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Performance Assessment Framework based on Competitive Priorities for Sustainable Freight Transportation Systems

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Abstract

Stringent environmental norms and growing demands for energy-efficient and cost-effective freight shipping have put organizations under immense pressure to consider sustainability aspects while assessing their performance. Moreover, amid growing awareness about competitive priorities, it has become prudent to understand how an organization's sustainability performance is balanced against competitive priorities. Therefore, this study attempts to develop an integrated performance assessment framework (PAF) on the basis of competitive priorities for sustainable freight transportation (SFT) systems. A unified approach consisting of fuzzy group decision-making, fuzzy evidential reasoning approach, and expected utility concept is utilized to assess critical success factors of SFT based on four competitive priorities. The applicability of the developed model is exhibited through a case example, and sensitivity analysis is also performed to examine its robustness. This competitive performance score based PAF would facilitate logistics professionals in selecting the most competitive SFT system.

Keywords: Performance Assessment Framework; Fuzzy Evidential Reasoning Algorithm (FERA); Fuzzy Group Decision-making (FGDM); Competitive Priorities; Sustainable Freight Transportation; Sensitivity Analysis.

1 INTRODUCTION

An economical, energy-efficient, and reliable freight transportation (FT) system is of prime significance for fulfilling the increasing demands of the industry. Freight transportation plays a pivotal role in the development of the regional economy, shaping smart cities, generating

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employment, and substantial revenue. The transportation sector contributes to about 20% of global energy consumption (Craig et al., 2013; Ratanavaraha and Jomnonkwao, 2015) and 24% of the global CO₂ emissions (Li and Zhang, 2020). Amid the unprecedented growth of the freight transport sector across the globe, it is also prudent to restrain its adverse effects on the environment and society, and hence to achieve sustainability in FT (Parikh, 2012).

Sustainability focuses on achieving the goals of economic growth, social well-being, and environmental integrity, which consist of strategic and long-term decision-making (Litman, 2007; Roth and Kåberger, 2002). Moreover, performance assessment is a managerial tool that is required for enhanced decision-making (Jakhar, 2015). As several complexities are involved in the transport system, it is pragmatic to use a performance management system (PMS) to analyze the system (Gholami and Ziaee, 2017). To enhance the performance of any freight transportation system, it is inevitable first to measure its current performance. Recent studies have witnessed the growing interest of scholars for evaluating the sustainability performance of the transport sector (Bandeira et al., 2019; Kumar and Anbanandam, 2020; Rajak et al., 2016). Moreover, researchers also indicate the growing negative externalities linked to FT (Bektas et al., 2019; Demir et al., 2015). Thus, to manage the negative externalities and be competitive in the prevailing dynamic market requirements, it becomes prudent for freight operators (e.g., carriers, logistics service providers (LSPs)) to analyze their sustainability performance.

1.1 Competitive Priorities for Freight Transport Sector

Competitive priorities denote an organization's strategic preferences that are chosen to contend in the market (Hayes and Wheelwright, 1984; Idris and Naqshbandi, 2019). The fundamental competitive priorities for the manufacturing and service sector are cost, delivery, quality, innovation, and flexibility (Bouranta and Psomas, 2017; Dangayach and Deshmukh, 2006). These are defined as follows (Bouranta and Psomas, 2017; Kathuria et al., 1999; Phusavat and Kanchana, 2008).

Cost: “ability to distribute and produce products at low cost”;

Quality: “ability to maintain high conformance to the service/product specification”;

Delivery: “ability to meet the promised delivery schedules for customer orders”;

Flexibility: “ability to respond to rapid changes in the service/ product or process”;

Innovation: “ability to commence innovative amendments to existing services/production processes and continuously develop new ones”.

In the service sector, the focus on competitive priorities facilitates to satisfy and fulfill customers' expectations (Phusavat and Kanchana, 2008). Researchers unanimously consider innovation, cost, and flexibility as the crucial competitive priorities for the logistics service sector (Liu and Lyons, 2011; Kroes and Ghosh, 2010; Yeung et al., 2012). 'Delivery of quality services' combines the principles of quality and delivery for service processes, and thereby 'delivery of quality services' is considered as one of the most significant competitive priorities for the service industry (Idris and Naqshbandi, 2019). Therefore, this research considers 'delivery of quality services' (DQ), 'innovation' (IN), 'cost' (CO), and 'flexibility' (FL) as the key competitive priorities for the FT sector.

1.2 Research Gap and Research Objectives

Recent studies published in "*Transportation Research Part D: Transport and Environment*" bring out the growing interest of researchers towards sustainability assessment in the transport sector. For instance, Stefaniec et al. (2020) assess the sustainability performance of inland transportation in China; Wang (2019) integrates environmental and safety factors to evaluate road transport sustainability; Bandeira et al. (2019) evaluate the sustainability performance of last-mile freight distribution strategies of a postal company; Stephenson et al. (2018) pinpoint key interventions for sustainable transportation in New Zealand, and Miller et al. (2016) analyze the sustainability performance of public transport by using a composite sustainability index. Furthermore, in a recent review study on environmental sustainability for LSPs, Centobelli et al. (2017) highlight that 'assessment of sustainability performance' and 'factors affecting the implementation of environmental sustainability programs' are the two key research gaps.

Moreover, in today's hypercompetitive market place, to outperform, organizations need to emphasize on achieving sustainability as well as competitive advantage. Competitive priorities assist in adopting sustainability measures, which, in turn, enhance the competitive advantage of an organization (Govindan et al., 2016). Competitive priorities play an indispensable role in achieving sustainability targets of an organization (Phusavat and Kanchana, 2008). It is thereby evident that there is a remarkable and growing literature on sustainable transportation; however, earlier studies have not given much attention to analyze the performance of sustainable freight transportation (SFT) based on competitive priorities (Galeazzo and Klassen, 2015; Lin and Tseng, 2016). In essence, it is prudent to analyze how an organization's sustainability performance is balanced against competitive priorities. Consequently, it becomes significant to evaluate the sustainability performance of FT

systems based on competitive priorities. Therefore, this study analyzes the critical success factors (CSFs) that affect the performance of SFT based on competitive priorities associated with service sector (i.e., DQ, IN, CO, FL) by utilizing a unified approach consisting of fuzzy group decision-making (FGDM), fuzzy evidential reasoning algorithm (FERA), and the concept of expected utility. Accordingly, the prime research objectives considered are delineated as follows.

- To assess and prioritize the CSFs of SFT on the basis of competitive priorities.
- To propose an integrated performance assessment framework based on competitive priorities to model uncertainties of the SFT system.

This is one of the very few studies that analyze the interaction between sustainability performance and competitive priorities (Galeazzo and Klassen, 2015; Laari et al., 2018). This research contributes to the existing literature by analyzing the sustainability performance of FT systems based on competitive priorities. This study also provides a comprehensive summary of the journal papers on sustainability performance assessment in the transport sector. This study proposes a competitive performance score (CPS) based performance assessment framework (PAF) for SFT systems and demonstrates its applicability through a case example. Moreover, this study exemplifies the use of an improved and efficient technique to aggregate individual fuzzy opinions of experts in the multi-criteria decision making (MCDM) environment. The outcomes of this study facilitate logistics practitioners in identifying key CSFs that are crucial to improve competitive performance. The computed CPS value acts as an objective measure for evaluating the competitive performance of an SFT system.

The rest of the paper is organized as follows. Section 2 presents a comprehensive literature review on performance assessment and competitive priorities for the transport sector. An integrated approach combining FERA, FGDM, and expected utility theory, to attain the specified objectives, is discussed in Section 3. Section 4 demonstrates the applicability of the proposed framework through a case example. A sensitivity analysis is carried out in Section 5. The subsequent section explains the effect of variations in the weight of competitive priorities on the CPS value of six dimensions of SFT. Section 7 presents results and discussion. Eventually, Section 8 brings out conclusions and scope for future research.

2 LITERATURE REVIEW

We review the extant literature in three parts; the first part examines the extant literature on performance assessment of sustainable transport sector, the second parts reviews the extant literature on competitive priorities for the transport sector, and the third part deals with the literature related to the interaction of competitive priorities and sustainability performance assessment.

2.1 Review of Literature for Performance assessment of Sustainable Transportation Sector

In a business environment, sustainability facilitates to handle economic, environmental, and social concerns in a holistic manner (Corbo and Glaus, 2019; Zhao et al., 2020). Havenga and Simpson (2018) highlight the significant contribution of freight logistics in achieving sustainability targets. The pressing need for sustainability and performance assessment is well reported among practitioners and researchers in the domain of operations management (Magon et al., 2018).

In the recent past, a few researchers have also highlighted the significance of sustainability performance assessment in the area of freight transportation (Kumar and Anbanandam, 2020; Rai et al., 2017; Stefaniec et al., 2020). For example, Kumar and Anbanandam (2020) propose an index-based model for assessing the social and environmental sustainability performance of FT by utilizing fuzzy logic and fuzzy best-worst technique. Abbasi and Nilsson (2016) assert that sustainability in logistics operations can be achieved by performing activities that cause the maximum economic and societal gains, whereas minimizing the detrimental environmental impacts. Green transport corridors (GTCs) indicate long-distance transportation of freight traffic between major hubs that aim to decrease environmental impact and to increase safety and energy efficiency by utilizing sustainable logistics solutions, inter-modality, and advanced technologies (Blinge, 2014; Hunke and Prause, 2013). Panagakos (2016) brings out that GTCs are environmentally sustainable and economically efficient. Prause (2014) proposes a balanced scorecard approach for green corridors. Prause and Schröder (2015) pinpoint different key performance indicators (KPIs) to check and manage the performance of GTCs. Moreover, Panagakos and Psaraftis (2017) propose a freight corridor evaluation method that comprises of disintegrating the entire corridor into various shipping chains, picking a set of chains based on the outcomes of the shipping model, evaluating disintegrated chains on the basis of KPIs, and subsequently by utilizing suitable weights compute the corridor-level KPIs by combining the chain-level KPIs. Table 1 illustrates the summary of published papers that address the issue of sustainability performance in the transportation sector.

