Central European Journal of Operations Research
https://doi.org/10.1007/s10100-023-00869-x

Analytic hierarchy process for urban transportation: a bibliometric and social network analysis

Zülal Diri Kenger[1] · **Ömer Nedim Kenger**[2] · **Eren Özceylan**[2]

Accepted: 6 June 2023

Abstract

Increasing population and urbanization create many problems, especially traffic problems in urban areas. Public transportation is becoming a necessity since it is seen as a solution for traffic problems. This paper conducts bibliometric and social network analysis on urban and public transportation literature that use Analytic Hierarchy Process (AHP) technique. In this study, 222 papers were reviewed. These papers were published between 1987 and 2022 and were extracted from the Web of Science database. Analyses are realized in order to identify trends, and key points in a more scientific and objective way. Analysis results show that there is great increase in number of publications in the last 10 years. Most active author according to publication number is Duleba S., the journal that has the most publications is "Sustainability", and most productive country is China. Hybrid methodologies such as AHP-TOPSIS and Fuzzy AHP also are frequently used in publications. Furthermore, the AHP technique has been frequently used for measuring service quality, bus selection, vehicle selection, determination of facility location, passenger satisfaction, and bus-bicycle routes. To achieve sustainable urban transportation, it is crucial to adopt smart and eco-friendly technological solutions that cater to the diverse needs of current and potential users. Integrating various transportation modes is also essential for ensuring safety and sustainability of urban transportation systems. Furthermore, public transportation vehicles based on clean technology should be prioritized over other options since they promote cleaner air in cities, particularly in densely populated areas, leading to better air quality and more livable cities.

Keywords Analytic hierarchy process · Public transport · Bibliometric · Social network analysis · Literature review

✉ Eren Özceylan
eozceylan@gantep.edu.tr

[1] Industrial Engineering Department, Hasan Kalyoncu University, 27100 Gaziantep, Turkey

[2] Industrial Engineering Department, Gaziantep University, 27300 Gaziantep, Turkey

Published online: 14 June 2023

1 Introduction

Urban transportation is a critical issue facing cities around the world. With increasing urbanization and population growth, the demand for transportation services is rising and cities are struggling to keep up (Chin et al. 2019). In recent years, traffic congestion has become a serious problem in urban areas, with private car usage on the rise and significant damage to the environment (Loukopoulos et al. 2005). Public transportation is seen as a key solution to this problem, and cities are investing in a wide range of transportation options to improve mobility and reduce congestion. As cities continue to grow and evolve, public transportation will play an increasingly important role in shaping the liveability and sustainability of urban areas (Hamurcu and Eren 2020a). Public transportation is a crucial part of any urban transportation system, providing an affordable, efficient, and sustainable way for people to move around the city (Loukopoulos et al. 2005). Public transportation can include buses, trains, subways, trams, and light rail, as well as bike-sharing programs.

Multi-criteria decision making (MCDM) have been successfully applied to solve decision problems in several research fields (Mardani et al. 2015; Zyoud and Fuchs-Hanusch 2017; Lotfi et al. 2023). Analytic hierarchy process (AHP) is a MCDM technique which has been widely used in numerous areas such as health, supply chain and logistics, energy sector, construction, and manufacturing (Zyoud and Fuchs-Hanusch 2017; Emrouznejad and Marra 2017). AHP is a technique that introduced by Saaty (1980) enables decision makers to tackle with complex and conflicting problems (Loukopoulos et al. 2005). Since it allows involving subjective criteria, it can be considered as an advance compared to other decision-making techniques. The AHP method also explicitly addresses consistency issues, as people may not always have the innate logical ability to remain consistent when making paired comparisons. By identifying the level of inconsistency and pinpointing areas for improvement, we can enhance the quality of decision-making. AHP not only detects inconsistencies, but also provides optimal solutions to improve the consistency of decision-making (Saaty 1994). MCDM techniques in the assessment of transportation projects have increase in importance, and have extensively used due to their simplicity, also (Hamurcu and Eren 2020a).

There have been exist a few review papers related to AHP technique (Kahraman 2018; Asadabadi et al. 2019; Darko et al. 2019; Liu et al. 2020; Khan and Ali 2020). In addition, bibliometric and social network analysis have been conducted on AHP technique (Zyoud and Fuchs-Hanusch 2017; Emrouznejad and Marra 2017). However, these papers are mostly general evaluation of AHP literature. Urban and public transportation is a specific area in which AHP technique is often used. Mardani et al. (2015) conducts a systematic review of literature on the use of MCDM techniques in transportation systems. The paper categorizes the studies into different transportation systems such as urban transportation, air transportation, freight transportation and maritime transportation. The paper summarizes the main findings and limitations of the studies reviewed and

provide a comprehensive overview of the state of the art in the use of MCDM techniques in transportation systems. Kramar and Topolsek (2018) describes the use of fuzzy AHP (FAHP) in evaluating and making decisions about urban mobility systems. The paper presents an overview of the FAHP method and its applications in various aspects of urban mobility, including transportation infrastructure, public transportation, and traffic management. Kügemann and Polatidis (2019) conducts a systematic review of the literature on the use of MCDM techniques in the evaluation of road transportation fuels and vehicles. It classifies the studies according to the type of MCDM method used and the criteria considered, and provides a summary of the main findings and limitations of the studies reviewed. The paper concludes that MCDM can be a useful tool for evaluating the trade-offs between different fuels and vehicles, but that more research is needed to improve the consistency and transparency of the methods used in the literature. The similar literature reviews are presented in Table 1.

