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DETERMINATION OF THE BEST TRANSPORT ALTERNATIVES BY ENTROPY BASED WASPAS METHOD: A COMPARATIVE STUDY ON CROSS-COMPETITIVE ROUTES

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ABSTRACT

Purpose- Users typically choose the option that is most convenient for them in terms of time or cost based on their preferences when multiple options are presented on the same line. In this regard, users' preferences are significantly impacted by the product components given by competing travel options. The aim of this study is to evaluate the criteria that are considered to be effective in competition and user preferences in transport corridors where there is cross-competition, and to rank the routes according to these criteria.
Methodology- In this context, transport corridors in Turkey and some European countries have been selected. The criteria evaluation of the selected routes was carried out using the Entropy method and then the ranking of the routes was carried out using the WASPAS method.
Findings- It can be seen that the London-Manchester air route is ranked first, while the Paris-Lyon air route is ranked last in the study. Taking into account the HSR ranking, the London-Manchester corridor is in first place, as in the airline sector. Among the selected routes, the Ankara-Istanbul HSR corridor is ranked the last. When it comes to bus transport, the Ankara-Istanbul route is in the top position. On the other hand, the Berlin-Frankfurt corridor comes last.
Conclusion- The results of the research are important in terms of understanding the factors that are effective in cross-competition By considering the performance criteria of these routes and their respective weightings, it can inform decisions related to the regulation of fares or the development of investment programmes to enhance the competitiveness of public transport modes such as High Speed Rail (HSR). In essence, this research fills a gap in transport decision studies by providing a comprehensive analysis of routes across all modes and providing actionable insights for policy makers.

Keywords: Cross competition, transportation modes, airline, WASPAS, entropy.
JEL Codes: D61, L91, L93.

1. INTRODUCTION

Cross-competition in the transportation industry refers to competition between several modes of transportation or among various transport providers (Airline, Coach or High Speed Rail: HSR) operating within a single mode. Competition for passengers or freight as well as initiatives to draw in and keep consumers are all included. The competitive environment may significantly affect the transportation system's effectiveness and efficiency. Additionally, there is cross-competition in the transportation industry, particularly in the distribution of transport flows among various modal subsystems (Costescu, 2018). Government rules and regulations are just one of the many variables that might affect competition in the transportation industry (Vilakazi, 2018). On the other hand, when multiple options are offered along the same route, consumers typically choose the one that best suits their needs in terms of cost or time. In this regard, users' preferences are significantly influenced by the product components provided by competing transport options.

Decisions related to the transport sector affect almost all aspects of human life in contemporary societies. Additionally, decisions are continually needed in the transportation sector, from strategic planning of projects and policies, to designing infrastructure projects, to choosing between alternatives, to putting specific policies into place (Yannis et al., 2020, p. 414). Therefore, decision-making is a crucial component of managing transport systems and typically entails steps like identifying current issues, defining the issue, and coming up with potential solutions (Karleuša et al., 2013, p. 620).

Complex decision making is an unavoidable part of any transport project. A large range of potential alternatives (answers to a stated issue) are available in addition to the numerous major repercussions that are present, many of which are frequently expressed in quantitative and qualitative terms (economic, environmental, technical, geographical, and social aspects) (Macharis & Bernardini, 2015, p. 177). There are occasions when a lot of parties are involved in the decision-making process. The decision-making process is complicated by all of these factors (Janic, 2003). Modeling, organizing, and structuring technologies give decision-makers an advanced tool for increasingly complex circumstances. It is possible to analyze several alternative projects or variants in accordance with various quantitative and qualitative criteria thanks to the Multi-Criteria Decision Analysis Aid (MCDA), which is derived from operations research (Stoycheva et al., 2018; Hansson et al., 2019).

Looking at the research in the literature, it is seen that there are many studies that use multi-criteria decision making methods in the field of transport, but some of them focus on areas such as pairwise comparisons (Sirikijpanichkul et al., 2017), while others focus on the evaluation of urban transport alternatives (Fearnley et al., 2018). Although there are studies that evaluate all transport modes together, it can be seen that these studies also examine areas such as transport policy (Hey et al., 1999), investment decisions (Cavone et al., 2018) or freight transport (Kopytov and Abramov, 2012). Unlike other studies, this study focuses on real corridors with similar characteristics where cross-competition in passenger transport exists.