Table 1 Summary of Papers on Sustainability Performance Assessment in the Transport Sector

S.No.	Authors	Type of study/ Country	Contribution	Competitive Priority	Focus Area	Sustainability Dimension			Additional Dimension	Methods/ Tools
						EC	EN	SO		
1.	Kumar and Anbanandam (2020)	Case Study/ India	This study develops an index-based model for analyzing the social and environmental sustainability performance of FT.	-	Freight	-	✓	✓	-	Fuzzy logic and Fuzzy best-worst technique
2.	Bandeira et al. (2019)	Review and case example/ Brazil	This study proposes a model to analyze different strategies for parcel distribution and signifies that the electric tricycle is the best alternative for the last mile postal delivery.	-	Freight	✓	✓	✓	-	Equations based assessment approach
3.	Kumar and Anbanandam (2019)	Case Study/ India	This study develops an index-based PAF for analyzing the social sustainability performance of FT.	-	Freight	-	-	✓	-	Fuzzy logic
4.	Pathak et al. (2019)	Case Study/ India	This study pinpoints the CSFs of SFT by performing a Delphi study. This research employs total interpretive structure modeling (TISM) to establish inter-relationship among the identified CSFs. It utilizes the Fuzzy Analytical Hierarchy Process (FAHP) to prioritize these CSFs.	-	Freight	✓	✓	✓	Safety, advanced technology, efficiency	Delphi study, TISM, FAHP
5.	Solomon et al. (2019)	Empirical study/ Southeast Europe countries	This study utilizes the concept of institutional theory and signifies that the implementation of resilient and green FT practices positively affects social performance.	-	Freight	✓	✓	✓	-	Structural equation modeling (SEM)
6.	Bandeira et al. (2018)	Case study/ Brazil	This study evaluates the sustainability performance of urban freight transport (UFT) from the perspective of freight operators. This research develops a composite index based framework to choose the best delivery alternative.	-	Freight	✓	✓	✓	-	Fuzzy logic
7.	Li et al. (2018)	Case study/ China	This research develops a framework to analyze the environmental performance of 21 freight transport seaports.	-	Freight	-	✓	-	-	Data envelopment analysis (DEA)
8.	Ellram and Murfield (2017)	Review	This study systematically analyzes the extant literature on environmental sustainability in FT and also reports future research directions.	-	Freight	-	✓	-	-	

9.	He et al. (2017)	Review and multiple-case study/ China	This study proposes a performance measurement system for analyzing low-carbon logistics.	-	Freight	✓	✓	✓	-	
10.	Rai et al. (2017)	Case study/ Belgium	This study proposes a policy assessment framework for UFT.	-	Freight	✓	✓	✓	-	Multi-actor multi-criteria analysis
11.	Rajak et al. (2016)	Case example/ India	This paper develops a sustainability performance assessment framework for urban transportation systems.	-	Freight as well as Passenger	✓	✓	✓	Transport system effectiveness	Fuzzy logic
12.	Khorheh et al. (2015)	Review and Empirical/ Australia	This study performs a socio-environmental performance analysis of transportation systems.	-	Freight	-	✓	✓	-	SEM
13.	Shiau et al. (2015)	Case example / Taiwan	This paper proposes a hierarchical indicator structure to assess transport sustainability and unveils that transport sustainability in the energy aspect is almost stable.	-	Freight as well as Passenger	✓	✓	✓	Energy	Principal component analysis
14.	Jeon et al. (2013)	Case study/ USA	This study signifies the role of sustainability performance evaluation in transportation planning.	-	Freight as well as Passenger	✓	✓	✓	Transport system effectiveness	Composite sustainability index (CSI) tool
15.	Shiau and Chuang (2012)	Case example / Taiwan	This study reveals that gravel transportation can be more sustainable by shifting loads from trucks to intermodal transport.	-	Freight	✓	✓	✓	-	AHP, SEE (social-eco-efficient) Approach
16.	Awasthi and Chauhan (2011)	Numerical Example/ Canada	This study utilizes a transport sustainability index-based framework to assess different sustainable city transport solutions.	-	Freight as well as Passenger	✓	✓	✓	Energy, Transport	AHP, Dempster-Shafer theory
17.	Ramani et al. (2011)	Case study/ USA	This paper develops a PAF to assess and improve the sustainability performance of a sustainable transportation agency.	-	Freight	✓	✓	✓	-	Delphi Analysis, MCDM
18.	Jeon et al. (2010)	Case study/ USA	This paper analyzes the sustainability performance for different transportation (and land use) scenarios.	-	Freight as well as Passenger	✓	✓	✓	Transport system effectiveness	MCDM, CSI, weighted sum model
19.	Litman (2007)	Review and Field study	This study facilitates to pinpoint indicators for sustainable and livable transportation planning.	-	Freight as well as Passenger	✓	✓	✓	-	

20.	Jeon and Amekudzi (2005)	Review	This study analyzes 16 sustainable transportation initiatives to define transport sustainability and how to evaluate it.	-	Freight as well as Passenger	✓	✓	✓	Transport system effectiveness	
21.	Richardson (2005)	Review/ USA	This study delineates analysis frameworks to represent interaction among indicators of transport sustainability.	-	Freight as well as Passenger	✓	✓	✓	-	

It is worth mentioning that the research by Pathak et al. (2019) is a good starting point to work on SFT, but their study requires substantial advancements to analyze the interaction between sustainability performance of FT systems and competitive priorities. Therefore, this research primarily extends the study of Pathak et al. (2019) by evaluating the identified CSFs of SFT on the basis of competitive priorities of the service sector. This study highlights the four key competitive priorities of the transport sector (delivery of quality services' (DQ), 'innovation' (IN), 'cost' (CO), and 'flexibility' (FL)). Pathak et al. (2019) developed a sustainability performance index (SPI)-based performance assessment framework (PAF) for assessing the performance of SFT systems. However, this study takes an extra step to identify key CSFs that are crucial to improve competitive performance and proposes a competitive performance score (CPS) based PAF for SFT systems by utilizing a unified approach consisting of fuzzy group decision-making (FGDM), fuzzy evidential reasoning algorithm (FERA), and the concept of expected utility. In this study, the integrated methodologies employed (i.e., FGDM and FERA) can easily handle uncertainties associated with the decision-making procedure due to subjective judgments and incomplete information.

2.2 Review of Literature on Competitive Priorities for the Transport Sector

In today's dynamic and hypercompetitive business environment, an organization's success is highly dependent on the correctness with which it opts the competitive priorities (Prajogo and Mcdermott, 2011). The growing competition requires an organization to focus on improving its internal operations and integrating its suppliers in the entire supply chain activities to build competitive capabilities (i.e., cost, flexibility, delivery, and quality) (Olhager and Prajogo, 2012). The research on competitive priorities in the domain of the logistics sector is still in its nascent stage. Logistics professionals should emphasize on competitive priorities of the service industry (i.e., DQ, IN, CO, FL) (Bouranta and Psomas, 2017; Idris and Naqshbandi, 2019) when trying to attain their sustainability goals.

Kroes and Ghosh (2010) highlight cost, quality, flexibility, innovation, and time priority as significant competitive priorities while evaluating the effect of congruence on supply chain performance. For a third-party LSP, Liu and Lyons (2011) signify that the earlier studies unanimously present that the combination of cost, quality, flexibility, delivery, and innovation may be used to represent operational performance. In the present dynamic market scenario, competitive priorities lead a firm to implement sustainability-related measures for attaining a higher competitive advantage (Govindan et al., 2016), which in turn will yield enhanced organizational performance (Li et al., 2006). Despite the indispensable role of competitive priorities in performance improvement, the existing literature significantly lacks to demonstrate any study on performance assessment and competitive priorities in the domain of SFT (as also evident from Table 1).

2.3 Review of Literature for the Interaction of Competitive Priorities and Sustainability Performance Assessment

Galeazzo and Klassen (2015) signify that sustainability is linked to competitive priorities. By incorporating sustainability concepts in a supply chain, an organization may effectively respond to the burgeoning stakeholder pressure and enhance revenue and competitiveness (Ansari and Kant, 2017). Despite the increasing interest in analyzing the interaction between competitive priorities and sustainability, merely a few researchers have attempted to study this interaction. For instance, Laari et al. (2018) propose a path analysis model to analyze the competitive priorities and green supply chain management (GSCM) practices of logistics service providers (LSPs) and investigate their association with financial and environmental performance. The findings reveal that GSCM practices do not affect financial performance but significantly affect environmental performance. Nonetheless, this paper has

overlooked the social sustainability aspect during the analysis. Galeazzo and Klassen (2015) report that manufacturing strategies consist of sustainability as well as the traditional competitive priorities. The authors also examine the relationships among manufacturing strategies, the organizational context, and the adoption of social and environmental practices. The outcomes of this study signify that sustainability is linked to the two dimensions of competitive priorities (i.e., quality and delivery).

In the recent past, sustainability performance assessment in the transport sector has gained proliferating research attention across the globe. The research on competitive priorities in the domain of the transport sector is also evolving at a faster pace. Nowadays, LSPs have started to focus on improving their sustainability performance. However, the biggest challenge before LSPs is to identify which sustainability factors would lead to attaining higher competitive advantage. Despite these growing interests, only a few researchers (Galeazzo and Klassen, 2015; Laari et al., 2018) have attempted to work on the interaction of competitive priorities and sustainability performance. As also evident from Table 1, earlier studies significantly lack to analyze the sustainability performance of FT based on competitive priorities. Consequently, this issue remains one of the significant research gaps in the extant literature. This research is an attempt to address this existing gap in the literature by analyzing the sustainability performance of FT based on competitive priorities.

3 AN INTEGRATED APPROACH TO ANALYZE THE CSFs OF SFT

Performance assessment in the field of SFT requires quantitative as well as qualitative assessment. Qualitative assessment is primarily based on the experts' subjective judgment and thus may have uncertainties involved in the decision-making. Therefore, this research employs a fuzzy evidential reasoning algorithm (FERA) to analyze the performance of SFT systems. FERA can handle multi-criteria decision making (MCDM) problems for subjective attributes and the combination of both quantitative and qualitative attributes (Ayati et al., 2012). A unified approach by using FGDM, FERA, and expected utility concept is utilized to assess and prioritize the CSFs of SFT based on competitive priorities. A step by step procedure is explained as follows.

3.1 Research Flow Diagram

The proposed framework for this study to attain the identified objectives is demonstrated, as shown in Figure 1.