This research is driven by several factors. Firstly, public transportation plays an essential role in urban life as it not only provides mobility to city residents but also helps reduce car traffic and carbon dioxide emissions, which has become increasingly important since the introduction of the Kyoto Protocol, Paris Agreement and finally, Green Deal. By promoting the use of public transport over private cars, emissions can be reduced. That is why our research has been centred on the field of public transport. Secondly, because of AHP technique's user-friendly nature, the frequency of its utilization in public transportation is considerably high. Thirdly, bibliometric and social network analysis have the potential to identify emerging research areas, trends and key points. Finally, to the best of our knowledge, no previous study has utilized bibliometric and social network analysis on the topic of urban and public transportation that use the AHP technique. The AHP technique is the most commonly used MCDM method in the transportation field, as compared to all other techniques available (Mardani et al. 2015). Through this study, we aim to establish a comprehensive understanding of the use of AHP in the context of urban and public transportation, and to provide guidance for researchers in this field.

The paper is organized as follows. Section 2 identifies the methodology used to the literature that will be reviewed and evaluated in this paper. Section 3 discusses the results and trends. Concluding remarks are presented in Sect. 4.

2 Review methodology and results

In this section, we first present the methods used to obtain the data and the number of publications over the years. We then discuss the software tools employed in this analysis, and present and discuss the results of the bibliometric and social network analysis.

2.1 Research methodology and initial data statistics

The keywords used for data collection consist of ("urban transport" or "public transport" (Topic), and "analytic hierarchy process", or "AHP" (Topic)) in Web of

Table 1 Overview over similar MCDM and transportation related literature reviews

Papers	Research area	Method	Systematic analysis	Bibliometric and social network analysis	Year Range	Number of papers reviewed
Mardani et al. (2015)	Transportation System Problems	Multiple Criteria Decision-Making Techniques	–		1993–2015	89
Kramar and Topolsek (2018)	Urban Mobility	Fuzzy Analytic Hierarcy Process	–		2009–2016	19
Kügemann and Polatidis (2019)	Road Transportation Fuels and Vehicles	Multiple Criteria Decision-Making Techniques	–		N.A.-2019	40
The current study	Urban and Public Transportation	Analytic Hierarcy Process		–	1987–2022	222

Science database. We collected the publications (articles, conference papers) for the defined search keywords. We reach the 282 publications in initial search. 60 of them are eliminated due to out of subjects, spelling language and duplication.

Figure 1 shows the trend of published articles. There is a great increase in number of publications in the last 10 years. The number of publications in the last 10 years occur approximately %87 of total number of publications. It was observed that there is a jump in the number of publications in 2013, and then the number of publications has tended to increase.

2.2 Bibliometric and social network analysis results

Bibliometric and social network analysis which has become popular in recent years is a convenient tool in order to determine emerging research areas in a specific field. Additively, social network analysis guides researchers by understanding various dynamics for future research direction through determining the most influential researchers, collaboration among researchers, and emerging research field trends (Emrouznejad and Marra 2017). Initially, the authors utilize Vosviewer to measure (degree) centrality, which is commonly used as an indicator of power or popularity (Freeman 1978). Although this type of measure can indicate power or popularity, it fails to uncover gaps or potential areas for future research based on the structural properties. Therefore, social network analysis is applied to identify such gaps and explore potential areas for future research. To analyze the network structure, a set of indicators provided by the UCINET software (Borgatti et al. 2005) is utilized. Social network analysis is performed using UCINET 6.759.

In this section, 222 publications related to urban and public transportation and AHP technique are analyzed. Citation, country, publication source, keyword and author analysis are conducted, respectively.

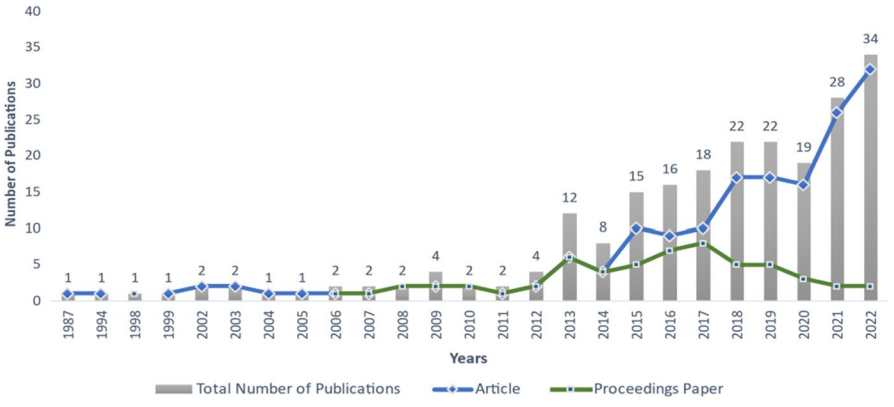


Fig. 1 Publishing trend of related publications

2.3 Citation analysis

In this subsection, citation analysis is conducted in order to determine the degree of relationship between cited to citing papers in a network. Table 2 presents the authors according to co-authorship total link strength (TLS). An author's TLS is determined by adding up the link connections they have established with other authors. The TLS calculation in all subsequent networks discussed in this paper is performed using the full-counting method. Accordingly, Duleba S. and Moslem S. are the first two authors with the most TLS. 1804 TLS exist in the network and Duleba S. and Moslem S. are in the top of the list with 41 and 38 TLS, respectively.