The purpose of this study is to prioritize the factors that are thought to be important for user preferences and competitiveness in cross-competitive routes and to identify which route is superior in terms of these factors. Entropy and WASPAS approaches, which are among the multi-criteria decision-making techniques, were used to assess the effectiveness of a few selected routes in Turkey and Europe that had similar characteristics.

The remainder of the study is structured as follows. Firstly, a summary of the literature on the subject is given. This is followed by the methodology section, which presents the methods and data used in the analysis. The third section provides information on the application and explains the research findings. Finally, the conclusion and recommendations section is presented.

2. LITERATURE REVIEW

There are many studies in the literature on transport where more than one mode is evaluated together. Some of these are listed in Table 1.

Table 1: Literature Summary

Authors (Year)	Method	Scope
Giuliano (1985)	ELECTRE	Santa Ana corridor in CA, USA
Hey et al. (1999)	REGIME	Common EU transport policy
Tsamboulas and Kopsacheili (2003)	AHP-MAUT	Athens Olympic Games transportation policies
Arslan (2009)	Fuzzy AHP	Selection of appropriate transportation projects
Shelton and Medina (2010)	AHP-TOPSIS	El Paso, Texas transportation improvement
Ramani et al. (2010)	AHP-MAUT	Nonlinearity in Transportation Planning
Sawadogo and Anciaux (2011)	ELECTRE	Intermodal transportation in green supply chain
Kopytov and Abramov (2012)	AHP	Multi modal freight transport system
Hickman et al. (2012)	MCA	Oxfordshire sustainable transport
Barfod and Salling (2015)	AHP-SMARTER	Most attractive alternative between D-S
Cavone et al. (2017)	TPN-DEA	Intermodal terminal in Bari
Cavone et al. (2018)	Fuzzy DEA	Intermodal terminal planning with uncertainty
This Study	*ENTROPY-WASPAS*	*Ranking of 6 European city pair routes*

Note: AHP: Analytic Hierarchy Process; TOPSIS: Technique for Order Preference by Similarity to Ideal Solution; MAUT: Multi-attribute utility theory; TPN: Timed Petri Nets; ELECTRE: Elimination and Choice Expressing Reality; WASPAS: Weighted Aggregated Sum Product Assessment; MCA: Multi-criteria assessment; D-S: Denmark-Sweden; SMARTER: Simple Multi-Attribute Rating Technique Exploiting Ranks.

Giuliano (1985) used the ELECTRE method to identify criteria for transport investment planning in a case study of a transport corridor in Orange County, California. The results show that the method identifies a small set of significantly different best compromise transport investment alternatives. Hey et al (1999) evaluated scenarios for European transport policy using the REGIME multi-criteria decision making method and formulated some strategic policy implications for future EU policy.

Three commonly used MCDM methods are the foundation of the evaluation framework presented by Tsamboulas and Kopsacheili (2003), which offers a thorough framework for the strategic assessment of instruments for spatial and environmental transport policy. To assist in the selection of suitable transportation projects for implementation, Arslan (2009) proposes a decision support model that integrates public involvement and public supervision using the Fuzzy AHP technique. A streamlined methodology for rating transportation projects using an integrated multi-criteria decision making (MCDM) procedure for prioritizing transportation projects is presented by Shelton and Medina (2010) in their research.

Ramani et al (2010) evaluated the impact of considering the non-linearity of the selected value functions in order to develop a multi-attribute utility theory approach for transport planning applications. As a result of the research, it was concluded that non-linear value functions can differentiate project outcomes. Sawadogo and Anciaux (2011) evaluated intermodal transport in a green supply chain using the ELECTRE method. Kopytov and Abramov (2012) presented the AHP method as the most appropriate approach for comparative evaluation of different routes and modes of freight transport. Hickman et al. (2012) examined the selection of alternatives for sustainable transport in the context of the Oxfordshire case study. Barfod and Salling (2015) aimed to identify the most attractive transport alternatives between Denmark and Sweden using AHP and SMARTER methods. Cavone et al. (2017) analysed intermodal terminal planning with TPN-DEA and Cavone et al. (2018) analysed intermodal terminal planning under uncertainty conditions with Fuzzy DEA.

