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SYSTEMATIC REVIEW **OPEN ACCESS**

A Systematic Literature Review and Thematic Analysis of DEMATEL in Transport Systems

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Abstract:

Introduction/Background: Multi-criteria decision-making (MCDM) approaches have been utilized recently in several types of research, including transport systems. MCDM can aid researchers in the decision-making process in complex situations that entail more than one criterion in the selection process. Among MCDM approaches, Decision-Making Trial and Evaluation Laboratory (DEMATEL), or the decision-making trial and evaluation laboratory, is a useful tool for examining the underlying connections between various components of complex systems.

Materials and Methods: This research conducts a systematic literature review and a thematic analysis that synthesizes the current body of literature that employed the DEMATEL technique within the context of transportation systems. We searched five electronic databases (ScienceDirect, Springer, Taylor & Francis, Scopus, and Web of Science) for studies from 2018 to 2024 using preset keywords. A total of 37 papers were retrieved, and after removing duplicates in Mendeley, 28 remained. Abstracts were manually reviewed based on inclusion criteria, followed by a quality assessment, resulting in a final dataset of 26 studies.

Results: The study presents potential research and future directions focusing on the sustainability and environmental impact within transportation systems.

Discussion: Findings underscore the diversity of DEMATEL applications, ranging from transport type, sustainable initiatives, and safety and risk management.

Conclusion: This review concludes with recommendations for future research directions aimed at addressing emerging challenges and advancing the field of decision-making in the transportation sector.

Keywords: Multi-criteria decision-making *(MCDM)*, *DEMATEL*, Transportation systems, Sustainability, Safety and risk management, Thematic analysis.

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1. INTRODUCTION

People's choices for transportation impact their activities and access to various opportunities, which in turn affects their mental and physical well-being [1]. By enabling the connection of people, goods, and services, the quality of transportation is essential to promoting economic development and improving the welfare of societies [2]. The potential of metropolitan areas and cities to evolve and maintain themselves as centers of employment and economic growth depends largely on their transportation infrastructure. Public transportation offers a means to connect homes with workplaces or recreational areas and enterprises with labor pools. A significant number of people can travel efficiently in densely populated areas thanks to regional and local public transit options, including buses, light rail, and the metro.

Transportation systems have gained increasing attention from researchers, focusing on different areas of research. For example, risk assessment and analysis have been broadly explored in the context of the transportation system [3-5]. Researchers have also focused on the sustainability and environmental impacts in the context of transportation systems [6-8]. The assessment of the resilience of transportation systems has also been explored in previous literature [9-11]. The performance of transportation systems has gained the attention of researchers focusing on several dimensions such as travel time, construction material, and sustainability performance [12-14]. These complex and interrelated areas highlight the need for robust approaches to evaluate the importance of different criteria in decision-making related to transportation systems.

The advancement of science and the economy has made decision-making more difficult. Numerous components with a hierarchical structure make up complex systems, and there are many different kinds of influence linkages between different variables within these systems. Effectively handling decision-making challenges in a complex system with diverse relationships requires reasonable decision-support tools and techniques. Numerous techniques for making decisions assume that the elements, criteria, and options are independent of one another and cannot accurately represent how interdependent the variables are [15]. The decision-making trial and evaluation laboratory (DEMATEL) method, created by the Geneva Research Center of the Battelle Memorial Institute, is a useful method for analyzing the influences and causal linkages among elements in an intricate structure using image and matrix capabilities [16]. DEMATEL has emerged as a crucial tool for resolving decision-making issues in complex systems because of its capacity to detect nonlinear correlations between variables. Nonlinear qualities characterize the impact of interactions among elements or subsystems [15].

A systematic review methodology guarantees a thorough and broad examination of the body of literature, offering a strong basis for comprehending the present level of knowledge in different areas of research. Through a methodical search, selection, and synthesis of pertinent research, systematic review methodology can locate bias and improve the reliability of the results. It makes it possible to identify important research trends, techniques, and gaps, providing scholars, decision-makers, and business professionals with insightful information. Additionally, it provides a well-defined study agenda and future research direction, directing upcoming studies and facilitating the field's targeted and knowledgeable advancement. This study aims to conduct a systematic review methodology in the context of the DEMATEL approach in the transport system. By doing so, the study aims to address the following research questions:

i. What are the main themes investigated in previous literature related to the DEMATEL approach and transportation systems?

ii. What are the main DEMATEL approaches that were deployed in the previous literature on transportation systems?

iii. What are the potential areas and future directions for the application of the DEMATE approach in transportation systems?

The rest of this study is structured as follows: Section 2 presents an introduction to the MCDM approach, Section 3 provides a detailed description of the DEMATEL approach, Section 4 displays the review methodology, Section 5 presents the results, Section 6 discusses the factors influencing transportation systems and the thematic analysis, and Section 7 concludes the study.

2. MULTI-CRITERIA DECISION-MAKING

MCDM approach does not depend on conventional statistical inferences; instead, it relies more on analyzing small-sized samples collected by interviewing stakeholders in specific areas, making it especially suited for managing intricate decision-making situations [17]. Integrating objective empirical data with expert judgments is the primary goal of MCDM. This process provides crucial managerial insights that help decision-makers create better strategies [18]. MCDM includes the definition of assessment criteria, calculation of the linked weights, and a combination of the efficacy of potential options [19]. Several concepts and ideas are included in the MCDM approach, depending on the type of decision-making problem, which we summarize based on Taherdoost and Madanchian [20]:

i. Various potential paths of behavior constitute the options.

ii. A quantifiable feature of the option refers to a specific attribute.

iii. The aggregation process entails choosing the option based on the performance of different options within a particular criteria.

iv. Decision variables refer to the elements of the option’s vector.

v. Feasible options represent the decision space.

vi. Measures are described as “the elements utilized to assign values or symbols to a feature in order to quantify an option to its attribute.”

vii. Criteria refer to the tools for assessing and contrasting options based on the effect of their choices.

viii. Preference refers to the level at which the option meets the needs of a decision-maker concerning a given attribute.

ix. Depending on the type of problem, which can include ordering, organizing, and choice, different decisions should be made.

