An integrated Decision-Making Approach for Road Transport Evaluation in a Sustainable Supply Chain

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One important step to achieve a sustainable transportation system is to control the impact and evaluate the effect of various influencing factors toward three dimensions of sustainability. Within this context, diverse analytical approaches have been developed to assess the sustainability level of various transportation systems, however, sustainability evaluation based on fuzzy multiple criteria decision-making approaches are still limited. In current research activity, an integrated quantitative evaluation technique is proposed to narrow the identified gap. The developed decision-making approach is consisted of two main phases. Firstly, fuzzy analytic hierarchy process is utilized to weigh the sustainability dimensions resulting in the incorporation of the experts' knowledge along with the evaluation process. Then, a proposed fuzzy inference mechanism is proposed to provide an indication on the performance of an evaluated road transportation system. The developed approach is applied on a real-world case study. Finally, future works are presented together with some concluding remarks.

1.   Introduction

Brundtland commission defined sustainability as development that meets the needs of the present without compromising the ability of future generations to fulfil their own requirements. Sustainability is bonded with a trade-off between the triple bottom line aspects on achieving economic success, environment cleanness, and social responsibility is introduced by Fairly et al; Olawumi & Chan and

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Venkatraman & nayak [1-3]. According to Takeshita and wang [4, 5], One of the main sources of fossil-fuel consumption and air emission is the increasing usage of commercial fossil-fuel based vehicles. Thus, Bai et al [6] has defined, in order to develop a sustainable supply chain and transportation system, identifying and selecting and sustainability conscious transportation vehicles is of great importance. Transportation has significant economic, social and environmental impacts in a typical supply chain and is one of the most important drivers in achieving sustainability in supply chains. The main aim is to integrate economic, social and environmental requirements of sustainable development at all phases of a transportation system design.

Bongardt et al [7] believed that, In order to devise an effective sustainable planning, a comprehensive evaluation approach is required which simultaneously considers all three dimensions of sustainability. Due to vagueness and ambiguity associated with the sustainability input data, conventional assessment approaches cannot neither suitably nor effectively handle such issues[8]. Decision support tools that can handle such issues would help organizations make more effective supply chain and transportation decisions by research of Fahiminia et al [9, 10]. Also, Vinodh & davadasan and Rajak et al [11, 12] identify that Fuzzy set theory provides a useful approach which eliminates the drawbacks like vagueness, uncertainties, ambiguity, and impreciseness.

An important task for achieving sustainable transport goals is to identify and evaluate the related sustainability criteria. Although, there has been some efforts to identify and evaluate criteria related to sustainable transportation systems by the Awasthi et al, Hsu et al, Reisi et al and Ngossaha et al [13-16], a holistic framework does not exist to act as a roadmap for industrial practitioners and transportation planners as defined Bai et al [6].The main challenge lies within the uncertainty and difficulties in quantifying many related influencing criteria. In addition, few efforts are made for sustainability evaluation of fossil-fuel based transportation vehicles. Therefore, an integrated approach is developed in this research activity to fill the gap in the related literature (see Section 2).

The novelty of the current research activity sits within introducing an integrated multi-criteria decision-making (MCDM) model for sustainable transportation system and its application on a real-world setting. Sustainable transport indicators were determined based logistic experts' opinions and a comprehensive literature review. FAHP was used to weigh the identified criteria and sub criteria selected by the experts. Then, a Fuzzy Inference System (FIS) is proposed to assess the sustainability performance of the considered transportation system. Integrating fuzzy inference mechanism with weighted dimensions results in the inclusive involvement of logistic experts' knowledge which makes the proposed integrated approach more precise than the other existing methods.

The reminder of this paper is as follows. A comprehensive literature review of previously developed tools for road transport evaluation is provided in Section 2. In Section 3, the developed integrated approach is presented in detail. This section is followed by Section 4 in which our case study and results are provided. Finally, some concluding remarks and discussions are provided in Section 5.

2. Literature Review

2.1. Road transport evaluation criteria

In this section, the related sustainable criteria for road transport evaluation are identified and classified into appropriate categories with respect to the triple bottom line defined by Awasthi et al, Bae et al, Bai and Sarkis, Rajak et al, Bai et al, Osorio-Tejada et al [6, 11, 13, 17-19]. The criteria are clustered into various categories due to the multi-faceted nature of sustainable transportation systems. Previous works have elucidated sustainable transportation measures and criteria from different perspectives. For instance, Shiftan et al and Mihyeon Jeon & Amekudzi [20, 21] analyze that Indicators have been classified into three main categories: environmental indicators: reductions pollution and energy savings; economic indicators: impacts of vehicles characteristics and other system elements (infrastructure, resources or fuels); and social indicators: safety and health, control training, and quality of life by . However, the literature on sustainable transportation management is rather limited. Consequently, a comprehensive list of sustainability indicators is proposed in this article. Table 1 summarizes the results of the proposed criteria categorization for road transport system evaluation.