Figure 1 Proposed Research Framework

3.2 Identification of CSFs of SFT

The CSFs can be termed as the key elements that are essential for any business organization to attain the specified goals and ensure its success (Rockart, 1979). By reviewing the extant literature and performing a Delphi study, Pathak et al. (2019) identify 34 CSFs that affect the sustainability performance of FT and classify these CSFs into six dimensions of sustainability. Pathak et al. (2019)

develop a sustainability performance index (SPI)-based framework for assessing the performance of SFT systems. The authors bring out the importance of three emergent dimensions (i.e., efficiency (EF), employing advanced technology (EM), and safety (SA)) along with the triple bottom line aspects of sustainability (i.e., social, economic, and environmental) in assessing the performance of SFT systems.

In this study, we consider 34 CSFs of SFT, as identified by Pathak et al. (2019). These CSFs are categorized into six dimensions of sustainability and significantly affect the sustainability performance of FT systems. For further information on these CSFs, interested readers may refer to Pathak et al. (2019). A list of the considered CSFs is depicted in Table 2.

Table 2. A Finalized list of CSFs influencing performance of SFT

Factors of SFT	Code	CSFs of SFT	References
Economic Factor (EC)	EC-1	Operating cost	Bandeira et al. (2018); Castillo and Pitfield (2010)
	EC-2	Personnel training	Kumar and Anbanandam (2019); Pathak et al. (2019)
	EC-3	Loading Factor	Bandeira et al. (2018); Piecyk and Mckinnon (2010); Liljestrand (2016);
	EC-4	Return on Investment (ROI)	Pathak et al. (2019)
	EC-5	Economic growth	Castillo and Pitfield (2010); Jeon and Amekudzi (2005)
Environmental Factor (EN)	EN-1	Air Pollution	Bandeira et al. (2018); Jeon et al. (2013); Reisi et al. (2014)
	EN-2	Noise Level	Bandeira et al. (2018); Kumar and Anbanandam (2020); Litman (2007)
	EN-3	Vibration Level	Khorheh et al. (2015)
	EN-4	Climate Change	Litman (2007); Rajak et al. (2016)
	EN-5	Conventional Fossil Fuel consumption	Litman (2007); Rajak et al. (2016)
	EN-6	Visual Intrusion	Demir et al. (2015); Taniguchi et al. (2014)
	EN-7	Complying with Government Regulations for Green Practices Implementation	Pathak et al. (2019)
Efficiency Factor (EF)	EF-1	Energy Efficiency	He et al. (2017); Shiau et al. (2015)
	EF-2	Quality Management	Awasthi and Chauhan (2011); Bandeira et al. (2018)
	EF-3	Drivers' Efficiency	ERTRAC (2011); Leonardi and Baumgartner (2004)
	EF-4	Efficient Transport Operations	Rajak et al. (2016)
	EF-5	On-time Delivery	Lai et al. (2002)
	EF-6	Distribution Planning	Awasthi and Chauhan (2012); Crainic and Laporte (1997)
Employing Advanced Technology Factor (EM)	EM-1	Electronic Data Interchange (EDI)	Perego et al. (2011); Yoshimoto and Nemoto (2005)
	EM-2	Radio Frequency Identification (RFID)	ERTRAC (2011); Yoshimoto and Nemoto (2005)
	EM-3	Global Positioning System (GPS)	Taniguchi et al. (2014); Yoshimoto and Nemoto (2005)
	EM-4	Intelligent Transportation System (ITS)	ERTRAC (2011); Yoshimoto and Nemoto (2005)
	EM-5	Top Management Support for ICT Usage	ERTRAC (2011); Mondragon et al. (2017); Tob-Ogu et al. (2018)
Safety Factor (SA)	SA-1	Accident Rate	Santos and Ribeiro (2013); Shiau et al. (2015)
	SA-2	Injury Severity Level	Bandeira et al. (2018); Shiau et al. (2015)
	SA-3	Cargo Security	Awasthi and Chauhan (2011); He et al. (2017)
	SA-4	Customer Satisfaction	Awasthi and Chauhan (2012); Reisi et al. (2014); Santos and Ribeiro (2013)
	SA-5	Adoption of Safety Standards	Pathak et al. (2019)
Social Factor (SO)	SO-1	Traffic Clogging	Bandeira et al. (2018); Janjevic et al. (2019); Kumar and Anbanandam (2019)
	SO-2	Equity	Jeon et al. (2010); Santos and Ribeiro (2013)
	SO-3	Health Risk	Kumar and Anbanandam (2019); Litman (2007); Santos and Ribeiro (2013)
	SO-4	Quality of Life	Behrends (2011); Jeon et al. (2010)
	SO-5	Awareness towards Injury Prevention Programs	Jeon and Amekudzi (2005)
	SO-6	Drivers' Healthcare	ERTRAC (2011)

3.3 Assessment of CSFs using Fuzzy Set Theory

After identifying the CSFs of SFT, the next step is to assess these CSFs on the basis of selected criteria. The literature on competitive priorities of the service sector forms the basis for the performance criteria considered in this study. Therefore, we consider four criteria (i.e., competitive priorities) to evaluate the competitive performance of all CSFs and sustainability dimensions of FT systems. All CSFs of SFT are qualitative in nature with an emphasis on assessing sustainability performance based on competitive priorities. As experts' expertise would be required in decision-making for performance evaluation, it is recommended to use linguistic variables (Wan et al., 2019). For linguistic assessment of CSFs, a five-point scale (very low, low, medium, high, and very high) is used to facilitate experts for analyzing CSFs on the basis of different competitive priorities. Afterward, the concepts of fuzzy set theory (FST) (Zadeh, 1965) are used to transform linguistic evaluations into triangular fuzzy numbers (TFNs) (please refer to Table 3) (John et al., 2014).

Table 3 Conversion of Linguistic Variables to TFN

Level of significance	Membership Function
Very Low [VL]	[0.00,0.00,0.25]
Low [L]	[0.00,0.25,0.50]
Medium [M]	[0.25,0.50,0.75]
High [H]	[0.50,0.75,1.00]
Very High [VH]	[0.75,1.00,1.00]

The significance level for CSFs of SFT to achieve competitive performance can be defined by using TFNs (as depicted in Table 4). A TFN is represented with the help of parameters a , b , and c . Further, a centroid value (C) can be utilized to compare the significance level of different CSFs of SFT. The centroid value (C) is calculated by using Equation (1) (John et al., 2014).

$$C = \frac{1}{3} (a + b + c) \quad (1)$$

Table 4 Details of the Linguistic Scale used for Performance Assessment of SFT

Linguistic scale for performance analysis of CSFs of SFT on the basis of competitive priorities	Description of assessment grades TFN	Centroid value (C)	Range of competitive performance score	Significance level of CSF
Very Low (VL)	(0.00, 0.00, 0.25)	0.083	0 – 0.24	Not significant at all
Low (L)	(0.00, 0.25, 0.50)	0.25	0.25 – 0.49	Slightly significant
Medium (M)	(0.25, 0.50, 0.75)	0.5	0.5-0.74	Moderately significant
High (H)	(0.50, 0.75, 1.00)	0.75	0.75-0.91	Significant
Very High (VH)	(0.75, 1.00, 1.00)	0.92	0.92 – 1.00	Extremely significant

3.4 Methodology

This study utilizes a unified approach consisting of FGDM, FERA, and expected utility theory to assess the CSFs of SFT on the basis of competitive priorities. These methodologies are briefly explained as follows.

3.4.1 Aggregation of Fuzzy Opinions

In an MCDM problem, as an expert's opinion for a particular criterion may encompass fuzziness, ambiguity, and subjectivity for the given alternative, FST offers an effective means to handle these uncertainties involved in the human judgments (Chen, 1998). When several experts participate in a decision-making problem, it becomes essential to combine individual fuzzy opinions of experts for attaining a collective opinion (Hsu and Chen, 1996). Chen (1998) proposes an improved and efficient method for aggregation of fuzzy opinions in the MCDM environment. The author reports several advantages of the proposed method over the similarity aggregation method for aggregation of fuzzy opinions, as presented by Hsu and Chen (1996).

Suppose that each expert E_d ($d = 1, 2, \dots, D$) uses a non-negative TFN $\tilde{R}_d = (a_d, b_d, c_d)$ to depict the subjective estimate of the rating to a given criterion and alternative, where $0 \leq a_d \leq b_d \leq c_d \leq 1$. Further, the degree of significance of an expert E_d is assumed as w_d , where $w_d \in [0, 1]$ and $\sum_{d=1}^D w_d = 1$. The five-step algorithm is explained as follows (Chen, 1998).

1: Estimate the degree of agreement $S(\tilde{R}_d, \tilde{R}_q)$ of the collected views for each pair of experts E_d and E_q , where $S(\tilde{R}_d, \tilde{R}_q) \in [0, 1]$, $1 \leq d \leq D$, $1 \leq q \leq D$, and $d \neq q$.

Let $\tilde{X}$ and $\tilde{Y}$ be two standardized TFNs, $\tilde{X} = (a_1, b_1, c_1)$, $\tilde{Y} = (a_2, b_2, c_2)$. The degree of agreement between $\tilde{X}$ and $\tilde{Y}$ is estimated as follows.

$$S(\tilde{X}, \tilde{Y}) = 1 - \frac{|a_1 - a_2| + |b_1 - b_2| + |c_1 - c_2|}{3} \quad (2)$$

2: For expert E_d , compute the average degree of agreement $DA(E_d)$ as follows.

$$DA(E_d) = \frac{1}{D-1} \sum_{d=1}^D \sum_{d \neq q} S(\tilde{R}_d, \tilde{R}_q) \quad (3)$$

3: For expert E_d , estimate the relative degree of agreement $RDA(E_d)$ as follows.

$$RDA(E_d) = \frac{DA(E_d)}{\sum_{d=1}^D DA(E_d)} \quad (4)$$

4: If the weight of the degrees of significance and the relative degree of agreement for experts are z_1 and z_2 , respectively, consensus degree coefficient $C(E_d)$ for expert E_d is computed as follows.

$$C(E_d) = \left(\frac{z_1}{z_1 + z_2} \times w_d \right) + \left(\frac{z_2}{z_1 + z_2} \times RDA(E_d) \right) \quad (5)$$

Where $z_1 \in [0, 1]$ and $z_2 \in [0, 1]$.