3. DATA AND METHODOLOGY

3.1. Entropy Weighting Method

In multi-criteria decision making, the weighting process is performed in two different ways, either objective or subjective. The determination of criterion weights is a common problem in many multi-criteria decision making (MCDM) techniques. It is important to pay special attention to the objectivity factor of criterion weights, considering that criterion weights can significantly affect the outcome of the decision making process (Odu, 2019, p. 1449). Objective weighting is more preferable because it provides healthier results in terms of analysis. Nowadays, many objective weighting methods are used together with MCDM. One of the most preferred methods among these objective methods is the entropy method (Zou et. al., 2006; Liu et. al., 2010). Although the entropy method was first proposed by Rudolf Clausius, it was not widely used. Later, the entropy method was used in the field of information by Shannon in 1948 (Wu et al., 2011, p. 5164). Wang et al. (2005) were the first to use the entropy method as a weighting method. The application steps of the entropy method are as follows (Wang and Lee, 2009, p. 8982).

Stage 1: The first step in the entropy method is to normalise the decision matrix..

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{1}$$

In the above equation; the value "*j*" represents the criteria, "*i*" the alternatives, "x_{ij}" the utilities and "p_{ij}" the normalised values.

Stage 2: In the second stage of the entropy method, the weight value " e_j " is calculated.

$$e_j = -k \sum_{j=1}^{n} p_{ij} ln p_{ij} \tag{2}$$

In the above equation, the value of "k" is calculated by the formula $(\ln(n))^{-1}$.

Stage 3: In the last step of the entropy method, after the " e_j " value and "$1- e_j$" values are calculated, the weight value " w_i " is calculated.

$$w_i = \frac{1 - e_i}{\sum_{i=1}^{m} (1 - e_i)} \tag{3}$$

In the above equation, the sum of " w_i " values is equal to 1.

3.2. Waspas Ranking Method

The WASPAS (Weighted Aggregated Sum Product Assessment) method, developed by Zavadskas et al. (2012), is defined as an integrated sum product assessment (Alinezhad and Khalili, 2019). The Waspas method, which is frequently used in MCDM, is a method that emerged as a result of the combination of the Weighted Sum Model (WSM) and the Weighted Product Model (WPM) models (Chakraborty and Zavadskas, 2014, p. 2). The Waspas method measures the performance of decision alternatives according to the relevant criteria by using the criterion weight value in multi-criteria decision problems and ranks the alternatives from best to worst as a result of the measurement (Chakraborty et al., 2015). The application steps of the Waspas method are described below (Chakraborty and Zavadskas, 2014: 2-3).

Stage 1: As in the entropy method, the decision matrix in the Waspas method is formed by Equation (4).

$$Y = [y_{ij}] = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} \quad (4)$$

Stage 2: In the second step of the Waspas method, the relevant alternatives are normalised using equation (5) if they are cost-oriented or equation (6) if they are benefit-oriented.

For cost-orientated criteria; $n_{ij}=\frac{x_{ij}}{max_i x_{ij}}$ i = 1, 2, …. m ve j= 1,2,…..n (5)

For benefit-orientated criteria: $n_{ij} = \frac{min_i x_{ij}}{x_{ij}}$ i = 1, 2, …m ve j= 1, 2, …. n (6)

Stage 3: In the third step of the Waspas method, the total relative importance value $Q_i^{(1)}$ for all alternatives according to the WSM (Weighted Sum Model) model is calculated with the help of Equation (7).

$$Q_i^{(1)} = \sum_{j=1}^{n} w_j n_{ij} \quad (7)$$

Stage 4: In the fourth step of the Waspas method, the relative product importance value $Q_i^{(2)}$ for all alternatives according to the WPM (Weighted Product Model) model is calculated by means of Equation (8).

$$Q_i^{(2)} = \prod_{j=1}^{n} n_{ij}^{wj} \quad (8)$$

Stage 5: In the fifth step of the Waspas method, as a result of the calculation process performed with both WSM and WPM models, the total relative importance value of the decision alternatives is determined with the help of Equation (9).

$$Q_i = \lambda Q_i^{(1)} + (1-\lambda)\, Q_i^{(2)} \quad (9)$$

The value of "λ" in the above equation can take a value between 0 and 1. If the value of "λ" is equal to 0, the relevant model becomes a weighted product model, and if it is equal to 1, the relevant model becomes a weighted total model.

Stage 6: In the sixth step of the Waspas method, the decision alternatives are ranked according to their "Q_i" values in order to make the final ranking of the decision alternatives. The decision alternative with the lowest "Q_i" value is considered the worst alternative, while the decision alternative with the highest "Q_i" value is considered the best alternative.