Table1. Transport sustainability evaluation criteria

Transportation Sustainability Dimensions	Transportation Sustainability criteria	Related Literature
Economic Sustainability	Benefit to economy	Awasthi et al, Griškevičiūtė-Gečienė, Wang [13, 22, 23]
	Mobility	Awasthi et al, Ngossaha et al, Wang, Mahdini et al[13, 15, 23, 24]
	Reliability	Mahdinia et al[24]
	Expenditure and benefit of transport system users	Mahdinia et al[24]
	Expenditure and revenues of transportation system operators	Mahdinia et al[24]
	Investment and operating cost	Wang [23]
	Operating revenues	Awasthi & Omrani[25]
	Transportation total cost	Byrne & Polonsky[26]
	Transportation system effectiveness	Jeon et al[27]
	Economic productivity	Litman[28]
	Economic development	Jeon et al, Deakin[27, 29]
	Infrastructure costs	Bai et al, Litman[6, 30]
	Business opportunities	Ngossaha et al[15]
	Transport system diversity	Mahdinia et al, Haghshenas & Vaziri[24, 31]

	Affordability	Salling & Pryn[32]
	Traffic congestion	Zhang & Zhang, Litman, Litman & Burwell[5, 30, 33]
	Traffic safety	Bai et al, Griškevičiūtė-Gečienė [6, 22]
	Vehicle price	Bai et al, Zhao & Melania[6, 34]
	Vehicle characteristics	Bai et al [6]
	Maintenance costs	Bai et al , Zhao & Melania [6, 34]
	Running costs	Bai et al , Reisi et al, Garcia & Freire[6, 16, 35]
	Loading capacity	Bai et al, Litman[6, 36]
	Diversity of vehicle	Mahdinia et al, Haghshenas & Vaziri[24, 31]
	Comfort of use (e.g. comfortable seats, accessories)	Bai et al, Awasthi et al, Tzeng et al[6, 13, 37]
	Competency	Awasthi et al[13]
	Improving of Information technology	Bai et al, Ngossaha et al, Srisawat et al[6, 15, 38]
Social Sustainability	Equity/Fairness	Awasthi et al, Litman[13, 30]
	Fatalities and injuries of accident	Reisi et al, Shiau et al[16, 39]
	Human safety, security and health	Bai et al, Mahdinia et al, Djekic et al[6, 24, 40]
	Quality of service	Bai et al, Awasthi et al[6, 13]
	Fuel subsidies	Bai et al, Byrne & Polonsky[6, 26]
	Governments subsidies or incentives	Zhang & zhang, Bai et al, Zhao & Melania, Gracia & Freire[5, 6, 34, 35]
	The number of employees	Djekic et al[40]
	Accessibility	Awasthi et al, Ngossaha et al, Reisi et al[13, 15, 16]
	Training	Bai et al, Litman, Russo & Comi[6, 41, 42]
Environmental Sustainability	GHG emissions rate	Bai et al, Awasthi et al[6, 13]
	Consumption of natural resources	Zegras[43]
	Unit fuel cost	Bai et al, Byrne & Polonsky[6, 26, 35]
	Alternative fuels	Bai et al, Byrne & Polonsky [6, 26]
	Energy saving	Bai et al, Awasthi et al[6, 13]

	Fossil fuel usage rate	Bai et al, Awasthi et al, Shiau et al, Djekic et al[6, 13, 39, 40]
	Renewable energy use	Bai et al, Awasthi et al, Shiau et al [6, 13, 39]
	Fuel efficiency	Zhang & zhang, Bai et al, Litman & Burwell[5, 6, 33]
	Clean technologies	Zhang & zhang, Bai et al, Zhao & Melania, Ulengin et al[5, 6, 34, 44]
	Energy consumption	Ngossaha et al, Mahdinia et al, Djekic et al[15, 24, 40]
	Non-renewable resources	Reisi et al, Litman, Gudmundsson [16, 28, 45]
	Control on Air pollution	Haghshenas & Vaziri[31]
	Control on Noise pollution	Haghshenas & Vaziri [31]
	Control on Water pollution	Tzeng et al, El-diraby et al[37, 46]
	Other air pollutants (e.g. NOx, VOCs, CO, particulates, toxics)	Bai et al, Awasthi et al[6, 13]
	Recycling costs	Bai et al, Gehin et al[6, 47]
	Recyclability rate	Bai et al, Ngossaha et al, Gehin et al[6, 15, 47]
	Recycled materials usage	Bai et al, Gehin et al, Shiau et al[6, 47, 48]

The issue related to sustainable development principles, definition, evaluation and implementation of sustainable transportation system have been studied by several authors. The main challenge in many of these influencing criteria is that they are not often measurable and are associated with uncertainty.