Economic, social, and environmental influences play a foundation role in transportation systems and the evaluation of potential future developments for the transportation sector is essential to adapting to these dynamic influences. Evaluation of transportation is seen to be crucial for increasing customer satisfaction with service quality and efficiency [21]. MCDM has emerged as a crucial decision-making method that numerous authorities, scholars, and researchers have employed while assessing transportation systems [21]. According to Camargo *et al.*, between 1982 and 2014, 58 distinct MCDM approaches were used in investigating urban passenger transportation systems, indicating their benefits for transportation systems' assessment and decision-making initiatives [22]. The importance of applying MCDM techniques in this subject is demonstrated by the recent increase in numerous investigations on urban and public transportation systems [23].

3. DEMATEL

Making decisions is a necessary aspect of our everyday lives, and doing so calls for serious thought. As a general understanding, decision-making frequently comprises a number of criteria, many of which are conflicting and prone to change, which complicates this process. To address complex problems, a variety of decision-making strategies must be used [24]. Battelle Memorial Association was the organization that first proposed the idea for the Decision Making Trial and Evaluation Laboratory (DEMATEL) to solve complicated problems [25]. As an MCDM technique, DEMATEL is utilized to ascertain both direct and indirect causal correlations between the components. It is regarded as a survey-based method. The idea of digraphs is the foundation of the DEMATEL. Because digraphs may display the directional linkages between components, they are frequently more beneficial than directionless diagrams. Furthermore, with the degree of impact indicated by the numerical value, the digraph depicts a fundamental concept of the contextual relationship between system components. Additionally, digraphs enable the grouping of pertinent elements into cause-and-effect categories. DEMATEL follows a structured methodology as described by Tzeng, *et al* [26]:

3.1. Phase 1

Explain the problem at hand and identify the crucial components or factors that are relevant to the difficult decision-making process.

3.2. Phase 2

When collecting information from a panel of experts, use a rating scale ranging from 0 to 4. On this scale, zero means there is no effect, one means there is a minimal effect, two means there is an average effect, three means there is a major effect, and four means there is an extreme effect on other components. Expert responses form a part of the construction of direct-influence matrices (Eq. **1**). When there are H experts participating in the process, these matrices are created by adding up the contributions of each expert.

$$X_{ij}^{k} = \begin{cases} X_{ij}^{k}, & i \neq j \\ 0, & i = j \end{cases}, for\ k = 1,2,\dots,H \tag{1}$$

In which x_{ij} reflects the degree of effect of component i on component j, and X^k refer to the direct-influence matrix received from the data collected from the kth participant.

3.3. Phase 3

The measurement of the initial direct influence matrix is conducted. The average matrix $A = [a_{ij}]_{nxm}$ is measured (Eq. **2**) as follows:

$$A = [a_{ij}]_{n\times n} = \begin{bmatrix} 0 & \frac{1}{H}\sum_{k=1}^{H} x_{21}^{k} & \cdots & \frac{1}{H}\sum_{k=1}^{H} x_{1n}^{k} \\ \frac{1}{H}\sum_{k=1}^{H} x_{21}^{k} & 0 & \cdots & \frac{1}{H}\sum_{k-1}^{H} x_{2n}^{k} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{H}\sum_{k=1}^{H} x_{21}^{k} & \frac{1}{H}\sum_{k=1}^{H} x_{21}^{k} & \cdots & 0 \end{bmatrix} \tag{2}$$

3.4. Phase 4

We applied the normalization on the average matrix $A = [a_{ij}]_{nxm}$. The matrix $D = [d_{ij}]_{nxm}$ (normalized initial direct-relation) is measured (Eq. **3**) as follows:

$$D_{ij} = \frac{A_{ij}}{max\left(max_i \sum_j A_{ij}, max_j \sum_i A_{ij}\right)} \tag{3}$$

In which principal diagonal components in $D = [d_{ij}]_{nxm}$ equal zero.

3.5. Phase 5

Next, the total relation matrix is measured (Eq. **4**) as follows:

$$T = \left[t_{ij}\right]_{n\times n} = \sum_{i-1}^{\infty} D_i = D(I-D)^{-1} \tag{4}$$

for i and j in the range of 1 to n, where I denotes the identity matrix, T reflects the total relation matrix and $(I\text{-}D)\ (I\text{-}D)^{-1}=I$.

3.6. Phase 6

In this phase, the Influential Relation Map (IRM) is formed by calculating r_i and c_j from the matrix T (Eqs. **5** and **6**) as follows:

$$r_i = \sum_{j=1}^{n} t_{ij} \tag{5}$$

$$c_j = \sum_{i=1}^{n} t_{ij} \tag{6}$$

As presented by the equation, r_i signifies the cumulative effects of the *ith* component on other components, while c_j denotes the cumulative effects that the *jth* component has from other components. Therefore, $r_i + c_j$ (i=j)

encapsulates the total effects given and received by the *i*th component. Additionally, $r_i + c_j$ serves as a metric for the importance of the *i*-th component and r_i-c_j represents the net effect contributed by the *i*-th element to the system. For r_i-c_j>0, the *ith* element signifies a net cause in the cause group, whereas for r_i-c_j<0, the *ith* component represents a net receiver or yields an effect in the effect group.