3.3. Data

The data obtained from secondary sources was used as a dataset in the research and information on the data in question is given in Table 2.

Table 2: Data Definitions

Data	Abv.	Definition / Calculation
Number of Firms Served	NFS	Number of companies (Airline-Coach or HSR) operating in the market
HSR/Coach/Airline Price for Km	MPRICEKM	Price for transport mode / Length of route
Total Price for Km	TPRICEKM	Total price that the user has to pay, including access to the transport mode / Total distance from centre to centre
Km for minutes	KMFM	Distance travelled in km per minute when travelling from centre to centre
Frequency	FREQ	Number of daily trips offered by the mode of transport on the route
Ratio of Access time to Travel Time	RATT	Ratio of access time from the centre to transport mode to travel time
Emissions for km (kg)	KMCO2	Emission release in kg per km

Table 2 provides brief descriptions of the data related to the criteria used in the research. For the NFS criterion, the number of airlines on the route was obtained from websites such as Google flights and skyscanner and verified by visiting the airlines' own websites. For the number of bus operators, the number of operators on the selected route was obtained separately from comparison sites such as omio.com, checkmybus.com and busbud.com. For HSR, thetrainline.com, where train tickets can also be bought, was accessed and analysed separately for each line, as for other modes. For another criterion, TPRICE, the fare paid for the mode was divided by the length of the route in km. The fare paid for the mode of transport was obtained from the sources mentioned above. For the length of the route, different sources were used for each mode of transport. For air, gcmap.com, for road, Google maps and for rail, official documents (official sources of the HSR operators such as Deutsche Bahn, TCDD, TGV) were used.

In addition to the fare paid for the mode of transport, the TPRICEKM criterion also includes the fare paid for the public transport alternative used to access the mode of transport from the city centre. For this data, the fare was obtained from the website of the operator providing the service in question. This fare is then added to the HSR, coach and airline fares to obtain the total fare data. For the KMFM criterion, total travel time data from centre to centre is required. This is done by adding the travel time from the city centre to the relevant mode (e.g. city centre- airport). The FREQ criterion uses the same data sources as the NFS criterion. RATT is a criterion obtained by the ratio of the author's access time from the centre to the mode to the travel time. Finally, for the KMCO2 criterion, which indicates the emissions emitted, the relevant data was obtained by entering the length of the line using the calculation tool on the carbonfootprint.com website.

4. FINDINGS AND DISCUSSIONS

In this section of the study, performance criteria are introduced and the application steps of Entropy and Waspas methods are mentioned. The study analyses the performance criteria of selected routes in Turkey and Europe where there is cross-competition. In the study, 6 criteria were used for HSR and 7 criteria were used for Coach and Airline.

4.1. Criteria Used in the Study

In assessing the performance of the selected routes where there is cross-competition, the criteria used were those that best reflect the performance of the routes in question. The criteria and ratios used in the study are shown in Table 3.

Table 3: Criteria and Codes Used in the Study

High Speed Train		**Coach**		**Airline**	
Performance Indicators	**Code**	**Performance Indicators**	**Code**	**Performance Indicators**	**Code**
Number of Firms Served	C1	Number of Firms Served	C1	Number of Airlines Served	C1
HSR Price for Km	C2	Coach Price for Km	C2	Airline Price for Km	C2
Total Price for Km	C3	Total Price for Km	C3	Total Price for Km	C3
Km for Min	C4	Km for Min	C4	Km for Min	C4
Frequency	C5	Frequency	C5	Frequency	C5
Ratio of Access time to Travel Time	C6	Ratio of Access time to Travel Time	C6	Ratio of Access time to Travel Time	C6
		Emissions for km (kg)	C7	Emissions for km (kg)	C7

4.2. Entropy Application

In this study, which examines the performance of city pairs with similar characteristics, the entropy method is used in the process of determining the weights of the criteria to be included in the analysis. The application of the entropy method was carried out separately for each mode of transport. However, for reasons of space, only the weighting table is presented in this section. The weight values obtained as a result of the entropy weighting procedure are given in Table 4.