Figure 2 displays a citation network of authors, where the authors are represented by nodes and the connections between them are represented by links. The size of the nodes corresponds to the number of citations an author has received. The analysis reveals that Duleba S. and Moslem S. have the strongest connection, as they have the most publications and frequently collaborate on the same papers.

2.4 Analysis of countries

This subsection presents the most productive countries which have at least 4 publications in the research area. According to Fig. 3, the most 3 productive countries are China, Turkey, and Hungary that have 44, 40, and 25 publications, respectively. The total number of publications of these countries accounts for 40% of publications on this research field.

2.5 Analysis of publication sources

This section presents the results of publication source analysis. There are 163 articles, 59 conference papers in a total of 222 publications. The journals that have published at least two articles are presented in Fig. 4. Accordingly, the journal that has the most publications is "*Sustainability*" with the 22 publications. The

Table 2 The top 10 author according to co-authorship total link strength

Authors	Documents #	Total Link Strength	Total Link Strength %
Duleba S.	23	41	2.27%
Moslem S.	17	38	2.11%
Alkharabsheh A.	5	11	0.61%
Baracli H.	3	9	0.50%
Ortega J.	2	9	0.50%
Lin C.	2	8	0.44%
Lin G.	2	8	0.44%
Roukouni A.	2	8	0.44%
Wang S.	2	8	0.44%
Xu H.	2	8	0.44%