Further, as highlighted by Hsu and Chen (1996), when there is no consideration for the degree of significance of experts (i.e., $\alpha = 0$)

$$C(E_d) = RDA(E_d) \quad (6)$$

Where, $\alpha = \frac{z_1}{z_1 + z_2}$ and $1 - \alpha = \frac{z_2}{z_1 + z_2}$

5: The aggregated fuzzy opinion $\tilde{R}$ is calculated as follows.

$$\tilde{R} = C(E_1) \otimes R_1 \oplus C(E_2) \otimes R_2 \oplus \dots \oplus C(E_D) \otimes R_D \quad (7)$$

Where, operators $\oplus$ and $\otimes$ denote fuzzy addition and multiplication operator, respectively.

3.4.2 Transformation of TFNs into Belief Degree Structure

A belief degree can be defined as the degree of expectation that, for a particular criterion, will provide an expected result to the given alternative (John et al., 2014). Aggregated TFN value is transformed into a belief degree structure by employing the concepts presented by earlier studies (Godaliyadde et al., 2010; John et al., 2014). Afterward, the normalized belief degree values for each CSF are calculated, as discussed in Section 4.2.

3.4.3 Evidential Reasoning Algorithm (ERA) and the Concept of Expected Utility

An ERA is proposed to analyze quantitative as well as qualitative attributes involved in multiple attribute decision-making problems (Wan et al., 2018; Yang, 2001; Zhou et al., 2019). ERA combines the concept of the Dempster-Shaffer (D-S) theory of evidence and a distributed modeling assessment framework (Wan et al., 2019; Qin et al., 2020). This distributed modeling framework facilitates to assess each attribute by utilizing a set of mutually exclusive assessment grades. Moreover, probabilistic uncertainty is addressed by a belief degree structure and fuzzy uncertainty by considering fuzzy linguistic assessment in the ERA. ERA can effectively handle different kinds of uncertainties (e.g., ignorance, fuzziness, and incomplete information) (Wan et al., 2019; Zhou et al., 2019).

Unlike most conventional MCDM techniques, ERA utilizes a belief degree structure to illustrate the estimation of an attribute as a distribution. Moreover, instead of aggregating average scores, ERA applies aggregation concepts of D-S theory to combine belief degrees (Akhoundi and Nazif, 2018; Wan et al., 2018). ERA facilitates combining multilevel criteria in a hierarchical framework, and it is easily implemented by using intelligent decision system (IDS) software (Yan et al., 2015). A rational means to express fuzziness is to use linguistic variables in place of numerical assessment. Thereby, for ease of decision-making process, FST offers a systematic approach to consider linguistic variables (Lai, 2008).

The FST can be combined with ERA to deal with pragmatic cases, where fuzziness and ignorance in data are prevailing (Yang et al., 2006). The FERA (i.e., the combination of FST and ERA) is extensively used by researchers in analyzing decision-making problems (Cao et al., 2019; John et al., 2014; Yang et al., 2009). This study utilizes FERA to analyze the performance of SFT systems. FERA is utilized as it is able to handle uncertainties involved in the decision analysis. To analyze the performance of SFT based on competitive priorities, a three-step ERA method, as proposed by Akhoundi and Nazif (2018), is utilized and explained as follows.

Step 1: The ERA distributed modeling framework-the belief degree structure

Assume performance assessment of SFT as an MCDM problem with M alternatives (i.e., CSFs) $o_l (l = 1, \dots, M)$, one overall goal and L basic criteria (i.e., competitive priorities) $f_i (i = 1, \dots, L)$. Suppose F as a set of L basic criteria:

$$F = \{f_i, i = 1, \dots, L\} \quad (8)$$

Assume this set comprises of all competitive priorities affecting the evaluation of the overall goal.

Suppose the relative weights of these L criteria are given by $\theta = \{\theta_i, i = 1, \dots, L\}$ and can be normalized as follows.

$$0 \leq \theta_i \leq 1, \sum_{i=1}^L \theta_i = 1 \quad (9)$$

Assume N distinct assessment grades are described by a comprehensive set as denoted by $G_n (n = 1, \dots, N)$, where G_n is the n^{th} assessment grade and it is considered that G_{n+1} is preferred to G_n .

$$G = \{G_n, n = 1, \dots, N\}. \quad (10)$$

An MCDM problem with $o_l (l = 1, \dots, M)$ alternatives and $f_i (i = 1, \dots, L)$ criteria is mathematically depicted as follows.

$$S(f_i(o_l)) = \{(G_n, \beta_{n,i}(o_l)), n = 1, \dots, N\}, \quad i = 1, \dots, L, \quad l = 1, \dots, M \quad (11)$$

Where, $\beta_{n,i}(o_l) \geq 0$ and $\sum_{n=1}^N \beta_{n,i}(o_l) \leq 1$. $\beta_{n,i}(o_l)$ indicates a belief degree. The evaluation outcomes of each alternative (i.e., CSF) on each competitive priority are denoted as follows.

$$D_g = (S(f_i(o_l)))_{L \times M}. \quad (12)$$

Note that a criterion may have its own set of evaluation grades that can be dissimilar from the other criteria.

Step 2: Attribute aggregation by using the ER algorithm

In this study, we consider four competitive priorities (i.e., DQ, IN, CO, FL) as an exhaustive set of criteria for analyzing the performance of SFT systems. The recursive ER algorithm is employed to assess the decision alternatives $o_l (l = 1, \dots, M)$ by aggregating L criteria. The assessments depicted in Equation (11) – (12) for an alternative o_l may be aggregated as follows.

$$f_i \ (i = 1, \dots, L)$$

The belief degree is converted into basic probability masses as follows:

Let $p_{n,i}$ is a basic probability mass that represents the amount for i^{th} basic attribute e_i which is evaluated to n^{th} grade G_n . $p_{n,i}$ and $p_{H,i}$ are determined as follows

$$p_{n,i} = \theta_i \beta_{n,i} (o_i), \quad n = 1, \dots, N; \ i = 1, \dots, L \quad (13)$$

Let $p_{H,i}$ is the residual probability mass unallocated to any individual grade. In the modified ER algorithm (Yang and Xu, 2002), this residual probability mass is decomposed into two parts: 1) $\bar{p}_{H,i}$ and 2) $\tilde{p}_{H,i}$, where

$$\bar{p}_{H,i} = 1 - \theta_i \quad \text{and} \quad \tilde{p}_{H,i} = \theta_i (1 - \sum_{n=1}^N \beta_{n,i}) \quad (14a)$$

$$\text{With } p_{H,i} = \bar{p}_{H,i} + \tilde{p}_{H,i} \quad (14b)$$

$\bar{p}_{H,i}$ is the first part of the residual probability mass unallocated to an individual assessment grade that indicates the degree to which other attributes can play a role in the assessment. And, $\tilde{p}_{H,i}$ is another part of the residual probability mass unallocated to an individual assessment grade that exists due to the incompleteness in the assessment $S(f_i)$.

Let $p_{n,I(i)}$ ($n = 1, 2, \dots, N$), $\tilde{p}_{H,I(i)}$, and $\bar{p}_{H,I(i)}$ represent the combined probability masses produced by combining the first i assessments. The aggregation process with two decomposed masses to compute the combined probability masses (i.e., $p_{n,I(i+1)}$, $\tilde{p}_{H,I(i+1)}$, and $\bar{p}_{H,I(i+1)}$) for the first $(i + 1)$ assessments is recursively performed as follows (Yang and Xu, 2002).

$$\{G_n\}: p_{n,I(i+1)} = NF_{I(i+1)} [p_{n,I(i)} p_{n,i+1} + p_{n,i+1} (\bar{p}_{H,i} + \tilde{p}_{H,i}) + p_{n,I(i)} (\bar{p}_{H,i+1} + \tilde{p}_{H,i+1})], \quad n = 1, \dots, N \quad (15)$$

$$\{G\}: \tilde{p}_{H,I(i+1)} = NF_{I(i+1)} [\tilde{p}_{H,I(i)} \tilde{p}_{H,i+1} + \tilde{p}_{H,I(i)} \bar{p}_{H,i+1} + \bar{p}_{H,I(i)} \tilde{p}_{H,i+1}] \quad (16a)$$

$$\{G\}: \bar{p}_{H,I(i+1)} = NF_{I(i+1)} [\bar{p}_{H,I(i)} \bar{p}_{H,i+1}] \quad (16b)$$

$$NF_{I(i+1)} = [1 - \sum_{t=1}^N \sum_{j=1}^N p_{t,I(i)} p_{j,i+1}]^{-1}, \quad i = 1, \dots, L - 1 \quad (17)$$

where, $NF_{I(i+1)}$ is a normalizing factor in facilitating $\sum_{n=1}^N p_{n,I(i+1)} + p_{H,I(i+1)} = 1$.

Note that $p_{n,I(1)} = p_{n,1}$ ($n = 1, 2, \dots, N$), $\tilde{p}_{H,I(1)} = \tilde{p}_{H,1}$, $\bar{p}_{H,I(1)} = \bar{p}_{H,1}$, and $p_{H,I(1)} = p_{H,1}$.

After aggregation of all L assessments, the combined belief degree is computed as follows (Yang and Xu, 2002).

$$\{G_n\}: \beta_n = \frac{p_{n,I(L)}}{1 - \bar{p}_{H,I(L)}}, \quad n = 1, \dots, N, \quad (18)$$

$$\{G\}: \beta_H = \frac{\tilde{p}_{H,I(L)}}{1 - \bar{p}_{H,I(L)}} \quad (19)$$

In the ERA method, β_n is the combined belief degree and β_H is the belief degree unallocated to any individual assessment grade. β_H denotes the amount of incompleteness in the assessment. It is mentioned that $\sum_{n=1}^N \beta_n(o_l) + \beta_H(o_l) = 1$ (Yang, 2001).

The aggregated assessment for (o_l) can be represented as follows.

$$S(y(o_l)) = \{(G_n, \beta_n(o_l)), n = 1, \dots, N\}. \quad (20)$$

Step 3: Utility estimation in the ERA method using the Expected Utility Theory

The theory of expected utility is used to obtain numerical values corresponding to the distributed estimation for each alternative on the basis of overall competitive performance score (John et al., 2014; Yang, 2001). If the utility of an assessment grade G_n is $u(G_n)$, the expected utility of the aggregated assessment $S(y(o_l))$ can be denoted by:

$$u(S(y(o_l))) = \sum_{n=1}^N \beta_n(o_l) u(G_n) \quad (21)$$

Where $u(G_n)$ depicts the utility value of each linguistic variable. If decision-makers' preference data is unavailable, it is supposed that the utilities of the assessment grades are evenly distributed, so that (Yang, 2001):

$$u(G_n) = (V_n - 1)/(V_N - 1) \quad (n = 1, \dots, N) \quad (22)$$

where V_n denotes the ranking value of the linguistic variable under consideration (G_n) and V_N is the ranking value of the most preferred linguistic variable (G_N).