3.7. Phase 7

A threshold value (δ) is used to create a Network Relationship Map (NRM). The cause-effect diagram incorporates only effects deemed significant, *i.e.*, those surpassing the threshold. Essentially, we eliminate the minor effects identified by the components in matrix *T*.

4. REVIEW METHODOLOGY

A strong basis for creating new information, advancing theory, and identifying research gaps in previous literature is performed using a methodical, organized, and effective literature review [27]. This study's primary goal is to identify the implementation and use of DEMATEL techniques in evaluating transportation systems, which will give academics new information and ideas for future research. Following the identification of the study's objectives, a systematic review was conducted using six activities: (1) identifying research questions; (2) identifying review protocol; (3) recognizing the research strategy, which includes deciding on search terms and electronic databases; (4) selecting studies, which includes deciding on inclusion and exclusion measures; (5) determining the quality assessment of the chosen literature; and (6) data extraction and synthesis. We will go into more depth about these endeavors in the sections that follow.

4.1. Review Protocol

For conducting the systematic literature review, we found the approach presented by Kitchenham [27] very useful. All studies that were accessible and pertinent to the research topics in the chosen electronic databases were interpreted at the start of the study. Fig. (**1**) shows the research protocol we adhered to. Using the preset keywords, we searched five electronic databases from 2018 to 2024: ScienceDirect, Springer, Taylor and Francis, Scopus, and Web of Science. We carefully selected these databases based on their relevance to the research domain and their extensive coverage of high-quality peer-reviewed literature. These databases encompass a wide range of interdisciplinary studies, ensuring that our review captures the most relevant and impactful research. For instance, Lu, Krutoff [28] referred to Web of Science and Scopus to conduct a systematic literature review focusing on transportation costs. In another systematic literature review, Yildizbasi, Celik [29] utilized only Scopus data for exploring the transportation infrastructure.

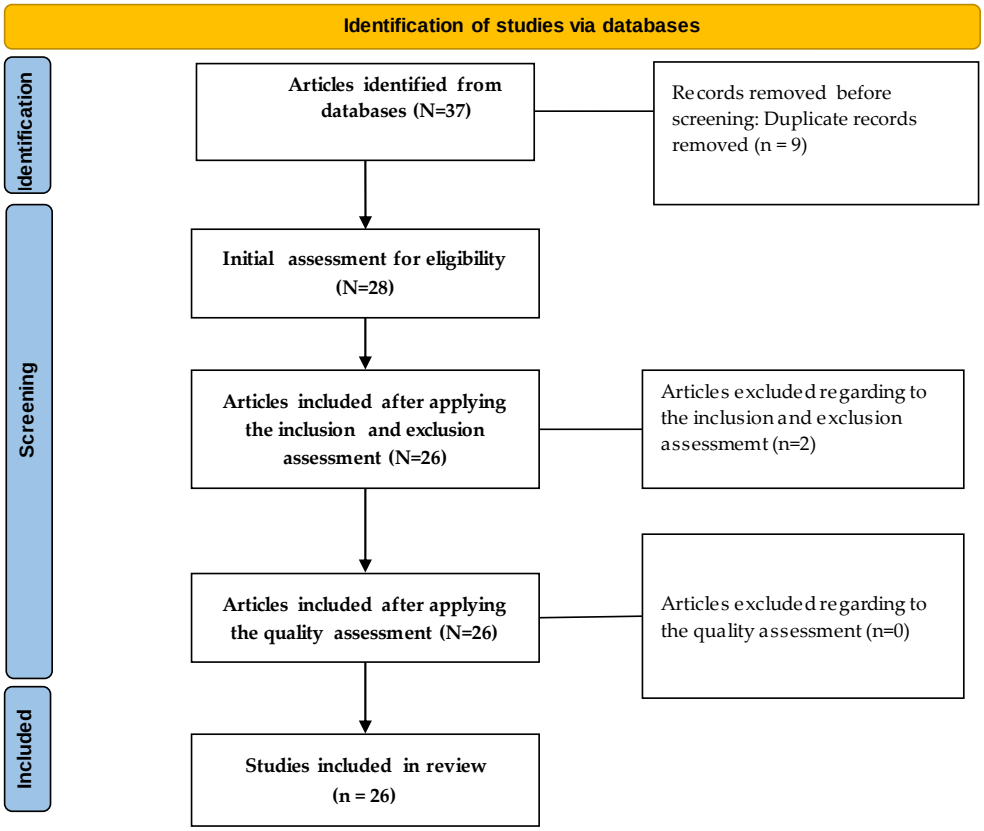

Fig. (1). Review protocol.

To find the papers within the allotted time frame, we employed these resources, conducted a thorough search, and adhered to our investigation's objectives and research questions. The predetermined inclusion criteria were applied to all of the chosen papers. The total number of downloaded papers was 37 papers. After downloading all the obtained references to Mendeley's program, duplicated papers were deleted, leading to 28 articles. The references were reviewed manually after that by reading the abstracts and selecting the papers that met the inclusion criteria. Following that, we applied a specific quality assessment procedure to get the final dataset of included studies. The final set of papers included 26 studies.

4.2. Search Strategy

We aim to explore the studies that focused on DEMATEL implementation in evaluating transport systems. Hence, we included two main areas in the search terms. The first relates to different approaches and techniques of DEMATEL and the second relates to transport systems.

4.3. Inclusion and Exclusion Criteria

Establishing the inclusion and exclusion criteria early within the research protocol is a crucial step for reviewing the previous literature. The literature review will include full-text articles on a relevant topic that were published in the English language. The phrase “relevant topic” refers to publications that fall under one of the primary predefined topics, which are “DEMATEL” and “Transportation”. At this point, we merely look at the abstracts and introductions of the studies to see if the topic of the study is within the scope of the literature review. Table **1** displays the inclusion and exclusion criteria.