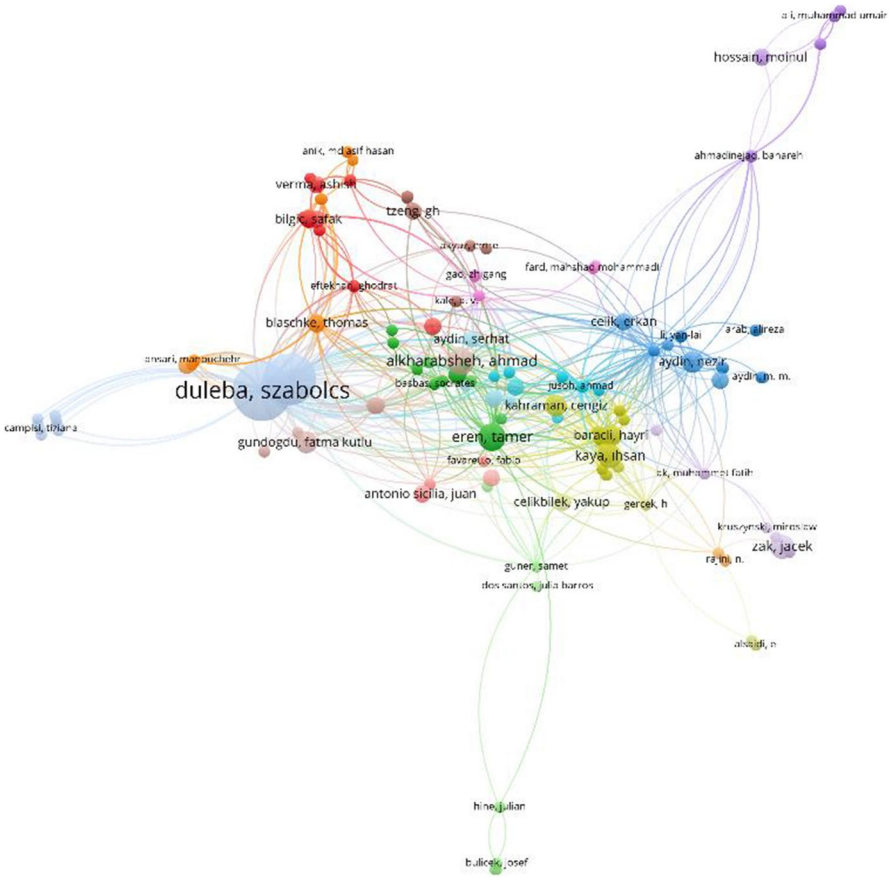


Fig. 2 Citation network of the authors

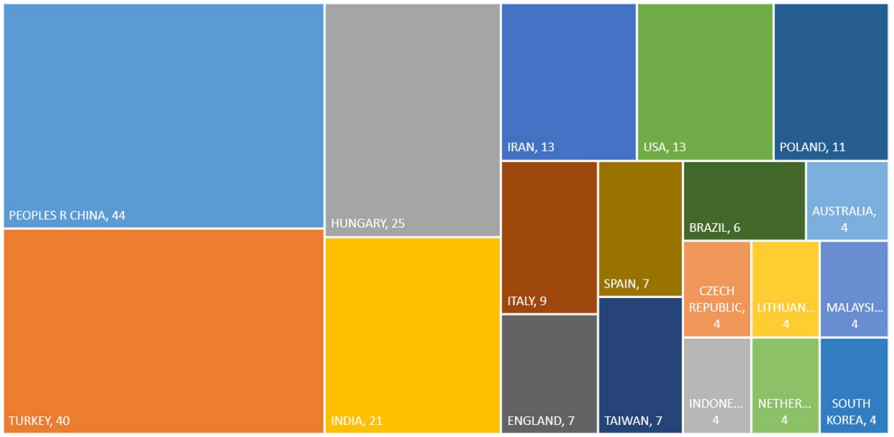


Fig. 3 The most productive countries

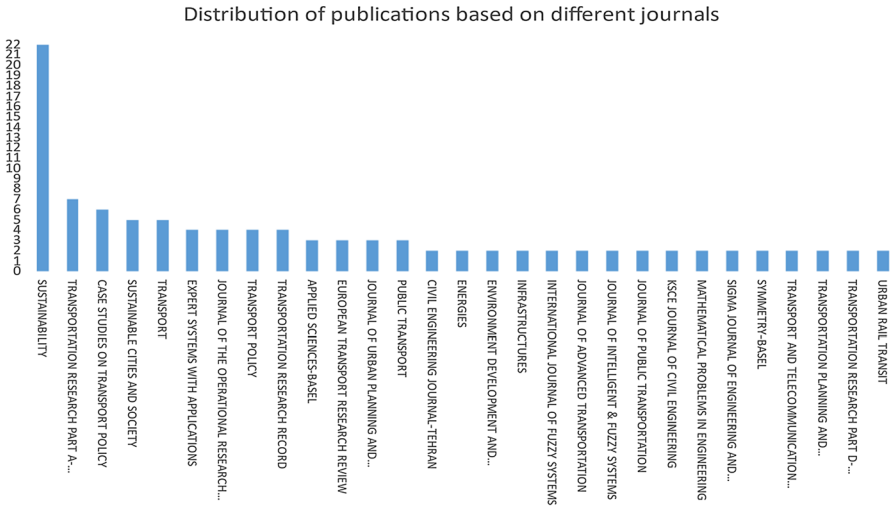


Fig. 4 Distribution of publications based on different journals (1987–2023)

"*Sustainability*" journal has a total share of 14% with the number of articles it publishes. The journals of "*Transportation Research Part A-Policy and Practice*", "*Case Studies on Transport Policy*", "*Sustainable Cities and Society*", and "*Transport*" follow the "*Sustainability*". The combined number of articles published in the top five journals in this field accounts for 28% of all articles in the field.

Figure 5 presents the top conferences which published at least two papers in this research area. *"Euro Working Group Transportation (EWGT)"* is the top conference

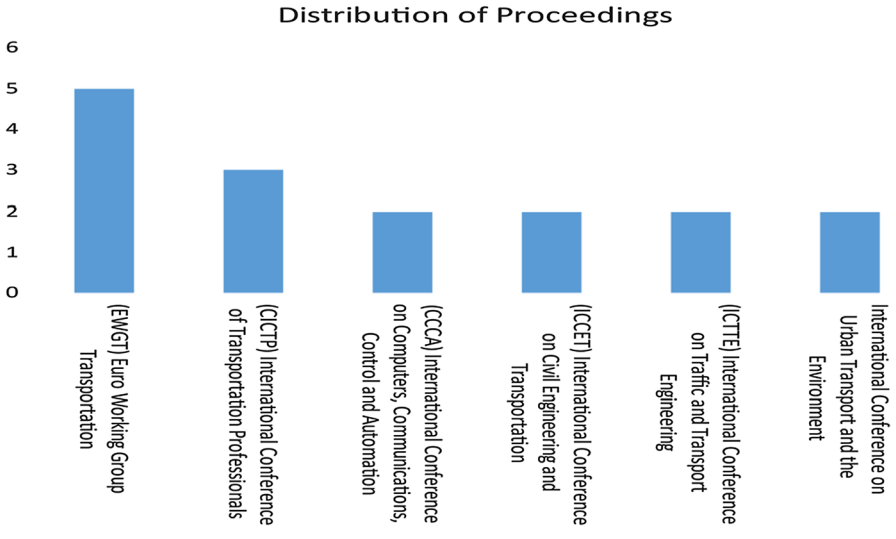


Fig. 5 Distribution of publications based on different conferences (1987–2023)

Table 3 The most frequently used keywords

Rank	Keywords	Occurrences #	Occurrences %	Total Link Strength	Total Link Strength %
1	Analytic hierarchy process (ahp)	108	11.04%	442	10.41%
2	Public transport	54	5.52%	230	5.42%
3	Multi criteria decision making (mcdm)	45	4.60%	198	4.66%
4	Fuzzy analytic hierarchy process (fahp)	13	1.33%	51	1.20%
5	Topsis	13	1.33%	61	1.44%
6	Urban transport	10	1.02%	47	1.11%
7	Sustainability	9	0.92%	38	0.89%
8	Sustainable development	9	0.92%	44	1.04%
9	Decision making	7	0.72%	33	0.78%
10	Geographic information systems	7	0.72%	31	0.73%
11	Group decision-making	6	0.61%	24	0.57%
12	Multi-criteria analysis	6	0.61%	31	0.73%
13	Service quality	6	0.61%	23	0.54%
14	Delphi method	5	0.51%	23	0.54%
15	Fuzzy logic	5	0.51%	25	0.59%
16	Supply quality	5	0.51%	19	0.45%
17	Transportation	4	0.41%	28	0.66%
18	Performance evaluation	4	0.41%	24	0.57%
19	Climate change	4	0.41%	23	0.54%
20	Indicator	4	0.41%	22	0.52%

with 5 papers and has a total share of approximately 10% of total conference papers. *"International Conference of Transportation Professionals (CICTP)"* is the second with 3 conference papers.