The belief degree $\beta_n(o_l)$ denotes the lower bound of the possibility that o_l is evaluated to G_n , while the upper bound of the possibility is denoted by $(\beta_n(o_l) + \beta_H(o_l))$ (Akhoundi and Nazif, 2018; Yang, 2001) that forms a utility interval for an incomplete evaluation. Assume, the least favored grade G_1 has

the minimum utility and the most favored grade G_N has the maximum utility. So the maximum, average, and minimum utilities of o_l are defined as follows:

$$u_{max}(o_l) = \sum_{n=1}^{N-1} \beta_n(o_l) u(G_n) + (\beta_N(o_l) + \beta_H(o_l)) u(G_N) \quad (23)$$

$$u_{min}(o_l) = \sum_{n=2}^N \beta_n(o_l) u(G_n) + (\beta_1(o_l) + \beta_H(o_l)) u(G_1), \quad (24)$$

$$u_{avg}(o_l) = \frac{u_{min}(o_l) + u_{max}(o_l)}{2} \quad (25)$$

If all the assessments $S(e_i(o_l))$ in the generalized decision matrix are complete, $\beta_H(o_l) = 0$ and $u(S(y(o_l))) = u_{max}(o_l) = u_{min}(o_l) = u_{avg}(o_l)$.

3.4.4 Sensitivity Analysis

Sensitivity analysis aims to examine the robustness of the proposed framework. In this paper, sensitivity analysis is performed to check how a slight change in the model input data affect the model output (Yang et al., 2009). The changes in the input data may be attained by varying the model parameters or belief degrees allocated to the linguistic terms (John et al., 2014; Wan et al., 2019). To validate the robustness and rational decision-making of the methodology, the proposed performance assessment model should satisfy the following three axioms of sensitivity analysis (Wan et al., 2019; Yang et al., 2009).

Axiom 1. “A slight decrement/increment in the belief degrees related to any linguistic variables of the lowest-level criteria (i.e., competitive priorities) will cause decrement/increment in the model output (i.e., CPS value of CSFs)”.

Axiom 2: “If the belief degrees related to the most preferred linguistic term of the lowest level criterion are reduced by a and b (i.e., simultaneously, the belief degrees related to its least preferred linguistic term are increased by a and b (where $1 > b > a$)), the computed utility value for the model’s output (i.e., U_a and U_b , respectively) will be of the order $U_a > U_b$.”

Axiom 3. “If x and y (where $y \in x$) criteria from all the lowest level criteria are considered, and the belief degrees related to the most preferred linguistic term of these x and y criteria are reduced by the same amount (i.e., simultaneously, the belief degrees pertaining to the least preferred linguistic term of these x and y criteria are increased by the equal amount), the computed utility value for the model’s output (i.e., U_x and U_y , respectively) will be of the order $U_y > U_x$.”

4 APPLICABILITY OF THE PROPOSED FRAMEWORK: AN EXAMPLE OF FREIGHT TRANSPORT SECTOR

This section explains in what way the developed framework may be utilized to evaluate sustainability CSFs based on competitive priorities for the smooth functioning of freight operators (i.e., LSPs, carriers) in the hypercompetitive market place. The applicability of the proposed model is demonstrated through an example of the freight transportation sector in India. The transport sector accounts for a 5% share in the gross domestic product of India (Statistics Times, 2019). In India, the freight transportation sector is significantly fragmented and unorganized, and the value of this sector is estimated to be about USD 307.70 billion by 2020 (Novonous Report, 2015). In India, the transport sector contributes to around 13% of CO₂ emissions, and it is the third most CO₂ emitting sector. Road transportation contributes to about 93% of total transit linked CO₂ emissions (IEA, 2018). In India, the freight transport sector is evolving and requires significant changes to achieve sustainability in the prevailing competitive business environment. Seven experts, associated with the transport and logistics companies in India, were interviewed for getting their opinions in linguistic terms to assess the CSFs of SFT based on competitive priorities. These experts were selected due to their expertise in the domain of sustainable logistics operations. They had the required knowledge and skills to be the key informants for this study. Each expert had a minimum experience of 14 years. Earlier studies signify that a sample size of 3-5 experts is adequate to conduct studies based on FERA (Ayati et al., 2012; John et al., 2014; Wan et al., 2019).

4.1 Aggregation of Fuzzy Opinions

The experts' views in the form of linguistic variables have been captured and then transformed into an equivalent TFN by using the scale as proposed by (John et al., 2014). In this study, we adopt a procedure, described by Chen (1998), to aggregate the fuzzy opinions of each expert to form a group consensus in an MCDM problem. Aggregated TFN value is computed by using Equations (2) – (7). Table 5 depicts the aggregation of experts' fuzzy opinion for CSFs (under economic dimensions) when assessed on the basis of DQ.

Table 4 Aggregation of Fuzzy Opinion for CSFs (under EC) on the Basis of DQ

S. No	CSF	Expert-1	Expert-2	Expert-3	Expert-4	Expert-5	Expert-6	Expert-7	Aggregated
1	EC-1	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.436, 0.686, 0.936)

2	EC-2	(0.75, 0.75, 1)	(0.75, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 0.75, 1)	(0.5, 0.75, 1)	(0.645, 0.895, 1)
3	EC-3	(0, 0.25, 0.5)	(0, 0.25, 0.5)	(0, 0.25, 0.5)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.170, 0.420, 0.670)
4	EC-4	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 0.75, 1)	(0.567, 0.817, 1)
5	EC-5	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 0.75, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.531, 0.781, 1)

Similarly, the aggregation is performed for the rest of the three competitive priorities (i.e., innovation, cost, and flexibility) and other CSFs.

4.2 Transformation of Aggregated TFNs into Belief Degree Structure

Further, aggregated TFN value for all CSFs is transformed into belief degree structure, and then a normalized belief degree has been calculated. When assessed on the basis of DQ, the transformation of TFN for the CSF 'EC-1' is demonstrated using Figure 2. The normalized belief degree values for each CSF can be calculated by using the following procedure, as proposed by John et al. (2014).

- First of all, a uniformly distributed graph is developed to show the fuzzy membership function of TFN for the adapted five-point scale.
- The aggregated $TFN_{(EC-1/DQ)}$ is mapped over the uniformly distributed graph for five assessment grades (VL, L, M, H, and VH). The triangle developed by plotting $TFN_{(EC-1/DQ)}$ is shown by green lines in Figure 2.
- This green triangle (representing $TFN_{(EC-1/DQ)}$) intersects with the four assessment grade triangles (i.e., L, M, H, and VH) on the uniformly distributed graph. These four intersection points are identified in Figure 2. The equivalent values for these intersecting points are determined by drawing the straight black lines, as shown in Figure 2.
- These intersecting point values represent the belief degree of $TFN_{(EC-1/DQ)}$ for the respective assessment grades. The belief degree values for $TFN_{(EC-1/DQ)}$ can be determined from Figure 2 and are depicted in Table 6.
- If the green triangle ($TFN_{(EC-1/DQ)}$) intersects any of the assessment grade triangles at more than one place, the highest value corresponding to the intersecting position is considered.
- In last, the belief degree values are normalized to get normalized belief degree.

Table 6 A Sample Calculation for Transformation of $TFN_{(EC-1/DQ)}$ into Normalized Belief Degree

$TFN_{(EC-1/DQ)}$ (0.436, 0.686, 0.936)					
Grade	VL	L	M	H	VH
Belief Degree	0.000	0.125	0.630	0.875	0.375
Normalized Belief degree	0.000	0.062	0.314	0.436	0.187

Figure 2 $TFN_{EC-1/DQ}$ Transformation into Belief Degree

Similarly, mapped belief degrees for all CSFs have been calculated, and then normalized belief degrees for all CSFs have been determined. Table 7 represents normalized belief degrees of all CSFs when assessed on the basis of four competitive priorities.