Table 1. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Written in the English language	Non-English
Full articles	Uncompleted studies
In the domain of the predetermined topics	Outside the domain of the predetermined topics.

4.4. Quality Assessment

Following the application of inclusion and exclusion criteria, it is crucial to assess the articles' quality by implementing quality instruments that other researchers used [27, 30]. Following a robust approach at the quality assessment stage might assist the researcher in evaluating the overall level of quality of the research articles. Table **2** displays the four quality assessment criteria that we created for this study.

Since we are not interested in articles that fall outside the scope of our research, we will instantly remove the articles if the first question has a “no” response. Following the computation of the sum of the points for each study, we retain the studies with scores of four and higher and exclude the studies with scores below four. At this point, the authors thoroughly read the full studies in order to properly apply the assessment's quality. To guarantee the accuracy of our findings, one author read each paper and another author reviewed it.

Table 2. Quality assessment.

S. No.	Quality Assessment	0	1	2
1	Is the main topic of the study related to both areas of research?	If the answer is no.	If it partially fulfills this criterion.	If the answer is yes.
2	Is the research methodology clearly described in the article?	If the answer is no.	If it partially fulfills this criterion.	If the answer is yes.
3	Is the data collection methodology clearly described in the article?	If the answer is no.	If it partially fulfills this criterion.	If the answer is yes.
4	Is the analysis of the data clearly presented?	If the answer is no.	If it partially fulfills this criterion.	If the answer is yes.

4.5. Data Extraction and Synthesis

In this stage, each article was read carefully to extract the required data. The extracted items were chosen carefully to meet the research objectives. The extraction process was done using Mendeley and manually. All the papers were added to Mendeley for easy reading and referencing, and then they were revised manually for data classification and extraction. Some of the attributes were classified automatically when importing the resources from the Mendeley program, such as title, authors, and year of publication. These attributes were reviewed carefully by the authors to ensure the correctness of the extracted data. After that, a manual extraction process was carried out by the authors to meet the research objectives. The extracted data is presented in Table **3**.

5. RESULTS

5.1. Yearly Distribution of Research Publications

Fig. (**2**) presents the yearly distribution of the included research papers. As the figure presents, the number of publications has increased rapidly from 2020 to 2022. In 2023, we have 4 studies, while in 2024, we have the highest number of publications of 10 studies. This result shows an increasing interest in the implementation of DEMATEL approaches in different areas of transportation.

Table 3. The extracted data.

S. No.	Extracted data	Explanation
1	Year	The year of publishing the article in the time interval of 2018-2024.
2	Title	The title of the article.
3	Authors	List of authors of the study
4	Country	The country in which the study was implemented
5	Theme	The main theme of the study
6	Methodology	The main methodology used by the DEMATEL approach.
7	Factors	The most significant factors

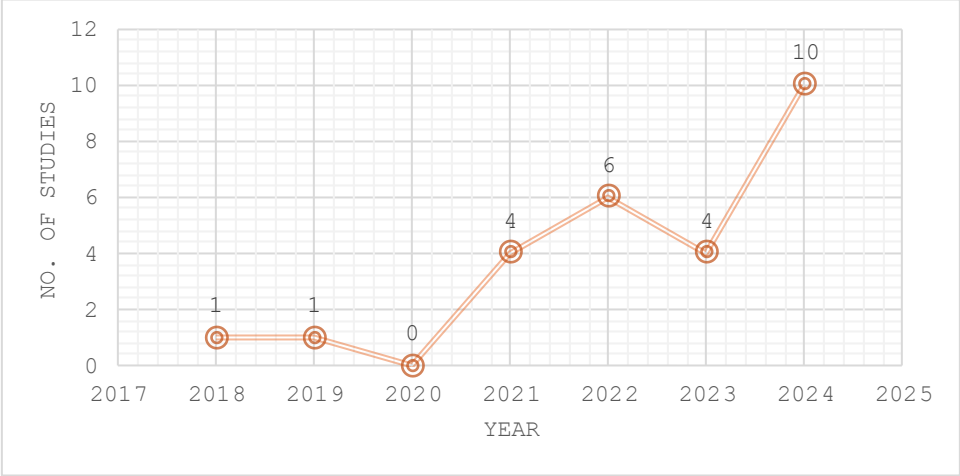

Fig. (2). Distribution of research publications over the year.

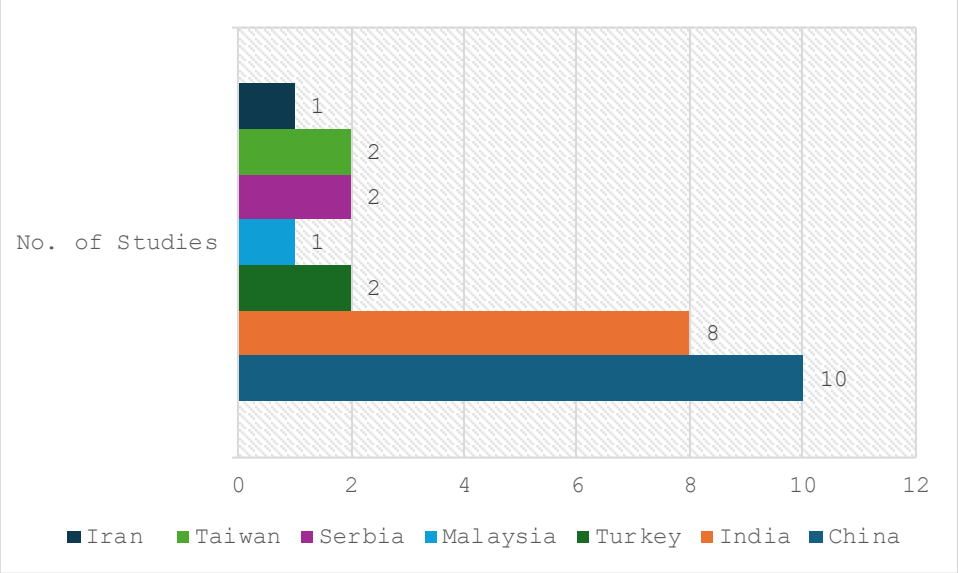

Fig. (3). Distribution of research publications over the country.