2.2. Road transport evaluation approaches

To identify, compare and select sustainable transportation system, efficient decision-making approaches are required. Many approaches have been developed and proposed by academic scholars for sustainability evaluation of transportation systems. Djekic et al [40] provided an analysis of transportation sustainability performance using Life cycle analysis and Fuzzy logic. Garcia & Freire [35] presented a fleet-based Life cycle approach by analyzing the key aspects underlying environmental and energy impacts of vehicle fleets. Mahdinia et al [24] developed a transportation sustainability index (TSI) to measure the sustainability of transportation systems. They utilized the Principal Component Analysis/Factor Analysis (PCA/FA) methodology and developed an algorithm that produces indices for each of the transportation sustainability dimensions as well as their subdivisions. Shiau et al [39] developed a methodology to evaluate transport sustainability based on rough set theory and two-stage principal component analysis (TSPCA) resulting in aggregating the information from 19 key indicators using available historical

data. Srisawat [38] proposed a decision support system based on Fuzzy Analytical Hierarchy Process (FAHP) to determine the weights of each sustainability criterion. Furthermore, they integrate the weighted criteria with raster-based analysis and GIS technology to evaluate logistics efficiency. Osorio-Tejada et al [19] presented a systematic approach based on the study of the multidimensional impacts of transportation systems and the application of multi-criteria decision making (MCDM) to assess the sustainability of alternative fuels. Shiau et al [48] applied Fuzzy Cognitive Maps (FCMs) and Analytic Hierarchy Process (AHP) to construct the cause–effect relationships between key indicators and to evaluate sustainable transport strategies. Bai et al [6] proposed a holistic framework for sustainable transport fleet appraisal incorporating various vehicle performance, economic and environmental criteria and introduced a novel hybrid approach for sustainable transportation vehicle evaluation and selection by combining a three-parameter interval grey number with a rough set theory and VIKOR method. Rajak et al [11] presented a fuzzy based approach to evaluate of transport sustainability performance resulting in development of a Fuzzy Transport Sustainability Index (FTSI). Shiau et al [49] integrated data envelopment analysis (DEA) and rough set theory (RST) methods for measuring transport sustainability to achieve effective decision support system for decision-makers. Ngossaha et al [15] presented an integrated approach for assessing the sustainability of the current transportation system design. They aimed at providing decision makers with a framework allowing them to choose the most eco-responsible transportation policy. Awasthi et al [13] proposed a multi-criteria decision-making approach for selecting sustainability transportation systems under partial or incomplete information. Fuzzy TOPSIS was used to generate aggregate scores for sustainability assessment and selection of best alternative. Zhang et al [5] adopted the AHP and Delphi methodologies to establish a comprehensive evaluation index for low carbon road transport systems. Reisi et al [16] developed a method for obtaining a composite transport sustainability index based on statistical local areas (SLAs) and PCA/FA for weighting indicators and avoiding double counting issue among indicators which ultimately provides an unbiased measure of the transport sustainability.

Reviewing the studies in the literature explain some limitations. A few number of indicators had been used to evaluate different aspects of sustainable transportation. Therefore, there is a lack of studies which use a diverse range of indicators to cover the broad and complex goal of sustainability evaluation in transportation systems. Consequently, developing an integrated fuzzy evaluation using all effective criteria have been required.

In this paper, we propose an integrated approach that can be used to evaluate the sustainability performance of vehicles using the identified attributes. Chang's [50]FAHP is utilized to weigh the identified criteria resulting in the incorporation of the experts' knowledge along with the evaluation process. Then, the weighted criteria are incorporated into a proposed fuzzy inference mechanism providing an indication on the performance of an evaluated road transport system. Integrating fuzzy inference mechanism with weighted criteria results in the inclusive involvement of logistic experts' knowledge making the proposed integrated approach more precise than the other existing methods.