2.6 Keywords analysis

In this section, keywords analysis is conducted to identify the key research fields in the current area. Table 3 shows the top 20 keywords most frequently used and total link strength. Accordingly, AHP is top of the list of the most frequently used keywords with a frequency use of 108. It includes the different spellings of AHP such as "Analytic Hierarchy Process", "AHP Method", "Analytic Hierarchy Process (AHP)", "Analytical Hierarchy Process". The second most frequently used keywords after AHP are "public transport" including "public transportation" with the frequency use of 54. Hybrid methodologies such as AHP-TOPSIS and Fuzzy AHP also are frequently used in publications (Bilişik et al. 2014; Arsovski et al. 2017; Hamurcu and Eren 2020a; Singh et al. 2020; Sobhani et al. 2020; Kutlu Gündoğdu et al. 2021; James et al. 2021; Buran and Erçek 2022; Eren 2022;

Cheemakurthy and Garme 2022). For this reason, it is found that the usage rate of these words is high. In the field of urban and public transportation, the AHP technique has been frequently used for measuring service quality (Güner 2018; Seker and Aydin 2020; Moslem and Çelikbilek 2020; Kutlu Gündoğdu et al. 2021) as well as bus selection and determination of facility location, bus-bicycle routes (Güner 2018; Saplıoğlu and Aydın 2018; Hamurcu and Eren 2020b; Ortega et al. 2020a, b, 2021; Balket and Asmael 2021; Shi et al. 2021; Canbulut et al. 2021). Also it is notable that TOPSIS is a remarkable supporting method of AHP in ranking the alternatives while the weight determination is done by AHP (Güner 2018; Sobhani et al. 2020; James et al. 2021). The internal combustion vehicles cause affects air quality in urban areas. Global warming, carbon footprint and environmental pollution that private car usage cause are also concern. Therefore, sustainability and climate change has become popular in public transportation in recent years, also (Tzeng et al. 2005; Topal 2017; Hamurcu and Eren 2020a, b; Seker and Aydin 2020; Rivero Gutiérrez et al. 2021; Ghosh et al. 2021; Aydin et al. 2022). Figure 6 illustrates the relationships between keywords in a co-occurrence network using data from 222 papers that contain a total of 588 keywords, with 501 of those keywords appearing together.In social sciences, concepts such as subgroups and cliques are commonly used in the analysis of social networks. A key aspect of this analysis is identifying cohesive subgroups within a network, which are defined as groups of actors that have strong, direct, and frequent ties with each other. One of the fundamental methods for identifying these subgroups is clique analysis. A clique is a subset of a network in which all members have symmetric relationships with one another, and the minimum

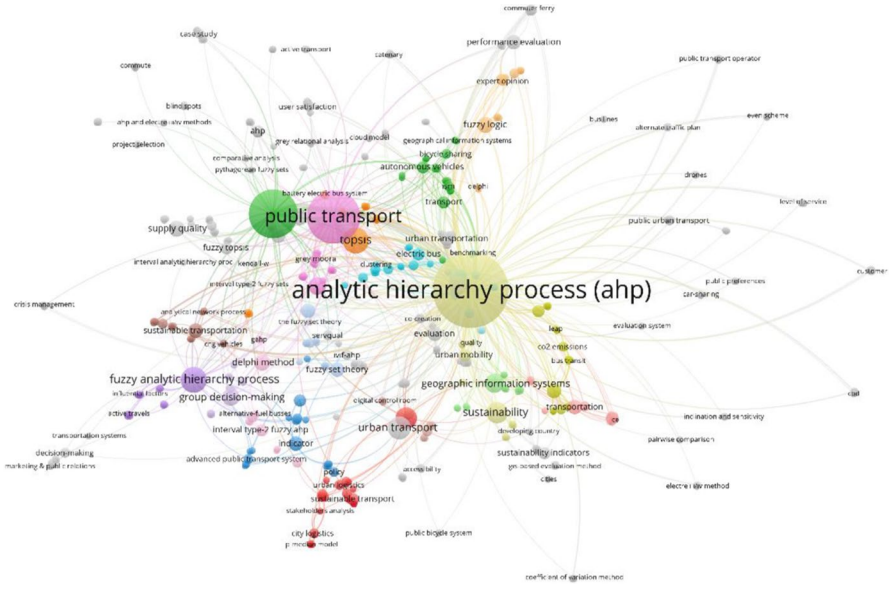
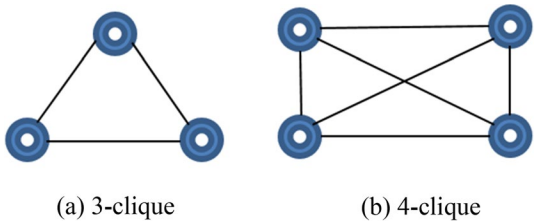


Fig. 6 Occurrence network of keywords



(a) 3-clique (b) 4-clique

Fig. 7 N-clique combination samples.