5.2. Distribution of Research Publications over Countries

Fig. (**3**) presents the number of papers based on the country in which the study was implemented. As the figure shows, the majority of studies were implemented in China (10 studies were conducted in China). Following that, India has the next highest number of studies (8 studies were conducted in India). Two studies were conducted in each of Taiwan, Turkey, and Serbia. Iran and Malaysia have one study each.

5.3. Distribution of Research Publications over Electronic Resources

Referring to Fig. (**4**), we have utilized five electronic resources to retrieve the studies. It is important to note that some of the studies might fall within more than one electronic resource. For instance, several studies can be retrieved from Scopus and Science Direct. Other studies that we retrieved from Science Direct can also be retrieved from the Web Of Science.

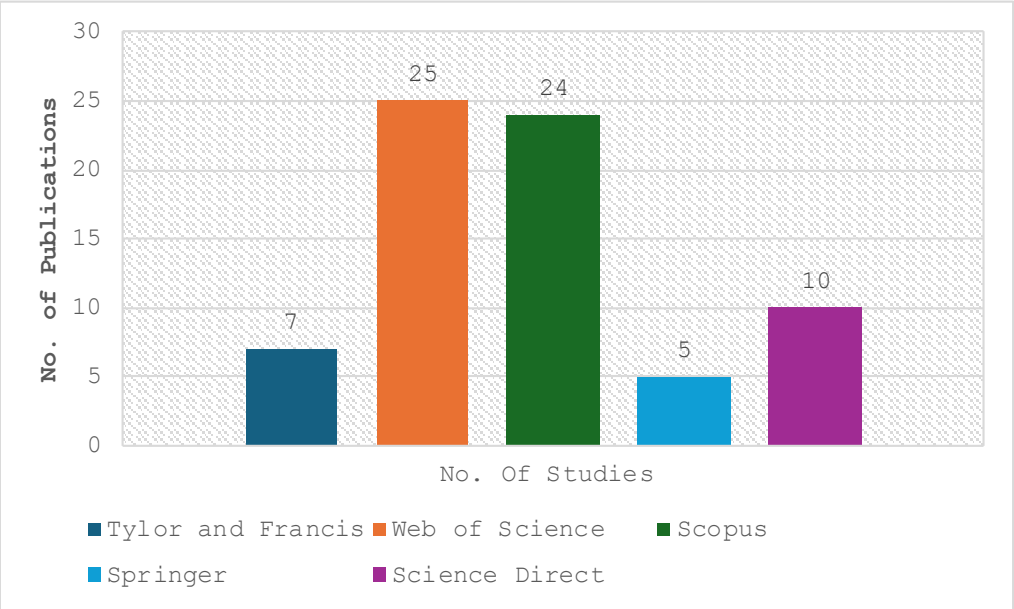

Fig. (4). Distribution of studies over electronic resources.

However, we deleted the duplicated studies, retaining only the version from the first resource through which the study was retrieved. In total, Web of Science contained 25 publications, while Scopus had 24 studies. ScienceDirect published 10 studies, followed by Taylor & Francis with 7 studies and Springer with 5 studies.

Table 4. Types of transportation investigated in the studies.

Authors/References	Transportation Type
Kuzu [31]	Maritime (ship anchoring)
Gao [32]	Maritime transportation (tanker cargo handling)
Trivedi, *et al*. [40]	Inland waterways
Wu, *et al*. [33]	Metro systems
Lo, *et al*. [41]	Mass rapid transit
Raj, *et al*. [34]	Alternative fuel vehicles
Pian, *et al*. [42]	Transportation networks
Singh, *et al*. [43]	Freight transportation
Tang, *et al*. [44]	Railway
Ma, *et al*. [45]	Bike sharing
Milenković, *et al*. [46]	Rail freight transport
Pandey and Mishra [47]	Truck haulage (mining industry)
Sang, *et al*. [36]	Electric buses
Asadi, *et al*. [35]	Electric vehicles
Mizrak and Akkartal [37], Sharma and Sharma [38], Chang *et al*. [39]	Aviation
Keshavarz-Ghorabaee [48]	Electric vehicles

5.4. Transportation Type

The investigated literature has focused on different types of transportation. The diversity in the types of transportation is reflected in Table **4**, ranging from maritime (ship anchoring and tanker cargo handling) to metro systems [31-33]. Several studies have explored different types of vehicles, including alternative fuel vehicles and electric vehicles [34, 35]. The “electric busses” were explored by Sang, *et al*. [36]. Aviation and airport services have also been explored in several studies [37-39].

5.5. Adopted Approaches

Table **5** presents a summary of the adopted approaches in the surveyed studies. As the table presents, all studies have deployed the DEMATEL approach. The majority of studies have integrated the DEMATEL with other methodologies to enhance and optimize the results. For instance, several studies have deployed ISM (Interpretive Structural Modeling) [40, 43, 49, 50]. ANP was deployed in several studies [33, 46, 51]. Other studies have integrated advanced fuzzy techniques [31, 36, 47, 50].

6. DISCUSSION

6.1. Factors Influencing Transportation Systems

In the surveyed studies several factors were investigated. Usually, in the DEMATEL approach, the research offers several influential factors impacting a specific area. The suggestion of these factors might be based on previous literature, or recommended by a panel of experts. In the next stage, these factors are assessed and ranked referring to experts, stakeholders, or decision makers. Hence, the results of the study that adopts the DEMATEL approach entail a rank of the factors and a classification of these factors as cause-and-effect variables.