Table 4: Criteria Weight Values Obtained by Entropy Method

Modes	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
HSR	0,1083	**0,2963**	0,2831	0,0562	0,1688	0,0870	N/A
Coach	**0,5278**	0,0201	0,0198	0,0022	0,3991	0,0292	0,0014
Airline	0,2239	**0,2297**	0,1933	0,0756	0,1292	0,1380	0,0098

According to the results presented in Table 4, the criterion weights of HSR, Coach and Airline are between 0.0562-0.2963, 0.0014-0.5278 and 0.0098-0.2297 respectively. In this respect, it can be seen that the variable with the highest weight on the cost-benefit performance of the selected routes for HSR is MPRICEKM, expressed by the C2 code, while the variable with the lowest weight is KMFM, expressed by the C4 code. If we look at the coach, we see that the variable with the highest weight on the cost-benefit performance of the selected routes is NFS, expressed with code C1, while the variable with the lowest weight is KMCO2, expressed with code C7. Finally, when evaluating the performance criteria on the selected routes where the airline operates, it can be seen that the C2 criterion (MPRICEKM) has the highest weight and the C7 criterion (KMCO2) the lowest.

4.3. WASPAS Application

In this part of the study, the criteria weighting values obtained by the Entropy method were added to the application part of the Waspas method and the performance of the selected routes was evaluated. The evaluation process is repeated for each mode.

The first step of the Waspas method is to organise the decision matrix of the evaluation criteria. In this direction, the decision matrix consisting of 6 lines (alternatives) and 6 criteria included in the analysis for HSR was arranged by equation (4). The decision matrix of the corresponding HSR routes is shown in Table 5.

Table 5: Decision Matrix (HSR)

	MAX	MIN	MIN	MAX	MAX	MIN
Routes	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Ankara- İstanbul	1	0,0243	0,0268	1,7831	12	0,1222
Barcelona-Madrid	3	0,0935	0,0997	3,5954	46	0,16
Roma-Milano	2	0,0802	0,0865	2,8713	72	0,0666
Berlin-Frankfurt	2	0,1108	0,1217	1,6184	22	0,064
Paris-Lyon	3	0,1584	0,1650	2,9021	29	0,1833
Londra-Manchester	1	0,3256	0,3387	1,8075	45	0,1230

The same step was repeated for the Coach. In this direction, the decision matrix consisting of 6 routes (alternatives) and 7 criteria included in the analysis was arranged through Equation (4). The decision matrix of the related Coach routes is shown in Table 6.

Table 6: Decision Matrix (Coach)

	MAX	MIN	MIN	MAX	MAX	MIN	MIN
Routes	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Ankara- İstanbul	50	0,0292	0,0313	1,0453	115	0,1075	0,0898
Barcelona-Madrid	2	0,0607	0,0665	1,2339	6	0,075	0,0958
Roma-Milano	3	0,0367	0,0424	1,0460	17	0,0901	0,1050
Berlin-Frankfurt	1	0,0326	0,0385	1,1924	4	0,0333	0,0907
Paris-Lyon	3	0,0343	0,0419	1,3010	8	0,1090	0,1072
Londra-Manchester	3	0,0535	0,0643	1,0268	12	0,0761	0,0892

Finally, the same procedure was applied to air transport. In this direction, the decision matrix consisting of 6 routes (alternatives) and 7 criteria included in the analysis was arranged by equation (4). The decision matrix of the corresponding airline routes is shown in Table 7.

Table 7: Decision Matrix (Airline)

	MAX	MIN	MIN	MAX	MAX	MIN	MIN
Routes	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Ankara- İstanbul	3	0,1128	0,1079	0,5643	13	2,0714	0,1417
Barcelona-Madrid	3	0,1611	0,1744	0,3822	20	0,55	0,1074
Roma-Milano	3	0,1624	0,1738	0,4207	13	1,5384	0,1291
Berlin-Frankfurt	1	0,3602	0,3496	0,4157	12	0,8285	0,1247

Paris-Lyon	1	0,2524	0,2795	0,3398	6	1,4923	0,1359
Londra-Manchester	1	0,5144	0,4773	0,7818	7	1,1230	0,1522

In the second step of the Waspas method, after the decision matrix has been arranged, the evaluation criteria are normalised according to whether they are cost or benefit oriented using equations (5) and (6). The normalised decision matrix for HSR is shown in Table 8.