Table 7 Normalized Belief Degrees of All CSF

	DQ					IN					CO					FL				
	VL	L	M	H	VH	VL	L	M	H	VH	VL	L	M	H	VH	VL	L	M	H	VH
EC-1	0.000	0.062	0.314	0.436	0.187	0.000	0.000	0.228	0.490	0.283	0.000	0.000	0.040	0.368	0.591	0.000	0.000	0.201	0.477	0.322
EC-2	0.000	0.000	0.128	0.433	0.439	0.000	0.000	0.166	0.458	0.376	0.000	0.000	0.082	0.400	0.518	0.000	0.000	0.166	0.458	0.376
EC-3	0.081	0.331	0.418	0.170	0.000	0.147	0.398	0.353	0.102	0.000	0.000	0.000	0.228	0.490	0.283	0.000	0.220	0.470	0.278	0.032
EC-4	0.000	0.000	0.201	0.477	0.322	0.000	0.062	0.314	0.436	0.187	0.000	0.027	0.277	0.471	0.225	0.000	0.186	0.434	0.314	0.066
EC-5	0.000	0.000	0.228	0.490	0.283	0.000	0.000	0.228	0.490	0.283	0.000	0.027	0.277	0.471	0.225	0.000	0.144	0.394	0.355	0.107
EN-1	0.280	0.493	0.228	0.000	0.000	0.000	0.062	0.314	0.436	0.187	0.223	0.471	0.278	0.027	0.000	0.280	0.493	0.228	0.000	0.000
EN-2	0.372	0.460	0.168	0.000	0.000	0.000	0.144	0.394	0.355	0.107	0.280	0.493	0.228	0.000	0.000	0.319	0.478	0.203	0.000	0.000
EN-3	0.147	0.398	0.353	0.102	0.000	0.000	0.186	0.434	0.314	0.066	0.280	0.493	0.228	0.000	0.000	0.280	0.493	0.228	0.000	0.000
EN-4	0.280	0.493	0.228	0.000	0.000	0.000	0.000	0.228	0.490	0.283	0.280	0.493	0.228	0.000	0.000	0.280	0.493	0.228	0.000	0.000
EN-5	0.280	0.493	0.228	0.000	0.000	0.000	0.144	0.394	0.355	0.107	0.280	0.493	0.228	0.000	0.000	0.319	0.478	0.203	0.000	0.000
EN-6	0.319	0.478	0.203	0.000	0.000	0.147	0.398	0.353	0.102	0.000	0.319	0.478	0.203	0.000	0.000	0.280	0.493	0.228	0.000	0.000
EN-7	0.064	0.315	0.436	0.186	0.000	0.000	0.000	0.166	0.458	0.376	0.028	0.279	0.473	0.220	0.000	0.104	0.353	0.396	0.147	0.000
EF-1	0.000	0.220	0.470	0.278	0.032	0.000	0.000	0.228	0.490	0.283	0.000	0.062	0.314	0.436	0.187	0.000	0.144	0.394	0.355	0.107
EF-2	0.000	0.000	0.040	0.368	0.591	0.000	0.000	0.201	0.477	0.322	0.000	0.027	0.277	0.471	0.225	0.000	0.077	0.330	0.432	0.161
EF-3	0.000	0.186	0.434	0.314	0.066	0.000	0.000	0.228	0.490	0.283	0.147	0.398	0.353	0.102	0.000	0.000	0.144	0.394	0.355	0.107
EF-4	0.000	0.000	0.166	0.458	0.376	0.000	0.000	0.128	0.433	0.439	0.000	0.062	0.314	0.436	0.187	0.000	0.000	0.128	0.433	0.439
EF-5	0.000	0.027	0.277	0.471	0.225	0.000	0.144	0.394	0.355	0.107	0.000	0.220	0.470	0.278	0.032	0.000	0.220	0.470	0.278	0.032
EF-6	0.000	0.062	0.314	0.436	0.187	0.000	0.027	0.277	0.471	0.225	0.000	0.062	0.314	0.436	0.187	0.000	0.000	0.082	0.400	0.518
EM-1	0.000	0.000	0.228	0.490	0.283	0.000	0.103	0.352	0.395	0.150	0.000	0.186	0.434	0.314	0.066	0.000	0.027	0.277	0.471	0.225
EM-2	0.000	0.027	0.277	0.471	0.225	0.000	0.062	0.314	0.436	0.187	0.000	0.144	0.394	0.355	0.107	0.000	0.027	0.277	0.471	0.225
EM-3	0.000	0.000	0.201	0.477	0.322	0.000	0.000	0.128	0.433	0.439	0.000	0.220	0.470	0.278	0.032	0.000	0.000	0.166	0.458	0.376
EM-4	0.000	0.000	0.082	0.400	0.518	0.000	0.000	0.082	0.400	0.518	0.000	0.027	0.277	0.471	0.225	0.000	0.000	0.082	0.400	0.518
EM-5	0.000	0.000	0.201	0.477	0.322	0.000	0.000	0.201	0.477	0.322	0.000	0.062	0.314	0.436	0.187	0.000	0.000	0.128	0.433	0.439
SA-1	0.000	0.000	0.082	0.400	0.518	0.000	0.031	0.287	0.476	0.206	0.028	0.279	0.473	0.220	0.000	0.000	0.062	0.314	0.436	0.187
SA-2	0.000	0.000	0.228	0.490	0.283	0.000	0.220	0.470	0.278	0.032	0.064	0.315	0.436	0.186	0.000	0.000	0.144	0.394	0.355	0.107
SA-3	0.000	0.000	0.040	0.368	0.591	0.000	0.062	0.314	0.436	0.187	0.000	0.144	0.394	0.355	0.107	0.000	0.000	0.082	0.400	0.518
SA-4	0.000	0.000	0.040	0.368	0.591	0.000	0.027	0.277	0.471	0.225	0.000	0.144	0.394	0.355	0.107	0.000	0.000	0.228	0.496	0.276
SA-5	0.000	0.000	0.040	0.368	0.591	0.000	0.000	0.228	0.490	0.283	0.000	0.062	0.314	0.436	0.187	0.000	0.000	0.082	0.400	0.518

SO-1	0.000	0.186	0.434	0.314	0.066	0.000	0.186	0.434	0.314	0.066	0.147	0.398	0.353	0.102	0.000	0.000	0.103	0.352	0.395	0.150
SO-2	0.319	0.478	0.203	0.000	0.000	0.147	0.398	0.353	0.102	0.000	0.223	0.471	0.278	0.027	0.000	0.064	0.315	0.436	0.186	0.000
SO-3	0.000	0.220	0.470	0.278	0.032	0.000	0.220	0.470	0.278	0.032	0.187	0.438	0.313	0.062	0.000	0.028	0.279	0.473	0.220	0.000
SO-4	0.000	0.000	0.228	0.490	0.283	0.000	0.186	0.434	0.314	0.066	0.000	0.186	0.434	0.314	0.066	0.000	0.214	0.465	0.287	0.035
SO-5	0.000	0.000	0.166	0.458	0.376	0.000	0.062	0.314	0.436	0.187	0.000	0.103	0.352	0.395	0.150	0.000	0.062	0.314	0.436	0.187
SO-6	0.000	0.000	0.228	0.490	0.283	0.000	0.220	0.470	0.278	0.032	0.147	0.398	0.353	0.102	0.000	0.104	0.353	0.396	0.147	0.000

4.3 Aggregation of Competitive Priorities through ERA

The evidential reasoning algorithm is used to aggregate belief degrees of CSFs for all competitive priorities and hence to get a combined belief degree. The normalized belief degrees of all CSFs for each competitive priority are aggregated by using the ERA algorithm. For this purpose, IDS software (Yang and Xu, 1999) is utilized to compute competitive performance score (CPS) value for CSFs, and the computed outcomes are represented in Table 9. Moreover, to understand the aggregation part of ERA, a sample calculation for aggregation of belief degree for ‘personnel training’ (EC-2) is provided in Appendix-I.

4.4 Use of Expected Utility Theory

For assessing the performance of a system, it becomes more pragmatic to evaluate the considered factors on the basis of a crisp value. Thus, the concepts of expected utility are utilized to get a numerical value (i.e., CPS) for all CSFs of SFT. The CPS value of a CSF represents its priority level for achieving better competitive performance by an SFT system. The utility value for each assessment grade and CPS value for all CSFs is computed by using Equations (22) – (25).

Table 8 depicts that ‘EC-1’ obtains an overall CPS value of 0.7841. This value shows the experts’ evaluation for ‘EC-1’ when assessed on the basis of competitive priorities. ‘EC-1’ can be classified as a ‘significant’ CSF, which facilitates to achieve higher competitive performance. Further, by using the expected utility theorem, the crisp value of aggregated belief degrees for each CSF is calculated to get the CPS for all CSFs. Table 9 depicts the CPS value and rank of all CSFs. From Figure 3, it is evident that 8 CSFs are considered as significant (represented by blue color); 18 CSFs are considered as moderately significant (represented by yellow color), and the remaining 8 CSFs are considered as slightly significant (represented by green color).

Table 8 Sample Calculation for CPS Value of EC-1

G_n	VL	L	M	H	VH
V_n	1	2	3	4	5
$u(G_n)$	$\frac{1-1}{5-1} = 0$	$\frac{2-1}{5-1} = 0.25$	$\frac{3-1}{5-1} = 0.5$	$\frac{4-1}{5-1} = 0.75$	$\frac{5-1}{5-1} = 1$
β_n	0	0.0131	0.1804	0.4638	0.3428
$\sum_{n=1}^5 \beta_n = 0 + 0.0131 + 0.1804 + 0.4638 + 0.3428 = 1 \rightarrow \beta_H = 0$					
$u(G_n) \times \beta_n$	0	0.00327	0.0902	0.3478	0.3428
$\sum_{n=1}^5 u(G_n) \times \beta_n = \text{CPS}_{\text{EC-1}} = \mathbf{0.7841}$					

Table 9 Competitive Performance Score of All CSFs

CSF	Aggregated normalized belief degree for competitive priorities					Competitive Performance Score (CPS)	Rank	Classification
	VL	L	M	H	VH			
EC-1	0.000	0.013	0.180	0.464	0.343	0.784	5	Significant
EC-2	0.000	0.000	0.119	0.447	0.434	0.829	2	Significant
EC-3	0.051	0.232	0.388	0.258	0.070	0.516	25	Moderately significant
EC-4	0.000	0.060	0.304	0.447	0.188	0.691	14	Moderately significant
EC-5	0.000	0.037	0.274	0.478	0.212	0.716	12	Moderately significant
EN-1	0.189	0.401	0.264	0.104	0.042	0.352	29	Slightly significant
EN-2	0.237	0.416	0.245	0.078	0.024	0.309	33	Slightly significant
EN-3	0.166	0.413	0.314	0.093	0.014	0.344	30	Slightly significant
EN-4	0.207	0.390	0.229	0.110	0.063	0.358	28	Slightly significant
EN-5	0.212	0.425	0.261	0.078	0.023	0.319	32	Slightly significant
EN-6	0.255	0.489	0.234	0.022	0.000	0.255	34	Slightly significant
EN-7	0.044	0.233	0.388	0.251	0.083	0.524	24	Moderately significant
EF-1	0.000	0.096	0.359	0.406	0.140	0.647	18	Moderately significant
EF-2	0.000	0.022	0.198	0.460	0.319	0.769	7	Significant
EF-3	0.032	0.173	0.369	0.322	0.105	0.573	22	Moderately significant
EF-4	0.000	0.013	0.168	0.459	0.360	0.791	4	Significant
EF-5	0.000	0.141	0.421	0.351	0.088	0.597	20	Moderately significant
EF-6	0.000	0.033	0.236	0.460	0.271	0.742	10	Moderately significant
EM-1	0.000	0.070	0.323	0.439	0.168	0.676	17	Moderately significant
EM-2	0.000	0.057	0.314	0.456	0.174	0.687	15	Moderately significant
EM-3	0.000	0.047	0.232	0.434	0.287	0.740	11	Moderately significant
EM-4	0.000	0.006	0.114	0.424	0.456	0.833	1	Significant
EM-5	0.000	0.013	0.196	0.480	0.311	0.772	6	Significant
SA-1	0.006	0.084	0.289	0.404	0.218	0.686	16	Moderately significant
SA-2	0.014	0.159	0.400	0.333	0.095	0.584	21	Moderately significant
SA-3	0.000	0.045	0.195	0.407	0.353	0.767	8	Significant
SA-4	0.000	0.037	0.224	0.446	0.293	0.749	9	Moderately significant
SA-5	0.000	0.013	0.150	0.438	0.399	0.806	3	Significant
SO-1	0.032	0.210	0.416	0.280	0.063	0.533	23	Moderately significant
SO-2	0.176	0.437	0.318	0.070	0.000	0.320	31	Slightly significant
SO-3	0.047	0.285	0.457	0.198	0.014	0.462	27	Slightly significant
SO-4	0.000	0.135	0.406	0.359	0.101	0.606	19	Moderately significant
SO-5	0.000	0.050	0.281	0.455	0.214	0.708	13	Moderately significant
SO-6	0.057	0.239	0.382	0.252	0.070	0.510	26	Moderately significant

Figure 3 Competitive Performance Order of CSFs of SFT

4.5 CPS Calculation for Each Category of SFT

After obtaining an aggregated normalized belief degree of competitive priorities for all CSFs, similar calculations are performed using Equations (13) – (20) to get a normalized belief degree for the six dimensions of SFT by aggregating normalized belief degree of all CSFs under each sustainability dimension. Table 10 depicts the normalized belief degree and classification of six dimensions of SFT based on CPS.