We focused on the factors that were determined by the researchers as the most influencing factors. Table **6** presents the factors that were highlighted in the surveyed

Table 5. Adopted approaches in the surveyed literature.

Ref.	Method
Hsu, *et al*. [52]	Integrated Quality Function Deployment and Multicriteria Decision-Making (QFD-MCDM) framework
Rajak, *et al*. [53]	Grey-based DEMATEL methodology
Pandey and Mishra [47]	Fuzzy DEMATEL approach
Milenković, *et al*. [46]	DEMATEL integrated with ANP
Ma, *et al*. [45]	Hybrid MCDM model combining DEMATEL and VIsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR)
Liu, Hu [50]	Fuzzy DEMATEL-ISM approach, MICMAC analysis
Tang, *et al*. [44]	Type-2 Fuzzy DEMATEL Method
Singh, *et al*. [43]	Fuzzy MICMAC analysis, ISM, grey-DEMATEL, integrated ISM-DEMATEL
Sharma and Sharma [38]	Hybrid AHP and DEMATEL approach
Pamucar, *et al*. [54]	MultiAtributive Ideal-Real Comparative Analysis (MAIRCA) with DEMATEL and sensitivity analysis
Pian, *et al*. [42]	G-DEMATEL model (integrating k-step gravity model and DEMATEL)
Raj, *et al*. [34]	Integrated DEMATEL and TOPSIS framework
Zhan, *et al*. [55]	Hybrid approach using CRITIC, DEMATEL, and deep learning features
Nila and Roy [56]	Pythagorean Fuzzy DEMATEL (PF-DEMATEL) method with trapezoidal fuzzy numbers and D-Numbers
Shoaib, *et al*. [49]	Exploratory Factor Analysis (EFA), Fuzzy DEMATEL, and ISM
Sahu, *et al*. [51]	Integrated grey-DEMATEL and ANP (grey-DANP) with sensitivity analysis
Chang *et al*. [39]	Modified DEMATEL combined with Dombi Weighted Aggregator method and modified VIKOR.
Lo, *et al*. [41]	Rough-Fermatean Fuzzy Decision-Making Trial and Evaluation Laboratory (RFF-DEMATEL)
Gao [32]	Cloud Model and DEMATEL
Wu, *et al*. [33]	DEMATEL and Analytic Network Process (ANP)
Trivedi, *et al*. [40]	DEMATEL and ISM
Kuzu [31]	Fuzzy logic and DEMATEL
Asadi, *et al*. [35]	DEMATEL
Sang, *et al*. [36]	Fuzzy DEMATEL and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) and PT
Mizrak and Akkartal [37]	DEMATEL and Quantum Spherical Fuzzy Sets (QSFS)
Keshavarz-Ghorabaee [48]	DEMATEL

Table 6. The most influential variables in the surveyed studies.

Title	Most Influential Factors
Hsu, *et al*. [52]	Safe work environment, customized products and services, production flexibility, control redundancy, real-time data collection and analysis.
Rajak, *et al*. [53]	Economic barriers, social-political barriers, environmental barriers, technical barriers.
Pandey and Mishra [47]	High speed and aggressive driving.
Milenković, *et al*. [46]	Reliability (departing/arriving on time, canceled services), lead time (idle time), investment cost (organizational culture, business process redesign)
Ma, *et al*. [45]	Tangibles, reliability, responsiveness, assurance, empathy.
Liu, Hu [50]	Risk warning and prediction, human resources management, inter-organizational synergies, resource reserve situations, organizational leadership, and organizational learning.
Tang, *et al*. [44]	Poor management, imperfect rules and standards, limited supervision/inspection, unsafe material conditions, and unsafe human conditions.
Singh, *et al*. [43]	Information distortion, lack of top management commitment, lack of strategic planning, dependency, and driving power of barriers.
Sharma and Sharma [38]	Multiagent technology (MAT), design and service factors, flight safety, interactive relationships among variables
Pamucar, *et al*. [54]	Different locations
Pian, *et al*. [42]	Polycentric, two-center, and monocentric networks; independent-type cities; functional differentiation; geographical conditions; distance from the central city; gravitational effects.

(Table 6) contd.....

Title	Most Influential Factors
Raj, *et al*. [34]	Long charging time, insufficient charging infrastructure, high initial cost of vehicles
Zhan, *et al*. [55]	Infrastructure density, railroad proportion, freight economic development level (total transportation demand), traffic efficiency, waterway freight proportion, and public transit availability.
Nila and Roy [56]	Zero emission, information security (a key concern for logistical participants), freight exchange platform (emphasis on information security for LC4.0 implementation).
Shoaib, *et al*. [49]	Customer and external management as critical enablers, organization/top management support, government regulation and legislation, and public and consumer pressure.
Sahu, *et al*. [51]	Government regulations, financial stability, and customer trust.
Chang *et al*. [39]	Pre-disaster preparation.
Lo, *et al*. [41]	Operations and performance (paramount factors), digital technology economy, sustainable supply chain management.
Gao [32]	Unsafe acts of the crew, cargo specification, communication during cargo watch, cargo handling equipment failure.
Wu, *et al*. [33]	Spatial and temporal heterogeneity, stages of resilience (disaster, resistance, repair, strengthening), impact indices on resilience, climate path scenarios, station location (suburban *vs*. city center), emergency flood response and pre-disaster drills, human emergency relief and drainage.
Trivedi, *et al*. [40]	Governance issues, policy bias, high-cost requirements, and lack of river interlinking.
Kuzu [31]	Environmental factors at anchorage area, training and competency of the crew, number of shackles paid out, anchoring method, selection of anchor (critical for anchor loss).
Asadi, *et al*. [35]	Environmental concerns, trust in EVs, personal norms, price value, attitudes regarding EVs, and subjective norms.
Sang, *et al*. [36]	Evaluation criteria (transportation, economy, technology, environment), macro and long-term criteria (coordination with power grid planning, total investment costs).
Mizrak and Akkartal [37]	Threat detection systems, regulatory compliance, user training, data encryption protocols.
Keshavarz-Ghorabaee [48]	Challenges of adopting electric vehicles are classified into three categories: social, economic, and technological.