Table 8: Normalised Decision Matrix (HSR)

	MAX	MIN	MIN	MAX	MAX	MIN
Routes	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Ankara- İstanbul	0,3333	0,0748	0,0792	0,4959	0,1666	0,6666
Barcelona-Madrid	1	0,2872	0,2944	1	0,6388	0,8727
Roma-Milano	0,6666	0,2465	0,2554	0,7986	1	0,3636
Berlin-Frankfurt	0,6666	0,3403	0,3593	0,4501	0,3055	0,3490
Paris-Lyon	1	0,4864	0,4870	0,8071	0,4027	1
Londra-Manchester	0,3333	1	1	0,5027	0,625	0,6713

The initial decision matrix for coach was also normalised. The normalised decision matrix for the coach is shown in Table 9.

Table 9: Normalised Decision Matrix (Coach)

	MAX	MIN	MIN	MAX	MAX	MIN	MIN
Routes	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Ankara- İstanbul	1	0,4812	0,4701	0,8034	1	0,9854	0,8377
Barcelona-Madrid	0,04	1	1	0,9483	0,0521	0,6875	0,8932
Roma-Milano	0,06	0,6058	0,6377	0,8039	0,1478	0,8267	0,9793
Berlin-Frankfurt	0,02	0,5381	0,5795	0,9165	0,0347	0,3055	0,8457
Paris-Lyon	0,06	0,5656	0,6306	1	0,0695	1	1
Londra-Manchester	0,06	0,8825	0,9663	0,7892	0,1043	0,6984	0,8321

Finally, the initial decision matrix for Airline is normalised using equations (5) and (6). Accordingly, the normalised decision matrix for Airline is shown in Table 10.

Table 10: Normalised Decision Matrix (Airline)

	MAX	MIN	MIN	MAX	MAX	MIN	MIN
Routes	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Ankara- İstanbul	1	0,2194	0,2262	0,7217	0,65	1	0,9308
Barcelona-Madrid	1	0,3132	0,3655	0,4888	1	0,2655	0,7056
Roma-Milano	1	0,3157	0,3643	0,5381	0,65	0,7427	0,8482
Berlin-Frankfurt	0,3333	0,7003	0,7325	0,5316	0,6	0,4	0,8190
Paris-Lyon	0,3333	0,4907	0,5856	0,4345	0,3	0,7204	0,8926
Londra-Manchester	0,3333	1	1	1	0,35	0,5421	1

In the third step of the Waspas method, the total relative importance of these banks was calculated according to the Weighted Sum Model (WSM) using equation (7). During the calculation process, the criterion weight (W_j) value obtained in the entropy method was multiplied by the normalisation value of each mode of transport and summed. As a result of the summation process, the value $Q_i^{(1)}$ was obtained. The relative importance values of the associated HSR routes according to the Weighted Sum Modelling (WSM) model are shown in Table 11.

Table 11: Relative Importance Values of Decision Alternatives According to WSM (HSR)

Routes	C1	C2	C3	C4	C5	C6	$Q_i^{(1)}$
Ankara- İstanbul	0,0361	0,0222	0,0224	0,0279	0,0281	0,0580	0,1948
Barcelona-Madrid	0,1084	0,0851	0,0834	0,0563	0,1079	0,0759	0,5170
Roma-Milano	0,0722	0,0731	0,0723	0,0450	0,1688	0,0316	0,4631
Berlin-Frankfurt	0,0722	0,1009	0,1017	0,0253	0,0516	0,0304	0,3822
Paris-Lyon	0,1084	0,1442	0,1379	0,0454	0,0680	0,0870	0,5909
Londra-Manchester	0,0361	0,2964	0,2831	0,0283	0,1055	0,0584	0,8078

The values obtained in Table 11 were also calculated for other modes of transport and the relative importance values of the relevant routes for coach according to the WSM model are shown in Table 12.

Table 12: Relative Importance Values of Decision Alternatives According to WSM (Coach)

Routes	C1	C2	C3	C4	C5	C6	C7	$Q_i^{(1)}$
Ankara- İstanbul	0,5279	0,0097	0,0093	0,0018	0,3991	0,0288	0,0013	0,9779
Barcelona-Madrid	0,0211	0,0202	0,0198	0,0022	0,0208	0,0201	0,0013	0,1055
Roma-Milano	0,0317	0,0122	0,0126	0,0018	0,0590	0,0242	0,0015	0,1430
Berlin-Frankfurt	0,0106	0,0109	0,0115	0,0021	0,0139	0,0089	0,0013	0,0591
Paris-Lyon	0,0317	0,0114	0,0125	0,0023	0,0278	0,0292	0,0015	0,1164
Londra-Manchester	0,0317	0,0178	0,0192	0,0018	0,0416	0,0204	0,0012	0,1337

The calculation of the relative importance value according to the WSM model, calculated using equation (7), was also performed for Airline and is shown in Table 13.