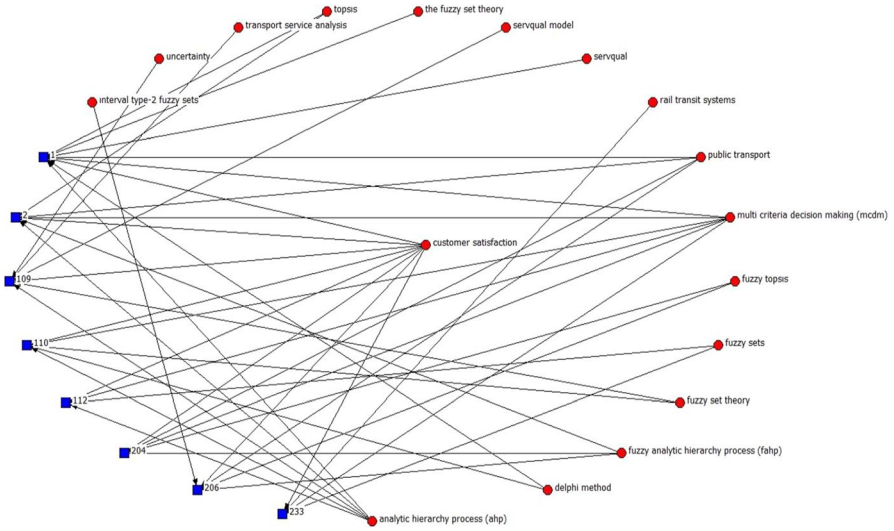


Fig. 8 Clique analysis result for the keyword "customer satisfaction"

size of a clique is three members. In a network, groups and subgroups connected by edges are referred to as n-Cliques, where "n" denotes the number of nodes in the subgroup. For instance, in Fig. 7a, there are three nodes that are connected to each other, called as 3-Clique. Figure 7b displays a 4-Clique network consisting of four nodes, each directly connected to the other nodes in the subgroup.

A clique analysis was performed on the most frequently used keywords in the network. The result revealed 237 cliques of size three or larger. It is unexpected to find the keyword "customer satisfaction" among the top 20 words in the clique analysis, as it is not on the list of the most frequently used keywords. Clique analysis can be a valuable tool for identifying key factors that may not be detected by other analysis. A number of AHP techniques have been proposed for determining and measuring customer demands, such as those described by (Bilişik et al. 2013; Moslem and Duleba 2018; Chin et al. 2019; Zhang et al. 2020; Duleba and Moslem 2021), with successful outcomes reported. Thus, it can be concluded that AHP is an effective tool for measuring customer satisfaction. Figure 8 displays the keywords that are in the same cliques as "customer satisfaction." The blue nodes indicate the clique numbers in which "customer satisfaction" is present.

Table 5 Most active authors (according to number of citations)

Authors	# Of Citations	%	Authors	# Of Citations	%
Duleba S.	473	4.82%	Shrestha R.M.	152	1.55%
Tzeng G.H.	410	4.18%	Yedla S.	152	1.55%
Lin C.W.	410	4.18%	Celik E.	142	1.45%
Opricovic S.	410	4.18%	Blaschke T.	125	1.27%
Moslem S.	387	3.95%	Ghorbanzadeh O.	125	1.27%

Table 4 Most active authors (according to number of publications)

Authors	# Of Publications	%	Authors	# Of Publications	%
Duleba S.	23	10.36%	Kaya I.	4	1.80%
Moslem S.	17	7.66%	Zak J.	4	1.80%
Alkharabsheh A.	5	2.25%	Aydın N.	3	1.35%
Eren T.	5	2.25%	Baracli H.	3	1.35%
Hamurcu M.	5	2.25%	Erdogan M.	3	1.35%

2.7 The analysis of authors

In this section, most active authors according to number of publications and number of citations are analysed. Table 4 shows the most active 10 authors according to publication number. Duleba S. and Moslem S. are the most active 2 authors working in the field of public transportation and its AHP applications. Duleba S. has 23 publications in this field with 10.36% rate in total publications. Moslem S. has 17 publications with 7.66% rate in total publications. Table 5 presents the most active 10 authors according to citation number. Duleba S. is the top author also according to citation number. Lin C. W. Opricovic S. and Tzeng G.H. follow Duleba S. with 4.18% rate.

Figure 9 illustrates the collaboration between authors in the academic field. Duleba S. and Moslem S. have the highest level of collaboration, having co-authored 15 articles together.

In this study, we also employed the (Freeman 1978) betweenness measure for the co-author network. Freeman computes the betweenness measure by adding up the ratios of the shortest paths between nodes that pass through a particular node. Consequently, removing a node with high betweenness may result in numerous pairs of nodes becoming fully disconnected or at least more distantly connected (Casanueva et al. 2016). Table 6 highlights an important finding that, despite not being ranked among the most active authors, Kahraman, C. and Aydın S. have a notable impact on the connections between authors due to their high betweenness degree. Notably, this high betweenness degree is achieved by a few publications, which is surprising.

Finally, the top 10 most influential publications with the highest number of citations are analyzed and presented in Table 7. The “Energy Policy” journal is at the

