled time (Güçlü, 2001)
Security: reducing threats to important assets (Ergüven 2016)
Convenience in payment: ease of paying for services
Courtesy: kind behaviors that are not based on any fear of authority (Basım & Şeşen 2006)

According to the hierarchy model, questions were asked in binary comparison on a 1–9 scale. The subjects, who use each of the uber, taxi, minibus, and busses at least once a month, were determined randomly.

Twenty-five people used inner-city transportation systems effectively and regularly participated in the study. Each criterion is compared to the others in a binary comparison

Table 2 Random index values (Saaty 1994)

N	1	2	3	4	5	6	7	8
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41
N	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
RI	1.45	1.49	1.51	1.48	1.56	1.57	1.59	

matrix. The matrix is processed as a binary matrix component by taking the results' geometric average.

$$A = \begin{array}{c|ccccccc|} & C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 \\ C_1 & 1 & 3.72 & 1.54 & 0.33 & 0.30 & 0.45 & 0.41 \\ C_2 & 0.27 & 1 & 0.35 & 0.18 & 0.19 & 0.62 & 0.19 \\ C_3 & 0.65 & 2.86 & 1 & 0.40 & 0.28 & 0.75 & 1.18 \\ C_4 & 3.03 & 5.56 & 2.50 & 1 & 0.58 & 3.69 & 1.97 \\ C_5 & 3.33 & 5.26 & 3.57 & 1.72 & 1 & 3.58 & 2.86 \\ C_6 & 2.22 & 1.61 & 1.33 & 0.27 & 0.28 & 1 & 1.28 \\ C_7 & 2.44 & 5.26 & 0.85 & 0.51 & 0.35 & 0.78 & 1 \\ \sum = & \mathbf{12.94} & \mathbf{25.27} & \mathbf{11.14} & \mathbf{4.41} & \mathbf{2.98} & \mathbf{10.87} & \mathbf{8.89} \end{array}$$

A matrix is normalized by dividing each value by the total value of the column using Formula 2. The arithmetic average of each row of the normalized matrix shows the weight value for each criterion.

According to Formula 3, the arithmetic average of the row elements of the B matrix is calculated, and the W vector is created, indicating the distribution of the weight values of the selection criteria in percentage.

$$W^t = \left| 0.089 \quad 0.040 \quad 0.090 \quad 0.236 \quad 0.312 \quad 0.104 \quad 0.129 \right|$$

$$B = \begin{array}{c|ccccccc|} & C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 \\ C_1 & 0.078 & 0.150 & 0.140 & 0.070 & 0.100 & 0.040 & 0.050 \\ C_2 & 0.022 & 0.040 & 0.030 & 0.040 & 0.070 & 0.060 & 0.020 \\ C_3 & 0.050 & 0.110 & 0.090 & 0.090 & 0.090 & 0.070 & 0.130 \\ C_4 & 0.230 & 0.220 & 0.230 & 0.230 & 0.190 & 0.340 & 0.220 \\ C_5 & 0.260 & 0.210 & 0.390 & 0.390 & 0.340 & 0.330 & 0.330 \\ C_6 & 0.170 & 0.060 & 0.060 & 0.060 & 0.090 & 0.090 & 0.140 \\ C_7 & 0.190 & 0.210 & 0.120 & 0.120 & 0.120 & 0.070 & 0.110 \\ \sum = & \mathbf{1} & \mathbf{1} & \mathbf{1} & \mathbf{1} & \mathbf{1} & \mathbf{1} & \mathbf{1} \end{array}$$

The consistency level of the 7-criterion A matrix can be determined by Formula 4 for consistency. The components of the A matrix are multiplied with the weight vector by the sum of the W values, and the matrix used for consistency analysis is obtained using Formula 5. Each resulting value is divided into the element of the W vector on its row, determining the T vector.

$$T^t = \left| 7.235 \;\; 7.096 \;\; 7.500 \;\; 7.521 \;\; 7.343 \;\; 7.730 \;\; 7.341 \right|$$

The total value of the T vector can be obtained by taking the column sum using Formula 6. The lambda (λ) value can be reached when the total value is divided by the number of criteria (n).

$$\lambda = \frac{\sum_{i=1}^{n} \frac{t_i}{w_i}}{n} = \frac{51.766}{7} = 7.395$$

After the value of λ has been determined, the consistency indicator (CI) can be calculated according to Formula 7.

$$CI = \frac{\lambda - n}{n - 1} = \frac{7.395 - 7}{7 - 1} = 0.065$$

The consistency indicator value (*CI*) can be calculated, using Formula 8, as the consistency value (*CR*) when the random indicator (RI) value is divided by 1.32, which is presented in the table. Because the CR value is less than 0.10, it can be said that the comparison is consistent.

$$CR = \frac{CI}{RI} = \frac{0.065}{1.32} = 0.049$$

When the decision points are considered ($F_{1=}$ Uber, F_2 = Taxi, F_3 = Minibus, F_4 = Bus), the following A matrix is obtained when each decision alternative is subject to binary comparison within the framework of the specified preference criteria (Table 3).