3. Proposed Approach

The aim of this research is to propose a precise evaluation decision making approach for devising a sustainable road transport system. Firstly, a FAHP model weighting mechanism based on expert's

ideas within the organization is developed to define importance weights of various identified criteria. Secondly, a fuzzy evaluation mechanism for evaluating the system performance is developed to help decision makers to plan and achieve more sustainable transportation system. In this section, the proposed framework of this research is shown in Figure 1 and explained in detail in the following.

- Step 1: selecting appropriate criteria and sub criteria

- Step 2: weighting the selected criteria

- Step 3: data collection

- Step 4: fuzzy evaluation

- Step 5: determination of sustainability index

A detailed description of each step is described as follows:

In step 1, selecting the criteria and sub criteria is done based on various studies, reviewing the literature and discussion with decision makers. In this study, expert's ideas and logistic experts' knowledge are used for validating the selected criteria and influencing factors. As shown in Figure 1, the environmental, economic and social dimensions related criteria are selected to perform the sustainability assessment.
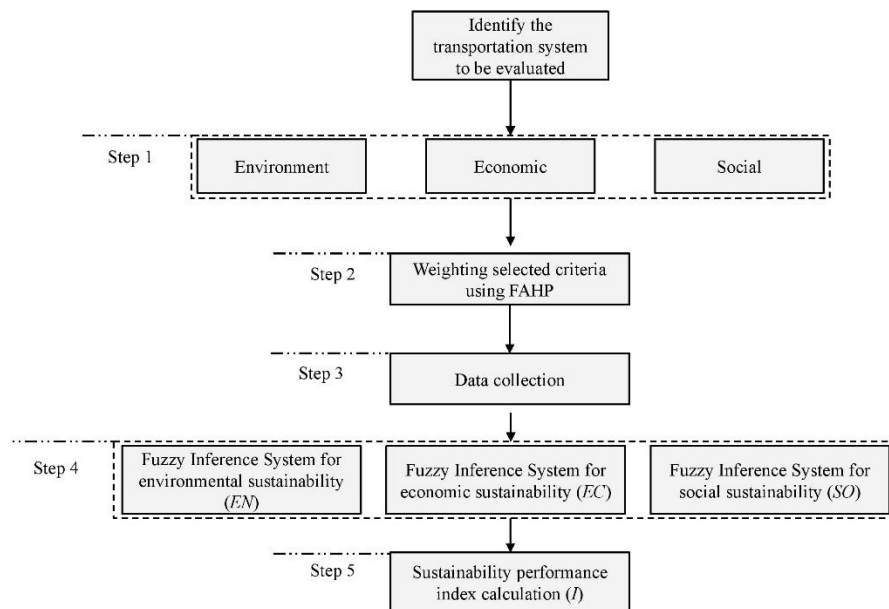
Figure. 1. Research framework used in this study

In step 2, the criteria and sub criteria of sustainable transportation are weighted using FAHP. Owing to space limitations, the steps of FAHP method are not presented in this paper. Potential readers can refer to Ghadimi et al [51] for a comprehensive description of Chang's (1996) FAHP method. Using these weights will make the assessment more precise and real because calculations of these weights are involved with the decision makers' expert ideas inside the organization.

In step 3, related data are collected from company logistic experts and transport experts. These data are related to the selected environmental economic and social dimension influencing factors.

In step 4, the crisp input and output variables have been transformed into grades of membership for linguistic terms of fuzzy sets. Then, using the fuzzified variables, a fuzzy rule base has been defined. Membership grades of the have been defined based on expert's ideas and also with reviewing the literature. Then, low, medium and high level were selected for input variables. Besides, it was decided to define low, low to medium, medium, medium to high and high as output variable membership grades. Moreover, MATLAB fuzzy logic package is utilized to implement the developed FIS model. The number of fuzzy rules used depends on the number effects and the degree of the input variables, which is determined using Equation 1 Cornelissen et al [52]:

$$R = n^v \tag{1}$$

where n is number of grades of membership function for input variables and v is the number of input variable for each sustainability criteria and R stands for the number of rules to be constructed.