Table 10 CPS Calculation for Six Dimensions of SFT

Sustainability Factors/ Dimensions	Aggregated normalized belief degree of competitive priorities					Competitive Performance Score	Rank	Classification
	VL	L	M	H	VH			
EC	0.009	0.060	0.246	0.444	0.241	0.712	3	Moderately significant
EN	0.178	0.418	0.276	0.096	0.032	0.346	6	Slightly significant
EF	0.005	0.071	0.289	0.432	0.203	0.690	4	Moderately significant
EM	0.000	0.033	0.224	0.473	0.270	0.745	1	Significant
SA	0.003	0.060	0.244	0.427	0.266	0.723	2	Moderately significant
SO	0.046	0.220	0.398	0.267	0.069	0.523	5	Moderately significant

From Table 10, it is evident that ‘employing advanced technology dimension’ (EM) is the most significant dimension with 0.745 CPS value. ‘Safety dimension’ (SA), ‘economic dimension’ (EC), ‘efficiency dimension’ (EF), ‘social dimension’ (SO), and ‘environmental dimension’ (EN) attain the second, third, fourth, fifth, and sixth position, respectively, with 0.723, 0.712, 0.69, 0.523, and 0.346 CPS value. The CPS value depicts the experts’ assessment of sustainability factors based on competitive priorities for FT systems. The outcomes from Table 9 represent that CPS value for all CSFs is more than 0.24, and thus, no CSF falls in the class of ‘not significant at all’ category. This study assists decision-makers in carrying out performance analysis for SFT based on competitive priorities and identify the key CSFs and dimensions of SFT for improving competitive performance. The considered procedure in this study depicts a viable approach for performance analysis of SFT systems on the basis of competitive priorities when objective or statistical data is not available.

5 SENSITIVITY ANALYSIS

The sensitivity analysis is carried out by employing the three axioms discussed in Section 3.4.4. These axioms facilitate to identify the most significant CSFs and sustainability dimensions that lead to a better competitive performance by an SFT system. To perform the sensitivity analysis, belief degrees related to the most preferred assessment term of the lowest level criteria (i.e., competitive priorities) are decreased by α , and then CPS values are computed for each CSF. It is significant to highlight that when lessening the belief degree, β_n , of the most preferred assessment term of a criterion by α , if $\alpha > \beta_n$, the residual belief degree (i.e., $\alpha - \beta_n$) is reduced from the belief degree of the next assessment term until α is completely exhausted (John et al., 2014).

The computed utility values (i.e., CPS values) after carrying out different experiments (i.e., lessening the belief degrees of the most favored assessment term (by 10%, 20%, and 30%, respectively) of all competitive priorities) are depicted in Table 11. The sensitivity of the obtained results for all CSFs is explicated in Table 11. These outcomes completely satisfy Axioms 1 and 2 (as discussed in Section 3.4.4).

Table 11 Sensitivity Analysis by Changing Belief Degrees

	DQ				IN				CO				FL			
	0%	10%	20%	30%	0%	10%	20%	30%	0%	10%	20%	30%	0%	10%	20%	30%
EC-1	0.687	0.613	0.541	0.491	0.764	0.714	0.664	0.618	0.888	0.838	0.788	0.738	0.788	0.738	0.688	0.638
EC-2	0.828	0.778	0.728	0.678	0.802	0.753	0.703	0.653	0.853	0.803	0.753	0.703	0.803	0.753	0.703	0.653
EC-3	0.419	0.344	0.277	0.227	0.353	0.278	0.227	0.177	0.76	0.71	0.66	0.61	0.53	0.47	0.42	0.37
EC-4	0.780	0.730	0.680	0.630	0.687	0.613	0.541	0.491	0.72	0.64	0.57	0.51	0.56	0.49	0.44	0.39
EC-5	0.764	0.714	0.664	0.618	0.764	0.714	0.664	0.618	0.72	0.64	0.57	0.51	0.60	0.53	0.48	0.43
EN-1	0.237	0.187	0.137	0.105	0.687	0.613	0.541	0.491	0.27	0.22	0.17	0.12	0.23	0.18	0.13	0.10
EN-2	0.199	0.149	0.107	0.082	0.606	0.531	0.480	0.43	0.23	0.18	0.13	0.10	0.22	0.17	0.12	0.09
EN-3	0.353	0.278	0.227	0.177	0.565	0.499	0.449	0.39	0.23	0.18	0.13	0.10	0.23	0.18	0.13	0.10
EN-4	0.237	0.187	0.137	0.105	0.764	0.714	0.664	0.618	0.23	0.18	0.13	0.10	0.23	0.18	0.13	0.10
EN-5	0.237	0.187	0.137	0.105	0.606	0.531	0.480	0.43	0.23	0.18	0.13	0.10	0.22	0.17	0.12	0.09
EN-6	0.221	0.171	0.121	0.095	0.353	0.278	0.227	0.177	0.22	0.17	0.12	0.09	0.23	0.18	0.13	0.10
EN-7	0.436	0.361	0.289	0.239	0.802	0.753	0.703	0.653	0.47	0.39	0.32	0.26	0.39	0.32	0.26	0.21
EF-1	0.531	0.473	0.423	0.373	0.764	0.714	0.664	0.618	0.68	0.61	0.54	0.49	0.60	0.53	0.48	0.43
EF-2	0.888	0.838	0.788	0.738	0.780	0.730	0.680	0.63	0.72	0.64	0.57	0.51	0.66	0.59	0.52	0.47
EF-3	0.565	0.499	0.449	0.399	0.764	0.714	0.664	0.618	0.35	0.27	0.22	0.17	0.60	0.53	0.48	0.43
EF-4	0.802	0.753	0.703	0.653	0.828	0.778	0.728	0.678	0.68	0.61	0.54	0.49	0.82	0.77	0.72	0.67
EF-5	0.723	0.649	0.574	0.517	0.606	0.531	0.480	0.43	0.53	0.47	0.42	0.37	0.53	0.47	0.42	0.37
EF-6	0.687	0.613	0.541	0.491	0.723	0.649	0.574	0.517	0.68	0.61	0.54	0.49	0.85	0.80	0.75	0.70
EM-1	0.764	0.714	0.664	0.618	0.648	0.573	0.511	0.46	0.56	0.49	0.44	0.39	0.72	0.64	0.57	0.51
EM-2	0.723	0.649	0.574	0.517	0.687	0.613	0.541	0.49	0.60	0.53	0.48	0.43	0.72	0.64	0.57	0.51
EM-3	0.780	0.730	0.680	0.630	0.828	0.778	0.728	0.678	0.53	0.47	0.42	0.37	0.80	0.75	0.70	0.65
EM-4	0.859	0.809	0.759	0.709	0.859	0.809	0.759	0.709	0.72	0.64	0.57	0.51	0.85	0.80	0.75	0.70
EM-5	0.780	0.730	0.680	0.630	0.780	0.730	0.680	0.63	0.68	0.61	0.54	0.49	0.82	0.77	0.72	0.67
SA-1	0.859	0.809	0.759	0.709	0.714	0.639	0.564	0.51	0.47	0.39	0.32	0.26	0.68	0.61	0.54	0.49
SA-2	0.764	0.714	0.664	0.618	0.531	0.473	0.423	0.37	0.43	0.36	0.28	0.23	0.60	0.53	0.48	0.43
SA-3	0.888	0.838	0.788	0.738	0.687	0.613	0.541	0.49	0.60	0.53	0.48	0.43	0.85	0.80	0.75	0.70
SA-4	0.888	0.838	0.788	0.738	0.723	0.649	0.574	0.51	0.60	0.53	0.48	0.43	0.76	0.71	0.66	0.61
SA-5	0.888	0.838	0.788	0.738	0.764	0.714	0.664	0.618	0.68	0.61	0.54	0.49	0.85	0.80	0.75	0.70
SO-1	0.565	0.499	0.449	0.399	0.565	0.499	0.449	0.39	0.35	0.27	0.22	0.17	0.64	0.57	0.51	0.46
SO-2	0.221	0.171	0.121	0.095	0.353	0.278	0.227	0.177	0.27	0.22	0.17	0.12	0.43	0.36	0.28	0.23
SO-3	0.531	0.473	0.423	0.373	0.531	0.473	0.423	0.37	0.31	0.24	0.19	0.14	0.47	0.39	0.32	0.26
SO-4	0.764	0.714	0.664	0.618	0.565	0.499	0.449	0.39	0.56	0.49	0.44	0.39	0.53	0.47	0.42	0.37
SO-5	0.802	0.753	0.703	0.653	0.687	0.613	0.541	0.49	0.64	0.57	0.51	0.46	0.68	0.61	0.54	0.49
SO-6	0.764	0.714	0.664	0.618	0.531	0.473	0.423	0.37	0.35	0.27	0.22	0.17	0.39	0.32	0.26	0.21

Subsequently, we investigate the impact of the variations in belief degree of the lowest-level criteria (i.e., all competitive priorities) on the CPS value of six dimensions of SFT. The changes represent several combinations of the lowest-level criteria. Table 12 illustrates 16 distinct combinations of variation in the lowest level criteria (i.e., competitive priorities) and their impact on the CPS value of six dimensions of SFT. According to *Axiom 3*, if the model represents robustness, rationality, and reality, the CPS value of the six dimensions of SFT related to x criteria (i.e., evidence) should be lesser than the one from x - y ($y \in x$) criteria (i.e., sub-evidence). This requirement is analyzed by examining the CPS values of the six dimensions of SFT, as depicted in Table 12. For instance, we take Row 13 as evidence to examine the robustness of the proposed model. Then, Rows 2, 3, 4, 7, 10, and 11 can be considered as the sub-evidence. Comparing the relevant CPS values of the six dimensions of SFT (e.g., CPS value of ‘EC’ in Row 13 is 0.665, that is lesser than 0.681, the one in Row 11), it is apparent that for Row 13, the proposed model is confirmed to be robust. Likewise, each row of Table 12 is examined carefully, and the outcomes of the proposed model are in harmony with *Axiom 3*.