Price

A =

	F_1	F_2	F_3	F_4
F_1	1	2.11	2.00	1.05
F_2	0.47	1	1.14	1.29
F_3	0.50	0.88	1	0.30
F_4	0.95	0.78	3.33	1
∑ =	2.92	4.77	7.47	3.64

B =

	F_1	F_2	F_3	F_4
F_1	0.342	0.442	0.267	0.288
F_2	0.161	0.210	0.153	0.354
F_3	0.171	0.184	0.134	0.083
F_4	0.326	0.164	0.446	0.275

$$\boldsymbol{J} = \begin{vmatrix} 0.3350 \\ 0.2195 \\ 0.1430 \\ 0.3025 \end{vmatrix}$$

4 Prestige

A =

	F_1	F_2	F_3	F_4
F_1	1	3.97	3.68	6.01
F_2	0.25	1	3.96	2.99
F_3	0.27	0.25	1	0.50
F_4	0.17	0.33	2.00	1
∑ =	**1.69**	**5.55**	**10.64**	**10.50**

B =

	F_1	F_2	F_3	F_4
F_1	0.591	0.715	0.345	0.572
F_2	0.148	0.180	0.372	0.285
F_3	0.159	0.045	0.094	0.048
F_4	0.101	0.059	0.188	0.095

$$\boldsymbol{J} = \begin{vmatrix} 0.556 \\ 0.246 \\ 0.086 \\ 0.110 \end{vmatrix}$$

Comfort

$$
A = \begin{array}{c|cccc|} & F_1 & F_2 & F_3 & F_4 \\ F_1 & 1 & 3.91 & 5.41 & 6.24 \\ F_2 & 0.26 & 1 & 3.49 & 3.83 \\ F_3 & 0.18 & 0.29 & 1 & 0.57 \\ F_4 & 0.16 & 0.26 & 1.75 & 1 \\ \sum = & \mathbf{1.60} & \mathbf{5.64} & \mathbf{11.65} & \mathbf{11.64} \end{array} \quad B = \begin{array}{c|cccc|} & F_1 & F_2 & F_3 & F_4 \\ F_1 & 0.625 & 0.716 & 0.464 & 0.536 \\ F_2 & 0.162 & 0.183 & 0.299 & 0.329 \\ F_3 & 0.112 & 0.053 & 0.086 & 0.049 \\ F_4 & 0.100 & 0.048 & 0.150 & 0.086 \end{array}
$$

$$
J = \begin{vmatrix} 0.585 \\ 0.243 \\ 0.075 \\ 0.096 \end{vmatrix}
$$

On-time Arrival

$$
A = \begin{array}{c|cccc|} & F_1 & F_2 & F_3 & F_4 \\ F_1 & 1 & 3.36 & 3.50 & 3.81 \\ F_2 & 0.30 & 1 & 3.37 & 3.77 \\ F_3 & 0.29 & 0.30 & 1 & 1.06 \\ F_4 & 0.26 & 0.27 & 0.94 & 1 \\ \sum = & \mathbf{1.85} & \mathbf{4.93} & \mathbf{8.81} & \mathbf{9.64} \end{array} \quad B = \begin{array}{c|cccc|} & F_1 & F_2 & F_3 & F_4 \\ F_1 & 0.540 & 0.681 & 0.397 & 0.395 \\ F_2 & 0.162 & 0.203 & 0.383 & 0.391 \\ F_3 & 0.157 & 0.061 & 0.113 & 0.110 \\ F_4 & 0.140 & 0.055 & 0.107 & 0.104 \end{array}
$$

$$
J = \begin{vmatrix} 0.503 \\ 0.285 \\ 0.110 \\ 0.101 \end{vmatrix}
$$

Safety

$$
A = \begin{array}{c|cccc|} & F_1 & F_2 & F_3 & F_4 \\ F_1 & 1 & 4.94 & 3.47 & 3.88 \\ F_2 & 0.20 & 1 & 2.85 & 2.17 \\ F_3 & 0.29 & 0.35 & 1 & 0.66 \\ F_4 & 0.26 & 0.46 & 1.52 & 1 \\ \sum = & \mathbf{1.75} & \mathbf{6.75} & \mathbf{8.84} & \mathbf{7.71} \end{array} \quad B = \begin{array}{c|cccc|} & F_1 & F_2 & F_3 & F_4 \\ F_1 & 0.571 & 0.732 & 0.392 & 0.503 \\ F_2 & 0.114 & 0.148 & 0.322 & 0.281 \\ F_3 & 0.166 & 0.052 & 0.113 & 0.086 \\ F_4 & 0.148 & 0.068 & 0.172 & 0.129 \end{array}
$$

$$
J = \begin{vmatrix} 0.549 \\ 0.216 \\ 0.104 \\ 0.129 \end{vmatrix}
$$

Convenience in payment

A =

	F_1	F_2	F_3	F_4
F_1	1	2.69	3.15	3.01
F_2	0.37	1	1.48	1.50
F_3	0.32	0.68	1	0.69
F_4	0.33	0.67	1.45	1
∑ =	2.02	5.04	7.08	6.20