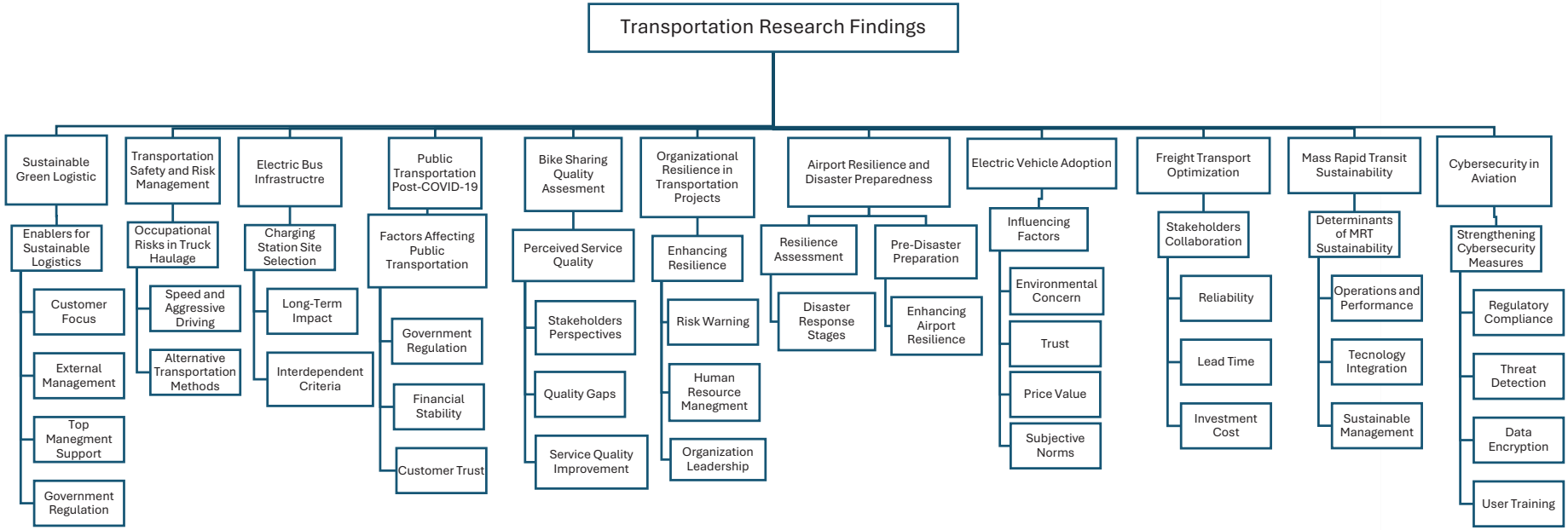

Fig. (5). Thematic map of the surveyed studies.

studies. In the literature, researchers have explored factors related to safety and risk prevention. For instance, a safe work environment and risk warning and prediction were explored by Hsu, *et al*. [52] and Liu, *et al*. [50]. On the other hand, high speed and aggressive driving were explored by Pandey and Mishra [47]. Additionally, unsafe acts of the crew and cargo handling equipment failure were explored by Gao [32]. Flight safety and threat detection systems were explored in the study by Sharma and Sharma [38] and Mizrak and Akkartal [37], respectively. Pre-disaster preparation was explored in the study by Hsu *et al*. [39]. Second, researchers have explored factors related to infrastructure and logistics, focusing on factors related to the organizational and physical infrastructure that underpins transportation, such as network structure, facility density, and site planning. For example, infrastructure density, railroad proportion, traffic efficiency, and number of public transportation per operating line were explored by Zhan, *et al*. [55]. Polycentric and monocentric networks were highlighted by Pian, *et al*. [42].

Third, operational efficiency and performance were explored by researchers, focusing on factors related to improving operational aspects of transportation systems, such as reliability, lead time, and efficiency. For instance, reliability (on-time, canceled services), and lead time (idle time) were explored in the study by Milenković, *et al*. [46]. Operations performance and economic allocation were investigated in the study by Lo, *et al*. [41]. Real-time data collection and analysis were highlighted in the study by Hsu, *et al*. [52]. Zhan, *et al*. [55] highlighted several factors, including traffic efficiency, and freight economic development level.

Fourth, the research revealed several factors related to environmental and sustainability concerns. These factors are mainly dealing with environmental impact, emissions, and sustainability-related barriers. Zero emission and environmental barriers were explored by Nila and Roy [56] and Rajak, *et al*. [53], respectively. Environmental concern was highlighted in the study by Asadi, *et al*. [35], which focused on the adoption of Electric Vehicles (EVs). Wu, *et al*. [33] explored climate path scenarios. Factors related to policy and governance issues were also highlighted in the surveyed studies, including factors that address regulations, governance structures, and barriers related to policy. Government regulations and financial stability were explored by Sahu, *et al*. [51]. Trivedi, *et al*. [40] explored policy bias and governance issues. Government regulation and legislation were explored by Shoaib, *et al*. [49]. Sixth, researchers focused on factors related to technology, those related to technological advancements, cybersecurity, and tools that enhance operational or safety functions. For example, information security and data encryption protocols were explored [37, 56]. Finally, researchers explored factors related to customer service and quality, such as tangibles, reliability, responsiveness, customer trust, and customized products [45, 49].