Step 5 is about the calculation of total current sustainability index. Sustainability index is the aggregate value of the three sustainability dimensions' weighted scores obtained by Equation 3. In this study, overall score for each sub criteria of environmental, economic and social sustainability are calculated by Equation 2.

$$I_j = \sum_i w_{ij} I_{ij} \tag{2}$$

where,

I_j= score of jth sustainability dimension,

W_{ij} = weight of ith influencing factor of jth sustainability dimension,

I_{ij}=score of ith influencing factor of jth sustainability dimension,

$i = 1. \dots . n$ index of influencing factor,

j = Environmental *(EN),* Economic *(EC)* and Social *(SO)*

$$I_{sustainability} = w_{EN}I_{EN} + w_{EC}I_{EC} + w_{SO}I_{SO} \qquad (3)$$

where,

I_{EN} =score of environmental sustainability,

I_{EC} =score of economic sustainability,

I_{SO} =score of social sustainability,

w_{EN} =weight of environmental sustainability,

w_{EC} =weight of economic sustainability,

w_{SO} =weight of social sustainability,

$I_{sustainability}$ =total sustainability index.

4. Case study and Result

A critical component of sustainable transport planning is the development of an integrated evaluation program that evaluates transport system performance based on an appropriate set of environmental, social and economic indicators by the researches of Bongardt et al [7]. Hence, to broaden the perspective of sustainability in all three dimensions (environmental, social and economic), methodologies have been proposed to evaluate the sustainability aspects of a given transport system. Such decision support tools and methodologies can help organizations to be more effective in sustainability decisions. As the Singh & Bailey and Zadeh & Aredebilipour [53, 54] evaluated, In order to evaluate sustainability aspect, fuzzy set theory can provide an appropriate foundation because it enables modeling of complex systems using ill-defined dynamics and inputs such as the situation considered in this study.

The goal of the proposed integrated technique is different from other approaches in term of the filtration and ranking processes. The developed methodology seeks to evaluate the most effective factors of sustainable transportation systems accurately and identify the destructive factors in companies. In order to evaluate, compare and select sustainable transportation system, efficient decision-making approaches are required. In this section, details about the case companies, data collection, sustainability assessment and comparison of transportation systems are presented**.**

- Step 1: About the case companies

This case study was conducted in three Iranian companies. Parastoo, Jam and Arya companies were selected, and their transportation systems have been evaluated and compared with regards to the sustainability aspects. The aim of this study is the sustainability evaluation of these companies using the proposed evaluation approach in previous section.

- Step 2: Criteria selection

In this study, selecting the influencing factors is done based on reviewing the literature, Reisi et al, Shiau et al, Rajak et al, Bai et al, Ngossaha et al, Osorio-Tejada et al, Fathi & Saen, Mahdinia et al [6, 11, 15, 16, 19, 24, 39, 55] and discussion with the decision makers and accessing the companies' historical records. The group of decision makers in this study are consisted of logistic experts and general managers inside each company. These experts' opinions are used for validating the selected influencing factors. The identified influencing factors are classified into the three sustainability dimensions, i.e., environmental, economic and social. Table 2 tabulates the selected influencing factors with respect to each sustainability dimension.

Table 2. Selected influencing factors for evaluating the sustainable transportation system

Dimension	Influencing factor
Economic	Benefit to economy
	Reliability
	Expenditure of transportation system operators
	Operating revenues
	Transportation total cost
	Economic productivity
	Infrastructure costs
	Maintenance costs
	Running costs
	Loading capacity
	Diversity of vehicle
	Comfort of use (e.g. comfortable seats, accessories)
	Improving of Information technology
Environmental	GHG emissions rate
	Consumption of natural resources
	Alternative fuels
	Energy saving
	Renewable energy use
	Clean technologies
	Control on Air pollution
	Control on Noise pollution
	Control on Water pollution
	Recyclability rate
Social	Equity/Fairness
	Fatalities and injuries of accident
	Human safety, security and health
	Quality of service
	Training
	The number of employees

- Step 3: Weighting selected influencing factors using FAHP

In this step, the three sustainability dimensions of sustainable transportation have been weighted using FAHP. The hierarchy structure including three levels has been made according to Table 2.

Levels present the main goal which is the sustainability index, dimensions and influencing factors. The linguistic variables and their corresponding fuzzy numbers are shown in Table 3. Based on fuzzy scales, company's experts as a group were asked to perform pairwise comparison to achieve the weights of three sustainability dimensions. The experts compared the sustainability dimensions with respect to the total sustainability index. The results of these pairwise comparisons are shown in Table 4. Consequently, based on Chang's FAHP steps, the three sustainability dimensions have been weighted. Owing to the limitation on space, only the final weights of these dimensions are presented in Table 5.