B =

	F_1	F_2	F_3	F_4
F_1	0.495	0.534	0.445	0.485
F_2	0.183	0.198	0.209	0.242
F_3	0.158	0.135	0.141	0.111
F_4	0.163	0.133	0.205	0.162

$$\boldsymbol{J} = \begin{vmatrix} 0.489 \\ 0.208 \\ 0.136 \\ 0.166 \end{vmatrix}$$

Courtesy

A =

	F_1	F_2	F_3	F_4
F_1	1	3.76	5.67	5.91
F_2	0.26	1	3.39	3.16
F_3	0.18	0.29	1	0.36
F_4	0.17	0.32	2.78	1
∑ =	**1.61**	**5.37**	**12.84**	**10.43**

B =

	F_1	F_2	F_3	F_4
F_1	0.621	0.700	0.442	0.567
F_2	0.161	0.186	0.264	0.303
F_3	0.111	0.054	0.078	0.035
F_4	0.105	0.059	0.216	0.096

$$\boldsymbol{J} = \begin{vmatrix} 0.582 \\ 0.228 \\ 0.069 \\ 0.119 \end{vmatrix}$$

By creating normalized matrixes for all decision points, the averages of the row values of each matrix are obtained, and J vectors are obtained for all decision points. In the next step, vectors are combined to achieve H matrices. Then, priority scores can be obtained for each decision point when the total of each row of the H matrix is multiplied by the sum of W vector values.

Table 3 Criteria and alternatives

Criteria	Alternatives
C1: Price	F1: Uber
C2: Prestige	F2: Taxi
C3: Comfort	F3: Minibus
C4: Arrive on time	F4: Bus
C5: Safety	
C6: Convenience in payment	
C7: Courtesy	

$$\boldsymbol{H} = \begin{vmatrix} 0.335 & 0.556 & 0.582 & 0.503 & 0.549 & 0.489 & 0.582 \\ 0.219 & 0.246 & 0.243 & 0.284 & 0.216 & 0.208 & 0.228 \\ 0.143 & 0.086 & 0.075 & 0.110 & 0.104 & 0.136 & 0.069 \\ 0.302 & 0.110 & 0.096 & 0.101 & 0.129 & 0.166 & 0.119 \end{vmatrix}$$

$$S = \begin{vmatrix} 0.335 & 0.556 & 0.582 & 0.503 & 0.549 & 0.489 & 0.582 \\ 0.219 & 0.246 & 0.243 & 0.284 & 0.216 & 0.208 & 0.228 \\ 0.143 & 0.086 & 0.075 & 0.110 & 0.104 & 0.136 & 0.069 \\ 0.302 & 0.110 & 0.096 & 0.101 & 0.129 & 0.166 & 0.119 \end{vmatrix} * \begin{vmatrix} 0.0897 \\ 0.0403 \\ 0.0900 \\ 0.2360 \\ 0.3120 \\ 0.1040 \\ 0.1290 \end{vmatrix}$$

$$= \begin{matrix} 0.5207 \\ 0.2368 \\ 0.1045 \\ 0.1368 \end{matrix}$$

The most recently obtained matrix shows the preferred values of alternatives in percentages for all decision points. Accordingly, UBER (F_1) has a preference value of 52.07%, while taxi (F_2) has 23.68%, minibus (F_3) has 10.45%, and Bus (F_4) has 13.68%.

5 Conclusions

This study analyzed the inner-city transportation modes and ranked them according to some predetermined criteria for Bursa. The Analytical Hierarchical Process (AHP) method, a Multiple Criteria Decision Making (MCDM) method, was used to create a general ranking for the modes of vehicles operating within the city. According to the answers given, the geometric averages of the responses to the comparative severity of each factor were obtained, and the matrices were created. The ratings of the importance of each criterion and alternatives are determined by using these matrices, while at the same time, their consistency is estimated. Estimations are consistent. In case of a judgment discrepancy, the reasons for this should be reviewed again by the experts, and the consistency rate should be reduced below the acceptable level of 10%.

The model results suggest that the decision-makers attach the most importance to safety (0.312), followed by timely arrival (0.236), courtesy (0.129), convenience in payment (0.104), comfort in transportation (0.090), price (0.0897), and prestige (0.0403). Accordingly, the hierarchy of importance is safety > arrive on time > courtesy > convenience in payment > comfort > price > prestige.

The uber transportation system got the highest importance value with 0.5207, followed by taxis (0.2368), buses (0.1368), and minibus (0.1045). In this case, the decision hierarchy is uber > taxi > bus > minibus.

The suggested model can be applied to regional transportation preferences by increasing criteria and alternatives. This method also helps managers assess bottlenecks in transportation planning.

In a general evaluation, the AHP Method is very useful in selecting the best vehicle for decision-making. In this context, AHP is a valuable tool for the decision maker in choosing a vehicle or ordering the preferences for more than one vehicle. Therefore, the bottlenecks that may occur can be prevented by investing in the relevant vehicles for the managers in selecting urban vehicles.

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Data availability The data will be presented when it is needed.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Scientific content and ethical rules have been obeyed in this study.

Consent for publication All authors give their consent for the publication.

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