6.2. Thematic Analysis

In this section, we aim to investigate the main themes that were explored in the surveyed studies. This will allow us to understand the topics that have gained more interest and focus by researchers, and the topics that gained less attention. This will also open the route for discussing research gaps and future research directions.

Researchers of transportation have focused on different themes. To understand the themes that have been investigated in the surveyed studies, we conducted a thematic analysis. Fig. (**5**) illustrates, there are several diverse themes in the surveyed studies. The main themes in the surveyed studies are as follows: (T1) Adopting Sustainable Green Logistics, (T2) Airport Resilience and Disaster Preparedness, (T3) Transportation Safety and Risk Management, (T4) Electric Vehicle Adoption, (T5) Electric Bus Infrastructure, (T6) Freight Transport Optimization, (T7) Public Transportation Post-COVID-19, (T8) Mass Rapid Transit Sustainability, (T9) Bike Sharing Quality Assessment, (T10) Cybersecurity in Aviation, and (T11) Organizational Resilience in Transportation Projects.

T1 focuses on sustainable green logistics. In this theme, researchers have focused on recognizing and ranking the factors that support sustainable logistics. The theme focuses on several factors including customer-based factors, top management support, and government regulation as vital factors for sustainable green logistics. T2 (Airport Resilience and Disaster Preparedness) focuses on evaluating resilience and risk at airports considering disaster response stages. The theme also explored pre-disaster preparation as a paramount factor for enhancing airport resilience. T3 focused mainly on the safety of transportation. Several criteria were explored in this theme, including speed and aggressive driving as primary risk factors. Electric vehicle (EV) adoption is the main fourth theme, in which different factors that influence the adoption of EVs have been explored, including environmental concern, trust, price value, and subjective norms. The fifth theme, on the other hand, focuses on electric bus infrastructure, highlighting the long-term impacts and interdependent criteria for effective site selection. The sixth theme focuses on freight transport optimization. It focuses on enhancing efficiency in freight transport through stakeholder collaboration. The theme also locates several important variables for shippers' mode choice, including reliability, lead time, and investment cost. The seventh theme focuses on public transportation in the post-COVID-19 era. It mainly focuses on the factors affecting the public transportation system post-pandemic. The theme highlighted the importance of government regulations as one of the most influential variables, suggesting the need for improving financial stability and customer trust. T8 (Mass Rapid Transit Sustainability) focuses on operations and performance factors alongside the integration of technology and sustainable management. T9 focuses on assessing perceived service quality from multiple stakeholders. It also identifies quality gaps among different stakeholders, suggesting improvements in service quality. In T10, the main focus was on cyber security, mainly in the aviation sector, stressing the need to adopt regulatory compliance and threat detection and emphasize user training and data encryption. T11 focuses on enhancing organizational resilience in transportation projects. It identifies several important factors, including risk warning, human resource management, and organizational leadership, as crucial factors for resilience.

CONCLUSION, FUTURE DIRECTIONS, AND LIMITATIONS

The study adopted a systematic literature review to explore the articles that implemented the DEMATEL approach in the context of transportation systems. We retrieved up-to-date studies from five electronic resources using predetermined keywords. The retrieved studies were evaluated and synthesized aiming at exploring the research trends in the topic. Following that, we have focused on 25 studies to extract the adopted methodology, influential factors, year, and country. In the next stage, we conducted a thematic analysis to investigate the main themes in the surveyed studies.

Based on the results, we found that there is an increasing number of studies that adopted the DEMATEL approach in the context of transportation systems. However, we found that the majority of studies were focused on developing countries with less focus on developed countries. This could be justified in that in developing countries, transportation systems face more challenges that call for more in-depth investigation. The results also revealed that in the context of the implementation of DEMATEL in transportation systems, researchers have focused on sustainability and environmental issues to improve transportation efficiency, reduce environmental impact, and enhance public safety. The study also offers directions for researchers by emphasizing the most influential variables in the surveyed studies. We have classified these factors into groups, which will provide a route that other researchers could build upon.

The study has some limitations that should be reported. The study has concentrated on the DEMATEL approach only in the context of transportation systems. Future studies could extend the topic by exploring other techniques of the MCDM approach. Several hybrid approaches have been utilized in the literature to evaluate transportation systems, such as Fuzzy TOPSIS [57] and GAHP (Group Analytic Hierarchy Process) [58]. Researching these approaches or combining DEMATEL with other MCDM systems could improve the accuracy of decisions. Second, the included studies were retrieved from five electronic resources. We have chosen these electronic resources specifically regarding their relevance and credibility in the field. However, future studies could include other electronic resources. Future studies might broaden the scope by adding other databases to guarantee more general coverage of pertinent material. Finally, this study does not account for thematic trends in transportation system research over the years. Factors such as emerging technologies, evolving policies, and socio-economic shifts can significantly influence decision-making outcomes.

AUTHORS' CONTRIBUTIONS

The authors confirm their contribution to the paper as follows: F.T.D.: Responsible for validation; M.A.S.A.S.A.: Prepared the draft manuscript. All authors reviewed the results and approved the final version of the manuscript.

LIST OF ABBREVIATIONS

MCDM	=	Multi-Criteria Decision-making
DEMATEL	=	Decision-Making Trial and Evaluation Laboratory

CONSENT FOR PUBLICATION

Not applicable.

STANDARDS OF REPORTING

PRISMA guidelines and methodology were followed.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article will be available from the corresponding author [M.A] upon reasonable request.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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SUPPLEMENTARY MATERIAL

Supplementary material is available on the publisher's website along with the published article.

PRISMA checklist is available as supplementary material on the publisher's website along with the published article.

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