Sustainable Transportation System

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Sustainable transport has become an important element in structuring urban operations. In this context, sustainable transportation is a key factor to tackle environmental, social, and economic challenges. Eventually, the incorporation of sustainable solutions into transportation networks has grown significantly. Such growth is strictly related to globalization and urban development due to the large increase in transport needs.

sustainable transport | sustainable | transportation | decision-making

1. Introduction

Transportation systems have significant environmental impacts due to their significant contribution to air pollution [1]. The increasing reliance on vehicles for daily needs presents various challenges, including climate change, environmental degradation, and health-related issues [2]. In fact, the harmful pollutants generated by the transportation sector have the potential to severely affect global health [3]. Therefore, it becomes crucial to develop a sustainable transportation infrastructure that prioritizes the efficient use of energy [4]. In this context, communities face the challenge of promoting sustainable transportation solutions to mitigate the different effects of pollution and excessive energy consumption [5]. Moreover, the growing population and business expansion bring new additional challenges, emphasizing the importance of sustainable transportation in meeting both social and economic requirements while sustaining the environment [6]. As a result, adopting sustainable transportation practices has the positive effect of aligning current and future economic development, enhancing transportation efficiency, and preserving the environment [7].

According to [8], sustainable transportation refers to a transportation system that reduces the social and environmental impacts. In fact, sustainable transportation solutions are needed to address the increasing requirement for transportation in expanding urban areas while preventing potential unfavorable social, economic, and environmental consequences [9]. Transportation planning, among the most challenging issues faced by urban transportation systems [10], frequently results in high costs, unscheduled delays, increased energy consumption, and increased emissions, pollution, and noise [11][12]. As a result, it has enormous environmental, economic, and social consequences. In addition, transportation planning in cities, particularly in developing countries, remains a serious concern due to growing urbanization [13]. It raises transportation costs by increasing fuel consumption, carbon emissions, and distribution inefficiencies, resulting in significant consequences for the environment and human health [14][15].

Given the number of conflicting economic, social, and environmental objectives involving sustainable transportation solutions, this issue can be classified as a multiple-criteria decision-making (MCDM) problem in which all of these objectives must be considered concurrently [16][17][18]. In current sustainable transportation problems such as route selection, the focus is not to achieve the lowest total price or the shortest delay [19]. Instead, the objective is to discover an optimal approach that maximizes beneficial impacts while also taking non-benefit characteristics into account [20]. As a result, decision makers are ultimately faced with a challenging set of parameters relative to the available alternative options.

Numerous studies have examined a broad range of variables from different perspectives in the field of route selection decision making [21][22]. These factors frequently include transportation cost effectiveness, time, capacity, and distance optimization. Previous works focused on environmental factors including fuel consumption, pollution, waste, and emissions [23][24][25]. These criteria have been commonly explored using MCDM techniques, allowing researchers to prioritize alternatives and suggest the most optimal choice based on their models. For example, the analytic hierarchy process (AHP) has different applications in the area of transportation [26]. For instance, AHP was used by [27] to determine the optimal logistics network for a crucial freight route. Moreover, [15] used AHP to select the best solutions for developing an environmentally friendly transportation system. In addition, route effectiveness is a critical factor in sustainable transportation. It is determined by several important variables that vary across various transportation network routes and regions.

The performance of transportation networks has frequently been a source of concern and requires more assessment [28]. In this context, the data envelopment analysis (DEA) approach may be performed to evaluate transport route efficiency given a particular set of inputs and outputs in the field of transportation [29]. It is extensively used in manufacturing, operation, leadership, and economics to experimentally evaluate operational effectiveness [30]. The DEA has a broad range of applications for transportation-related issues. For example, [31] presented an approach to employing DEA in maximizing the efficiency of metropolitan public transportation networks. Furthermore, [32] used DEA to assess the effectiveness of possible various state transportation agencies in roadway management. The authors of [33] developed a framework to examine the operational effectiveness of transportation networks. In addition, [34] presented a solution to the logistics challenge that takes into account various inputs and outputs associated with each transportation route. Other research proposed a multimodal transportation routing approach based on the cost and emissions criteria [35].

2. Sustainable Transportation System

Sustainable transport has become an important element in structuring urban operations [36]. In this context, sustainable transportation is a key factor to tackle environmental, social, and economic challenges [37]. Eventually, the incorporation of sustainable solutions into transportation networks has grown significantly. Such growth is strictly related to globalization and urban development due to the large increase in transport needs [2]. The rise in interest in sustainable transportation can be related to community initiatives that emphasize a higher focus on living standards and the efficient administration of public assets [38]. As a result, developing a sustainable transportation system is vital to address significant major problems including climate change, air pollution, traffic congestion, and resource depletion [5].

In fact, traditional transportation planning is primarily concerned with expanding availabilities to meet economic issues. Nonetheless, it overlooked social and environmental challenges such as energy consumption, noise pollution, emissions, energy consumption, ecological damage, waste generation, and road safety [38][39]. Consequently, effective transportation planning which includes route selection is a crucial contributing component in establishing sustainable transportation systems [40]. Indeed, the classification of various transportation routes based on sustainable considerations assists in evaluating their significance in achieving established objectives [28]. However, economic, environmental, and social factors may not exclude the selection of other vital components for transportation route planning. In other words, current transportation planning must be achieved by balancing sustainable aspects and transportation features.