Table 3. The linguistic variables and their corresponding fuzzy numbers

Linguistic scale	Triangular fuzzy scale
Just equal	(1,1,1)
Weakly important	(2/3,1,3/2)
Strongly important	(1,3/2,2)
Very strong important	(3/2,2,5/2)
Absolutely more important	(2,5/2,3)

Table 4. Fuzzy pairwise comparisons

	Environment	Economic	Social
Environment	(1,1,1)	(2/3,1,3/2)	(1,3/2,2)
Economic	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)
Social	(1/2,2/3,1)	(2/3,1,3/2)	(1,1,1)

Table 5. Results of the dimension weights

Dimensions	Weight
Environment	0.3837
Economic	0.3301
Social	0.286

- Step 4: Data collection

For environmental dimension, 10 influencing factors were selected. For economic category, 13 influencing factors and for social dimensions, six factors were selected. The influencing factors data were collected based on discussions and meetings help with each company's decision makers (logistic/transport experts and general managers). The collected data with respect to each of these influencing factors are shown in Table 6.

Table 6. Amount of parameters

Influencing factors	Parastoo	Jam	Arya
Benefit to economy	Very high	High	High
Reliability	Very high	High	Very high
Expenditure of transportation system operators	36000000	304000000	68000000
Operating revenues	118000000	320000000	280000000

Transportation total cost	72000000	450000000	400000000
Economic productivity	Very high	High	High
Infrastructure costs	18000000	62000000	48000000
Maintenance costs	12000000	60000000	216000000
Running costs	6000000	24000000	68000000
Loading capacity	0.85	0.6	0.3
Diversity of vehicle	6	2	3
Comfort of use (e.g. comfortable seats, accessories)	High	High	Medium
Improving of Information technology	High	High	Medium
GHG emissions rate	0.8	0.55	0.3
Consumption of natural resources	High	Medium	Medium
Alternative fuels	High	Medium	Medium
Energy saving	High	High	Medium
Renewable energy use	Very high	High	High
Clean technologies	Very high	Medium	Medium
Control on Air pollution	Medium	High	High
Control on Water pollution	High	High	High
Control on Noise pollution	Very high	High	Medium
Recyclability rate	0.3	0.25	0.2
Equity/Fairness	High	High	High
Fatalities and injuries of accident	0	0	0
Human safety, security and health	Medium	High	High
Quality of service	Medium	High	High
Training	Very low	High	High
The number of employees	50	25	15

- Step 5: Fuzzy evaluation

At first, in this section, the crisp input and output variables have been transformed into grades of membership for linguistic terms of fuzzy sets, as shown in Tables 7-9. Then, a fuzzy rule base has been constituted using the fuzzified variables. Membership grades of the crisp input and output variables have been defined based on decision maker's opinion. Then, low, medium and high were selected for input variables. Besides, it was decided to define low, low to medium, medium, medium to high and high as output variable membership grades. Moreover, MATLAB fuzzy logic package was utilized in step 5.

Table 7. The membership functions of environmental sub criteria

Linguistics value	Numerical range	Linguistics value	Numerical range
GHG emission rate:		Clean technology	
Low	[0 0.25 0.5]	Low	[0 1 2]
Medium	[0.25 0.5 0.75]	Medium	[1 2 3]
High	[0.5 0.75 1]	High	[2 3 4]
Consumption of natural resource:		Control on air	
Low	[0 1 2]	Low	[0 1 2]
Medium	[1 2 3]	Medium	[1 2 3]
High	[2 3 4]	High	[2 3 4]
Alternative fuels		Control on water	
Low	[0 1 2]	Low	[0 1 2]
Medium	[1 2 3]	Medium	[1 2 3]
High	[2 3 4]	High	[2 3 4]
Energy saving		Control on noise	
Low	[0 1 2]	Low	[0 1 2]
Medium	[1 2 3]	Medium	[1 2 3]
High	[2 3 4]	High	[2 3 4]
Renewable energy use		Recyclable rate	
Low	[0 1 2]	Low	[0 1 2]
Medium	[1 2 3]	Medium	[1 2 3]
High	[2 3 4]	High	[2 3 4]

Table 8. The membership functions of economic sub criteria

Linguistics value	Numerical range	Linguistics value	Numerical range
Benefit to economy:		Economic productivity:	
Low	[0 0.25 0.5]	Low	[0 1 2]
Medium	[0.25 0.5 0.75]	Medium	[1 2 3]
High	[0.5 0.75 1]	High	[2 3 4]
Reliability:		Loading capacity:	
Low	[0 1 2]	Low	[0 0.25 0.5]
Medium	[1 2 3]	Medium	[0.25 0.5 0.75]
High	[2 3 4]	High	[0.5 0.75 1]
Expenditure of transport system operators:		Diversity of vehicles:	