Table 13: Relative Importance Values of Decision Alternatives According to WSM (Airline)

Routes	C1	C2	C3	C4	C5	C6	C7	$Q_i^{(1)}$
Ankara- İstanbul	0,2240	0,0504	0,0438	0,0546	0,0840	0,1381	0,0092	0,6040
Barcelona-Madrid	0,2240	0,0720	0,0707	0,0370	0,1292	0,0367	0,0070	0,5765
Roma-Milano	0,2240	0,0726	0,0705	0,0407	0,0840	0,1025	0,0084	0,6026
Berlin-Frankfurt	0,0747	0,1609	0,1417	0,0402	0,0775	0,0552	0,0081	0,5584
Paris-Lyon	0,0747	0,1128	0,1133	0,0329	0,0388	0,0995	0,0088	0,4806
Londra-Manchester	0,0747	0,2298	0,1934	0,0757	0,0452	0,0748	0,0099	0,7035

In the fourth step of the Waspas method, the relative importance of these lines according to the WPM is calculated using equation (8) and the $Q_i^{(2)}$ value is determined. The relative importance values of the associated HSR routes according to the WPM are shown in Table 14.

Table 14: Relative Importance Values of Decision Alternatives according to the WPM (HSR)

Routes	C1	C2	C3	C4	C5	C6	$Q_i^{(2)}$
Ankara- İstanbul	0,8878	0,4639	0,4878	0,9613	0,7390	0,9653	4,5050
Barcelona-Madrid	1,0000	0,6909	0,7074	1,0000	0,9271	0,9882	5,3137
Roma-Milano	0,9570	0,6604	0,6795	0,9874	1,0000	0,9157	5,2000
Berlin-Frankfurt	0,9570	0,7266	0,7484	0,9561	0,8186	0,9125	5,1191
Paris-Lyon	1,0000	0,8077	0,8158	0,9880	0,8577	1,0000	5,4691
Londra-Manchester	0,8878	1,0000	1,0000	0,9620	0,9237	0,9659	5,7394

Table 15 shows the relative importance values for Coach according to WPM.

Table 15: Relative Importance Values of Decision Alternatives according to the WPM (Coach)

Routes	C1	C2	C3	C4	C5	C6	C7	$Q_i^{(2)}$
Ankara- İstanbul	1,0000	0,9853	0,9851	0,9995	1,0000	0,9996	0,9997	6,9693
Barcelona-Madrid	0,1828	1,0000	1,0000	0,9999	0,3077	0,9891	0,9998	5,4793
Roma-Milano	0,2265	0,9899	0,9911	0,9995	0,4663	0,9945	1,0000	5,6677
Berlin-Frankfurt	0,1268	0,9876	0,9892	0,9998	0,2617	0,9659	0,9997	5,3308
Paris-Lyon	0,2265	0,9886	0,9909	1,0000	0,3451	1,0000	1,0000	5,5511
Londra-Manchester	0,2265	0,9975	0,9993	0,9995	0,4057	0,9896	0,9997	5,6178

According to the WPM model calculated using equation (8), the relative importance value has also been calculated for Airline and is shown in Table 16.

Table 16: Relative Importance Values of Decision Alternatives according to the WPM (Airline)

Routes	C1	C2	C3	C4	C5	C6	C7	$Q_i^{(2)}$
Ankara- İstanbul	1,0000	0,7057	0,7502	0,9756	0,9458	1,0000	0,9993	6,3767
Barcelona-Madrid	1,0000	0,7659	0,8231	0,9473	1,0000	0,8327	0,9966	6,3656
Roma-Milano	1,0000	0,7673	0,8226	0,9542	0,9458	0,9598	0,9984	6,4481
Berlin-Frankfurt	0,7819	0,9214	0,9416	0,9533	0,9361	0,8812	0,9980	6,4135
Paris-Lyon	0,7819	0,8491	0,9017	0,9389	0,8559	0,9557	0,9989	6,2821
Londra-Manchester	0,7819	1,0000	1,0000	1,0000	0,8731	0,9190	1,0000	6,5739

In the final stage of the Waspas method, the values of $Q_i^{(1)}$ and $Q_i^{(2)}$ calculated according to the WSM (Weighted Sum Model) and WPM (Weighted Product Model) models are calculated using equation (9) and the value of " Q_i " of the corresponding routes is obtained. The value of λ in equation (9) is generally taken as (λ=0.5). The performance rankings of the related lines according to their " Q_i " values are given in Table 17.