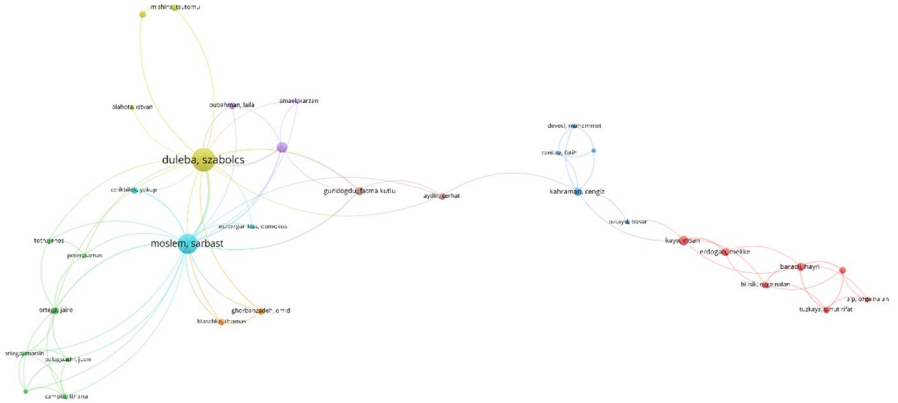


Fig. 9 Co-author relationship network

Table 6 The top 10 authors according to co-authorship betweenness centrality

Rank	Author	Betweenness centrality	Betweenness centrality (%)
1	Kahraman C.	255	21.44
2	Aydin S.	240	20.18
3	Moslem S.	182	15.33
4	Duleba S.	175	14.74
5	Kaya I.	156	13.12
6	Baracli H.	56	4.74
7	Bilisik O.N.	28	2.35
8	Roukouni A.	16	1.35
9	Ortega J.	12	1.01
10	Larrode E.	10	0.84

top of the list of the 10 most influential documents with the only publication it has published in this field. The "Transportation Research Part A-Policy and Practice" and "Transport" have high citation rates as well as being active journals in this field. However, the "Sustainability", despite having the most publications in the field, appears on the list of the most influential documents with just one publication, which is unexpected.

3 Discussion

The AHP technique has been frequently used for measuring service quality (Moslem and Çelikbilek 2020; Kutlu Gündoğdu et al. 2021), bus selection (Hamurcu and Eren 2020b), vehicle selection (Canbulut et al. 2021), determination of facility location (Bilişik et al. 2014; Arsovski et al. 2017), passenger satisfaction (Zhang et al. 2020; Duleba and Moslem 2021), bus-bicycle routes (Saplıoğlu and Aydın 2018). In

Table 7 The top 10 most influential publications

Rank	Title	Year	Authors	# Of Citations	Keywords	Journal
1	Multi-criteria analysis of alternative-fuel buses for public transportation	2005	Tzeng G.H.; Lin C.W.; Opricovic S.	410	Alternative fuel; electric bus; public transportation; multi-criteria analysis; compromise solution; TOPSIS; VIKOR	Energy Policy
2	Multi-criteria approach for the selection of alternative options for environmentally sustainable transport system in Delhi	2003	Yedla S.; Shrestha R.M.	152	AHP; CNG vehicles; delhi; qualitative and quantitative criteria; sustainable transportation	Transportation Research Part A-Policy And Practice
3	Multiple criteria decision-making techniques ın transportation systems: a systematic review of the state of the art literature	2016	Mardani A.; Zavadskas E.K.; Khalifah Z.; Jusoh A.; Nor K.M.D.	123	Multiple criteria decision-making techniques (MCDM); AHP; Fuzzy-AHP; decision-making; transportation systems	Transport
4	Comparing the output of cost benefit and multi-criteria analysis - An application to urban transport investments	2006	Tudela A.; Akiki N.; Cisternas R.	92	Multi-criteria analysis; analytic hierarchy process; stated preference; urban transport investments; decision making; transport environmental impacts	Transportation Research Part A-Policy And Practice
5	Sustainable urban transport planning considering different stakeholder groups by an interval-ahp decision support model	2019	Ghorbanzadeh O.; Moslem S.; Blaschke T.; Duleba S.	83	Sustainable transport policy; multi-criteria decision making (MCDM); interval calculus; supply quality; stakeholder engagement	Sustainability
6	A hierarchical customer satisfaction framework for evaluating rail transit systems of Istanbul	2015	Aydin N.; Celik E.; Gumus A.T.	74	Customer satisfaction; rail transit systems; multi criteria decision making; fuzzy sets	Transportation Research Part A-Policy And Practice

Table 7 (continued)

Rank	Title	Year	Authors	# Of Citations	Keywords	Journal
7	Examining pareto optimality in analytic hierarchy process on real data: An application in public transport service development	2019	Duleba S.; Moslem S.	72	Analytic Hierarchy Process (AHP); pareto optimization; public transport; passenger demand; multi criteria decision making	Expert Systems Wıth Applıcatıons
8	Application of AHP and VIKOR methods under interval type 2 fuzzy environment in maritime transportation	2017	Soner O.; Celik E.; Akyuz E.	68	Maritime transportation; IT2FSs; multi-attribute decision making; hatch cover	Ocean Engineering
9	An integrated MCDM approach to evaluate public transportation systems in Tehran	2017	Nassereddine M.; Eskandari H.	66	MCDM; public transportation system; delphi method; GAHP; PROMETHEE	Transportation Research Part A-Policy And Practice
10	A multiple criteria approach for the evaluation of the rail transit networks in Istanbul	2004	Gercek H.; Karpak B.; Kilincaslan T.	57	Analytic hierarchy process; MCDM application; rail transit networks; urban transportation	Transportation

addition, Nalmpantis et al. (2019) determined the importance levels of the criteria affecting public transportation innovation activities according to the AHP method and the innovation performance of public transportation innovation activities in general, based on 97 samples using public transportation. As a result of the research, the degree of importance of the innovation criteria according to the public transport innovation activities is listed as Utility, Feasibility and Innovativeness.