Low	[0 83600000 167200000]	Low	[0 1.75 3.5]
Medium	[83600000 167200000 250800000]	Medium	[1.75 3.5 5.25]
High	[167200000 250800000 334400000]	High	[3.5 5.25 7]
Operating revenues:		Comfort of use:	
Low	[0 88000000 176000000]	Low	[0 1 2]
Medium	[88000000 176000000 264000000]	Medium	[1 2 3]
High	[176000000 264000000 352000000]	High	[2 3 4]
Transport total cost:		Infrastructure costs:	
Low	[0 123750000 247500000]	Low	[0 17050000 34100000]
Medium	[123750000 247500000 371250000]	Medium	[17050000 34100000 51150000]
High	[247500000 371250000 495000000]	High	[34100000 51150000 68200000]
Maintenance costs:		Running costs:	
Low	[0 59400000 118800000]	Low	[0 18700000 37400000]
Medium	[59400000 118800000 178200000]	Medium	[18700000 37400000 56100000]
High	[118800000 178200000 237600000]	High	[37400000 56100000 74800000
Improving of IT:			
Low	[0 1 2]		
Medium	[1 2 3]		
High	[2 3 4]		

Table 9. The membership functions of social sub criteria

Linguistics value	Numerical range	Linguistics value	Numerical range
Equity/fairness:		Quality of	

		services:	
Low	[0 1 2]	Low	[0 1 2]
Medium	[1 2 3]	Medium	[1 2 3]
High	[2 3 4]	High	[2 3 4]
Fatalities and injuries of accident:		The number of employees:	
Low	[0 2.5 5]	Low	[0 15 30]
Medium	[2.5 5 7.5]	Medium	[15 30 45]
High	[5 7.5 10]	High	[30 45 60]
Human safety and health:		Training:	
Low	[0 1 2]	Low	[0 1.5 3]
Medium	[1 2 3]	Medium	[1.5 3 4.5]
High	[2 3 4]	High	[3 4.5 6]

Equation 1 was used to compute the number of rules to be constructed for each sustainability dimensions. Some realistic rules of the rule base have been created by decision maker's knowledge. A sample of these fuzzy IF-THEN rules is given in Table 10. These rules determine the sustainability index from some input variables and membership grades (low, medium and high).

Table 10. Some rule examples from the rule base

Rule no.	Rules
Rule 1	IF (benefit to economy is low) AND (reliability is low) AND (expenditure of operators is low) THEN (output is low)
Rule 2	IF (alternative fuels is medium) AND (energy saving is high) THEN (output is high)
Rule 3	If (loading capacity is high) AND (improving of IT is medium) AND (infrastructure costs is medium) THEN (output is high)
Rule 4	If (services quality is medium) AND (training is high) THEN (output is high)
Rule 5	If (GHG rate is low) AND (consumption of resource is high) THEN (output is medium)
Rule 6	If (equity is low) AND (safety is medium) THEN (output is low)
Rule 7	If (control of noise is medium) AND (recyclability rate is high) THEN (output is high)

- Step 6: Determination of the sustainability elements index

Overall scores for the environmental, economic and social sustainability dimensions were calculated using Equation 2. Table 11 demonstrates the obtained scores for each sustainability dimension. Based on these results, the total sustainability index was calculated using Equation 3 (see Table 12). The three companies involved in this study were ranked based on their sustainability

index. According to Table 12, Jam company had the best performance index for their employed road transportation system.

**Table 11.** Overall sustainability score of each case company

Company	Environmental aspect		Economic aspect		Social aspect	
	unweighted score	weighted score	unweighted score	weighted score	unweighted score	weighted score
Parastoo	0.55	0.211	0.681	0.2248	0.583	0.1667
Jam	0.8	0.3069	0.652	0.2152	0.723	0.2067
Arya	0.7	0.2685	0.394	0.1294	0.783	0.2239