Table 17: Ranking of Selected Lines by Q_i Value Based on Transport Mode

Routes	HSR	Coach	Airline
Ankara- İstanbul	6	**1**	2
Barcelona-Madrid	3	5	4
Roma-Milano	4	2	3
Berlin-Frankfurt	5	6	5
Paris-Lyon	2	4	6
Londra-Manchester	**1**	3	**1**

Table 17 shows that the London-Manchester route ranks first among the routes included in the study, while the Paris-Lyon line ranks last. When analysing the HSR ranking, the London-Manchester corridor ranks first, as in the airline sector. The Ankara-Istanbul HSR route ranks last among the selected corridors. If we look at the coach, we can see that the Ankara-Istanbul route is in first place this time. On the other hand, the Berlin-Frankfurt route ranks last.

When analysing the ranking of the routes by mode, the London-Manchester is in first place for HSR and air, and in third place for road. In the general evaluation of the route, it can be seen that it is ahead of the other lines in terms of cost-benefit according to the selected criteria. Of course, there could be several reasons for this. First of all, the frequency values of the route in question are quite high. The high frequency reduces the total journey time and gives the user a time advantage. Returning to the routes, the Berlin-Frankfurt line comes last in the ranking of all transport modes. The Berlin-Frankfurt corridor is an important corridor on the east-west axis of Germany, but unlike the other lines, the frequency of buses is quite low. In addition, it can be seen that ticket prices on this route are high due to the fact that only traditional airlines operate. For these reasons, this route lags behind the others in the ranking.

If we look at the Ankara-Istanbul route, the high frequency compared to other transport options and the relatively low ticket prices due to this intense competition have brought it to the first place in this field. The main reason for the high frequency is undoubtedly the fact that the Ankara-Istanbul line is also part of the road connecting Istanbul with the eastern provinces of the country. Almost every company coming from the eastern cities passes through Ankara, and this linear line is also contains the Ankara-Istanbul route. Otherwise, the Barcelona-Madrid and Rome-Milan routes were generally in the middle of the list for each mode of transport.

5. CONCLUSION AND IMPLICATIONS

The aim of this study is to compare transport corridors (routes) with similar characteristics in terms of different criteria, and in this context the performance evaluation was carried out using Entropy and WASPAS, which are multi-criteria decision making methods. Prior to the performance evaluation, the criteria were identified and each criterion was weighted according to objective criteria. The weighted criteria were then calculated using the WASPAS method and the best and worst performing routes for each mode were ranked.

This research is considered to make several theoretical and practical contributions. Firstly, although there have been many studies of multi-criteria decision making in the transport sector, they have been either sector specific or have compared at most two modes of transport. The few studies that have included all modes have evaluated factors such as investment decisions and transport policies, as well as factors related to future steps to be taken in this direction. In contrast to other studies, this study compares and ranks the routes on which all modes of transport operate simultaneously and which have similar characteristics according to criteria established using real data. On the other hand, it is expected that the results obtained will also guide decision-makers. In particular, taking into account the weighting of the performance criteria of the routes, the tariffs of the route concerned can be regulated or an investment programme can be set up to make the public transport modes (e.g. HSR) more competitive.

The research has several limitations. The first is that the evaluations are limited to the secondary data obtained during the ranking of the lines. Although the criteria used in the research are related to the transport industry and in particular to passenger transport, they can be applied to different industries (e.g. freight, logistics, etc.). In this context, it is expected that the generalisability of the research results will increase with more different industries and more criteria in future studies.

Future studies to be carried out in the field of transport can also analyse routes in different countries and evaluate the differences between countries. Another limitation of the study is related to the methodology used. The entropy method was used to weight the criteria used in the evaluation process and the WASPAS method was used to rank the routes. Other weighting methods (BWM, F/AHP, SWARA, etc.) and ranking methods (ARAS, EDAS, VIKOR, etc.) can be used in future studies.

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