Sustainable transportation planning is known as an integrated approach to elaborate effective, balanced, and environmentally responsible transportation systems [10]. It entails integrating numerous transportation variables such as vehicle, route type, distance, and time. To develop connected, accessible, and safe transportation networks, the planning process considers various aspects such as organizational and environmental elements, urban design, infrastructure, and technological development. It also addresses the requirements of different communities and nations [11]. Sustainable transportation planning promotes the use of renewable energy sources and cutting-edge technologies to maximize energy efficiency and reduce the overall environmental impacts [41]. Sustainable transportation planning seeks to build flexible and resilient transportation systems that support economic growth, enhance public health, and contribute to a more sustainable urban environment. This is achieved by promoting collaboration among stakeholders and engaging with public regulations [39][42].

In this context, previous researchers have studied the effectiveness of various public transportation systems, including cars, buses, trains, light rail, and innovative mobility solutions like ride-sharing and bike-sharing programs [43]. Many researchers have investigated the economic and environmental benefits and challenges associated with different transportation techniques and solutions [44]. MCDM techniques have been extensively applied to address transportation planning challenges and find optimal solutions that consider multiple criteria and objectives. Indeed, MCDM approaches help transportation administrators in making informed decisions by considering several factors [45]. These factors include the studies of transportation mode selection [46], route prioritization [40], infrastructure investment [12], public transport planning [38], transport policy evaluation [47], and freight urban planning [48].

To handle transportation-planning challenges, AHP is frequently used when combined with other MCDM techniques such as DEA, TOPSIS (technique for order preference by similarity to ideal solution), ELECTRE (elimination and choice translating reality), VIKOR, and GRA (grey relational analysis). For example, Ref. [49] used integrated AHP with TOPSIS to address public transportation regarding bus selection. The study proposed a framework based on the hybrid technique to optimize the bus design with respect to a set of decision variables. Additionally, Ref. [50] employed AHP combined with VIKOR to determine efficient petrol station selection in transportation sectors. Moreover, Ref. [51] used an integrated approach of AHP and ELECTRE approach for sustainable path selection to determine transport-effective alternative solutions. Ultimately, these methods help decision makers to analyze complex trade-offs between conflicting objectives and arrive at informed and robust decisions for more optimized transportation systems [52]. In addition, the integration of methodologies into a hybrid evaluation of decisions is not a novel concept; it has been frequently recommended to develop an effective strategy by leveraging their strengths and complementing their limitations [53]. There are several papers on hybrid MCDM techniques for transportation systems as shown in **Table 1**.

Table 1. Existing studies on transportation MCDM combined approaches.

Reference	Research Context	Applied Approach	Sustainability Dimension
[28]	Multimodal transportation networks	MCDM, DEA	Economic
[49]	Bus fleet network	AHP, TOPSIS	Economic, environmental
[54]	Submarine power cable routing selection	G-MCDA, DEA	Economic, social
[55]	Emergency evacuation paths of the urban metro station	TOPSIS, GRA	Social, environmental
[56]	Route selection in multimodal transportation networks	AHP, DEA, TOPSIS	Economic
[57]	Transmission network of nuclear power plant	Fuzzy AHP	Environmental, social
[51] [58]	Sustainable tourism paths Tourism optimal path selection	AHP, ELECTRESWOT, AHP	Economic
[17]	Airline new route selection	MCDM	Economic
[41]	Route selection in multimodal supply chains	Fuzzy MCDM	Economic
[44]	Path and site landfill selection	AHP, GIS	Social, economic
[59]	Municipal solid waste landfill siting	AHP, GIS	Environmental, socio-economic
[60]	Optimization of public transport networks	AHP	Economic
[61]	Transport service on public roads and passenger transport	AHP	Economic
[62]	Operational efficiencies of Turkish airports	AHP, DEA	Economic
[63]	Sustainable supply network optimization	DEA	Economic

Reference	Research Context	Applied Approach	Sustainability Dimension
[11]	Vehicle routing optimization model	AHP	Environmental, economic
[64]	Regional transport sustainability	SBM, DEA	Economic, environmental, social
[48]	Multimodal freight transportation systems	AHP, DEA	Economic, environmental
[18]	Optimal routing for mass transit systems	MCDM	Economic, environmental, social
[7]	Sustainable route selection of petroleum transportation	MCDM	Economic, environmental, social
[46]	An optimization model for sustainable transportation in the mining industry	AHP, DEA	Economic, environmental
[40]	Route prioritization of urban public transportation	MCDM	Economic, environmental, social
[65]	Public road transportation systems	AHP, DEA	Economic
[53]	Multicriteria route selection	AHP, TOPSIS	Economic
[66]	Multimodal green logistics:	AHP, DEA	Environmental, economic
[35]	Route selection in multimodal transportation	AHP	Environmental, economic
[67]	Distribution network planning reliability	AHP, DEA	Economic
[68]	Environmental assessment of land transportation	DEA	Environmental
[69]	Sustainable intermodal transport affected by COVID-19	AHP, DEA	Environmental, economic
[39]	The last-mile delivery problem with service options	MCDE	Environmental, social, economic

As reported in **Table 1**, and according to the literature, the integration of sustainable aspects in handling transportation route selection decision-making problems has not been widely addressed in the literature. In

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addition, the integration of AHP and DEA for managing sustainable transportation systems for route selection has not been done in the published research.

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