Hybrid approaches, such as AHP-TOPSIS and Fuzzy AHP, are commonly employed in academic publications to accomplish research objectives (Bilişik et al. 2014; Arsovski et al. 2017; Hamurcu and Eren 2020a; Singh et al. 2020; Sobhani et al. 2020; Kutlu Gündoğdu et al. 2021; James et al. 2021; Buran and Erçek 2022; Eren 2022; Cheemakurthy and Garme 2022). It is worth mentioning that TOPSIS can be an excellent complementary technique to AHP for ranking alternatives, especially when AHP is used for weight determination (Güner 2018; Sobhani et al. 2020; James et al. 2021). A remarkable result regarding word analysis is the issue of customer satisfaction, which is a key actor in this field, although it is not in the list of the most frequently used keywords. In conclusion, AHP proves to be a useful instrument in evaluating customer satisfaction (Bilişik et al. 2013; Moslem and Duleba 2018; Chin et al. 2019; Zhang et al. 2020; Duleba and Moslem 2021).

Sustainability and environmentally-friendly vehicles have gained importance in urban transportation in recent years. Increasing human mobility as a result of the increasing population of the country has led to the rapid depletion of scarce resources. Human mobility has also increased the demand for transportation vehicles. As a result of rapid production and consumption, the increase in air and water pollution, the gradual depletion of limited resources, and the awareness of leaving a livable world to future generations, renewable energy sources have become more critical. The intensive use of fossil fuels in transportation not only causes the depletion of these scarce resources but also causes the release of harmful gases to the environment and the formation of non-recyclable wastes in nature with the chemical reactions occurring in the energy production process. For sustainable urban transportation, it is necessary to have smart and environmentally-friendly technological solutions that cater to the needs of different user groups, including current and potential users. This helps in avoiding any opposition from citizens and enables sustainable development decisions to be supported (Ghorbanzadeh et al. 2019). One strategy could be to invest in more efficient and sustainable modes of transportation such as electric buses or trains for reasons such as increasing environmental awareness, global warming, and taxes (Tzeng et al. 2005; Topal 2017; Hamurcu and Eren 2020a, b; Rivero Gutiérrez et al. 2021). As a growing trend, private car usage instead of public transportation increases CO2 emissions. Public transport is essential since it reduces car traffic and carbon footprint highlighted in the Kyoto protocol, Paris agreement and finally, Green deal (Hamurcu and Eren 2020b). At this point, electric vehicles are more suitable to prefer compared to alternatives.

Another strategy could be to improve the connectivity of different transportation systems such as buses, trains, and bikes to make it easier for people to get around. The integration of different transportation modes is a crucial aspect for ensuring the safety and sustainability of urban transportation systems (Saplıoğlu and Aydın 2018). By offering short-term bike rentals for a fee, a bike-sharing system (BSS)

provides an intelligent bike-rental solution to city residents who need to travel short distances. These systems aim to reduce traffic congestion and combat climate change, while simultaneously promoting physical activity. Thanks to BSSs, urbanites now have access to bikes as a healthier and more eco-friendly mode of transportation (Eren and Katanalp 2022). The application of AHP in this area is limited, making it an open research topic. Additionally, cities and city managers can work to make public transportation more accessible. This could involve investing in more frequent and reliable transportation services as well as building new transportation infrastructure in these areas. Overall, managing public transportation systems is a complex task that requires careful consideration of multiple factors including economic, social, and environmental factors.

Another important strategy that cities and city managers can use to improve public transportation systems is to invest in technology and data analytics. This can include using real-time data to optimize routes and schedules as well as investing in smart transportation systems that can provide information to riders about delays and disruptions. Additionally, cities can use data analytics to identify patterns in transportation usage such as peak travel times or areas of high demand which can inform decision-making around infrastructure investments or service adjustments. Smart transportation systems can be designed to give priority and promote eco-friendly transportation modes such as public transport, cycling, and electric vehicles. Furthermore, implementing technology such as contactless payment systems, mobile apps, and digital information systems can improve the overall user experience and make public transportation more attractive to riders (Oladimeji et al. 2023). As a whole, investing in technology and data analytics can help cities to better understand and respond to the transportation needs of their communities.

4 Conclusions

Rapid urbanization and increasing population have caused several problems in urban areas. One of these critical problems is transportation. Public transportation is a good solution to cope with increasing human mobility. This paper conducts bibliometric and social network analysis on urban and public transport related publications using the AHP technique. Citation, country, publication source, keyword, and author analysis are done in this field and results can be sorted as follows:

- "Sustainability" is the journal in which the most articles are published in this field. "(EWGT) Euro Working Group Transportation" is the conference that has most conference papers are published, also.
- Although the second most active author is Moslem S. according to number of publications, Lin, C. W., Opriovic, S., and Tzeng, G.H. receive a higher number of citations than Moslem, S.
- The most frequently used keyword is AHP and its synonyms such as Analytic Hierarchy Process, AHP Method, Analytic Hierarchy Process (AHP), and Analytical Hierarchy Process. Also, we can deduce from the word analysis that the

sustainability has gained importance in the field of urban and public transportation.
- The clique analysis reveals that the "customer satisfaction" is among the crucial issues which are studied frequently in this field.
- The most productive 3 countries are China, Turkey, and Hungary and total number of publications of these countries correspond 40% of all publications.
- The authors who have academic cooperation between them are Duleba S. and Moslem S., since these authors work together in academic publications.

For future studies, the bibliometric analysis could be extended or analysis could be done related to other MCDM methods used in public transportation such as the analytic network process (ANP), ELECTRE, PROMETHEE, VIKOR, and hybrid applications.

Acknowledgements The authors express their gratitude to the anonymous reviewers for their valuable comments on the paper.

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