Table 12. Final score of sustainability index for companies

Company	Sustainability score	Rank
Parastoo	0.6025	3
Jam	0.7288	1
Arya	0.6218	2

As shown in Figure 2, although the overall sustainability index of Jam company is scored as the highest among the three companies, it is found that it is ranked as the best performing company only regarding environmental aspect (0.8>0.7>0.55). Besides, Parastoo company's economic sustainability is the best among the three companies (0.681>0.652>0.394), however, its overall sustainability index was ranked as the worst one. This important finding strengthens the fact that companies that try to devise cost-efficient systems would usually lag behind the social and environmental sustainability aspect of sustainable development. This important finding was also highlighted by Ghadimi et al, Zimmer et al [56-59].
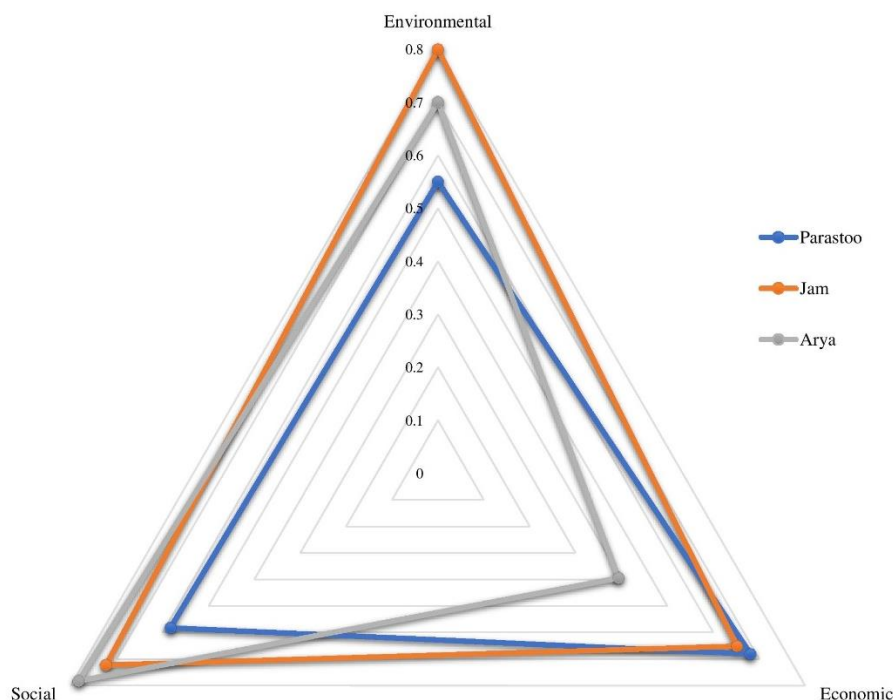
Figure 2. Sustainability dimension scores comparisons

By further investigating the results depicted in Figure 2, it can be observed that Arya company's sustainability performance in terms of environmental and social sustainability is almost the best comparing with the other two companies. However, these good performances resulted in a low economic sustainability score. Therefore, not always performing well in one or two dimensions of sustainable development can guarantee a good overall performance. As also highlighted by Ghadimi et al [57] companies need to always seek for trade-offs between all dimensions of sustainability. Providing a sustainable service or product to end-customers requires companies to improve their systems (in general) with regards to all aspects of sustainable development in a simultaneous manner.

5. Conclusion

Commercial vehicles usage is one of the most important sources of fossil-fuel consumption and air pollutants emission that affects our environment, society and economy. Moreover, Fahiminia et al [60] realized that an unsustainable transportation system can lead to excessive waste and use of toxic material. Given the critical significance of the environmental burdens of transportation activities the development of decision support tools for evaluation of sustainable transportation system deem to be required. In this research article, an FIS based evaluation mechanism was developed to compare and rank the considered transportation systems within the three case companies. As managerial implications, it was found that the FIS approach provides the managers and decision makers with a deeper understanding and insights about the actual sustainability issues within their organizations. As theoretical implications, the current research work narrows the gap identifies in the literature in terms of a lack in utilizing fuzzy inference approach in measuring the sustainability practices of road transportation systems.

This research contributes to this area by introducing an integrated MCDM technique which has been proposed to solve the problem of sustainable transportation performance evaluation. Firstly, FAHP method was utilized to calculate the weights of sustainability dimensions. Next, a FIS model has been developed to evaluate various sustainable transportation system. The resulting indicator is a sustainability performance index acting as a mean to compare various evaluated transportation systems. This approach allows for consideration of intangibility and ambiguity from expert judgment amongst the sustainability dimensions. The main strength of this approach is its ability to treat heterogeneous, uncertain and incomplete data coming from multiple information sources. Providing the influencing factors with regards to each sustainability dimension for assessing a given transportation system in a tabular framework can be considered as another contribution of this work. The methodology was implemented using real world data collected from industry experts in three related industrial organizations.

For future work, there are opportunities to develop a comprehensive framework and mathematical programming models for sustainable transportation system which consider all dimensions of sustainable development aiming to provide a trade-off between economic aspects with environmental and social issues.

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