Table 12 Sensitivity Analysis by Changing Belief Degree of Lowest Level Criteria

	DQ	IN	CO	FL	Competitive Priority Score					
					EC	EN	EF	EM	SA	SO
1	0	0	0	0	0.712	0.346	0.690	0.745	0.723	0.523
2	1	0	0	0	0.696	0.330	0.674	0.730	0.708	0.511
3	0	1	0	0	0.696	0.332	0.674	0.729	0.706	0.507
4	0	0	1	0	0.696	0.331	0.672	0.729	0.705	0.507
5	0	0	0	1	0.696	0.331	0.673	0.729	0.706	0.506
6	0	1	0	1	0.681	0.317	0.658	0.713	0.689	0.489
7	0	1	1	0	0.681	0.317	0.657	0.713	0.688	0.490
8	0	1	1	1	0.665	0.301	0.641	0.697	0.671	0.471
9	0	0	1	1	0.681	0.315	0.656	0.713	0.689	0.489
10	1	1	0	0	0.681	0.316	0.658	0.714	0.691	0.493
11	1	0	1	0	0.681	0.314	0.656	0.714	0.691	0.493
12	1	0	0	1	0.681	0.315	0.657	0.714	0.692	0.493
13	1	1	1	0	0.665	0.301	0.641	0.698	0.673	0.477
14	1	1	0	1	0.665	0.301	0.642	0.699	0.675	0.475
15	1	0	1	1	0.665	0.298	0.639	0.698	0.674	0.476
16	1	1	1	1	0.650	0.285	0.625	0.683	0.657	0.459

Note: “1” means that a 10% belief degree is redistributed (i.e., from the most favored assessment term to the least favored assessment term) for each competitive priority

Afterward, to graphically show the results of sensitivity analysis, the aggregated normalized belief degree of competitive priorities is computed for all CSFs by aggregating normalized belief degree of individual competitive priority using ERA. Then, this aggregated normalized belief degree for competitive priorities (as represented in Table 9) is varied by 10%, 20%, and 30%. The sensitivity of the obtained results for all CSFs is graphically presented in Figure 4. From Table 11 and Table 12, it is evident that the proposed model completely satisfies all three axioms of sensitivity analysis (John et al., 2014; Wan et al., 2019; Yang et al., 2009).

Figure 4 Sensitivity of CPS Value to the Variation in Aggregated Normalized Belief Degrees of Competitive Priorities

6 EFFECT OF VARIATIONS IN THE WEIGHT OF COMPETITIVE PRIORITIES

This paper also analyzes the effect of variations in the weight of competitive priorities to bring out the key sustainability dimensions that lead to attaining higher competitive advantage for different weight allocation scenarios. While calculating the aggregated normalized belief degrees for all CSFs, it is considered that the significance of each competitive priority for the performance assessment is the same. Therefore, equal weight was allotted to them. Ramani et al. (2011) signify that, in an MCDM problem, weight distribution has always been challenging as weight allocation usually affects outcomes. Therefore, to examine the effect of variations in the weight of each competitive priority on the CPS value of six dimensions of SFT, we vary weight on a scale of 0 to 1 (with an interval of 0.2) and repeat the entire analysis for different weights. When a particular value of weight is assigned to a competitive priority, the other three competitive priorities will have equal normalized weight. For instance, If

‘delivery of quality services’ (DQ) is allotted a weight of 0.4, the other three competitive priorities (i.e., ‘innovation’ (IN), ‘cost’ (CO), and ‘flexibility’ (FL)) will have an equal normalized weight of 0.2. The effect of variation in weight of each competitive priority (i.e., DQ, IN, CO, and FL) on the CPS value of six dimensions of SFT is depicted in Table 13.

Table 13 Categorization of Six Dimensions of SFT Based on the Variation in Weights of Each Competitive Priority

Dimensions of SFT	Original CPS	CPS values due to the variations in the weight of																							
		DQ						IN						CO						FL					
		0	0.2	0.4	0.6	0.8	1	0	0.2	0.4	0.6	0.8	1	0	0.2	0.4	0.6	0.8	1	0	0.2	0.4	0.6	0.8	1
EC	0.712	0.715	0.712	0.710	0.706	0.703	0.701	0.722	0.714	0.704	0.692	0.684	0.681	0.682	0.704	0.736	0.768	0.789	0.796	0.729	0.716	0.698	0.678	0.664	0.658
EN	0.346	0.374	0.353	0.324	0.295	0.278	0.271	0.264	0.324	0.424	0.533	0.605	0.629	0.374	0.353	0.323	0.295	0.278	0.272	0.381	0.354	0.318	0.283	0.261	0.253
EF	0.69	0.685	0.689	0.694	0.699	0.701	0.702	0.669	0.685	0.706	0.728	0.742	0.747	0.714	0.696	0.669	0.642	0.622	0.614	0.690	0.690	0.689	0.688	0.686	0.685
EM	0.745	0.730	0.741	0.757	0.772	0.781	0.784	0.736	0.743	0.751	0.759	0.764	0.765	0.784	0.755	0.712	0.667	0.635	0.622	0.727	0.741	0.759	0.776	0.788	0.792
SA	0.723	0.671	0.710	0.766	0.819	0.853	0.866	0.736	0.726	0.713	0.700	0.690	0.686	0.775	0.736	0.678	0.618	0.578	0.561	0.708	0.720	0.734	0.748	0.757	0.760
SO	0.523	0.495	0.516	0.548	0.582	0.605	0.613	0.518	0.522	0.528	0.533	0.537	0.539	0.559	0.532	0.494	0.454	0.426	0.416	0.522	0.523	0.525	0.527	0.528	0.529

As some organizations give more emphasis to ‘DQ’ while others consider ‘IN’ or ‘CO’ or ‘FL’ more important, the weight of a competitive priority primarily depends on the considered organization and its business strategy. Therefore, the above-detailed analysis (i.e., changing weights of competitive priority on a scale of 0 to 1 (with an interval of 0.2)) presents a well-structured way to handle such situations and elucidates the following findings.

6.1 Variations in the Weight of ‘Delivery of Quality Services’ (DQ)

Figure 5 delineates the effect of variations in the weight of DQ on the CPS value of six dimensions of SFT. As the weight of DQ increases, the CPS value of ‘EM’, ‘SA’, and ‘SO’ significantly increases, while the CPS value of ‘EN’ significantly reduces. Alternatively, the CPS value of ‘EC’ and ‘EF’ slightly varies (i.e., ‘EC’ slightly decreases and ‘EF’ slightly increases) with an increase in the weight of DQ. The outcomes of this analysis reveal that organizations, whose business strategy is to give more weightage to DQ as compared to the other three competitive priorities, will eventually have ‘SA’ and ‘EM’ as the two most important dimensions of SFT with higher CPS and ‘EN’ with the least CPS value.

Figure 5 Variations in the Weight of DQ

6.2 Variations in the Weight of ‘Innovation’ (IN)

Figure 6 delineates the effect of variations in the weight of IN on the CPS value of six dimensions of SFT. As the weight of IN increases, the CPS value of ‘EN’, ‘EF’, and ‘EM’ significantly increases, while the CPS value of ‘EC’ and ‘SA’ significantly reduces. On the other hand, the CPS value of ‘SO’ slightly increases with an increase in the weight of IN. The outcomes of this analysis reveal that organizations, whose business strategy is to give more weightage to IN as compared to the other three

competitive priorities, will eventually have ‘EM’ and ‘EF’ as the two most important dimensions of SFT with higher CPS and ‘SO’ with the least CPS value.

Figure 6 Variations in the Weight of Innovation

6.3 Variations in the Weight of ‘Cost’ (CO)

Figure 7 delineates the effect of variations in the weight of cost on the CPS value of six dimensions of SFT. As the weight of ‘cost’ rises, the CPS value of ‘EC’ significantly increases, while the CPS value of ‘EM’, ‘EF’, ‘SA’, ‘SO’, and ‘EN’ significantly reduces. The outcomes of this analysis reveal that organizations, whose business strategy is to give more weightage to cost as compared to the other three competitive priorities, will eventually have ‘EC’ and ‘EM’ as the two most important dimensions of SFT with higher CPS and ‘EN’ with the least CPS value.

Figure 7 Variations in the Weight of Cost

6.4 Variations in the Weight of 'Flexibility' (FL)

Figure 8 delineates the effect of variations in the weight of flexibility on the CPS value of six dimensions of SFT. As the weight of 'flexibility' increases, the CPS value of 'EM' and 'SA' significantly increases, while the CPS value of 'EC' and 'EN' significantly reduces. On the other hand, the CPS value of 'EF' and 'SO' slightly varies (i.e., 'EF' slightly decreases and 'SO' slightly increases) with an increase in the weight of flexibility. The outcomes of this analysis reveal that organizations, whose business strategy is to give more weightage to flexibility as compared to the other three competitive priorities, will eventually have 'EM' and 'SA' as the two most important dimensions of SFT with higher CPS and 'EN' with the least CPS value.

Figure 8 Variations in the Weight of Flexibility

7 RESULTS AND DISCUSSION

This research aims to assess the sustainability performance of freight transportation systems on the basis of competitive priorities. The outcomes of this study reveal that 'employing advanced technology dimension' (EM) is the most significant sustainability dimension with the highest competitive performance score (CPS) value. 'Safety dimension' (SA) and 'economic dimension' (EC) attain the second and third positions, respectively. Earlier studies have also signified that the implementation of advanced technologies (e.g., ITS, EDI) facilitates in enhancing the sustainability performance of FT (Mondragon et al., 2017; Shankar et al., 2019; Zhao et al., 2020). The four most significant CSFs influencing the competitive performance of SFT are 'intelligent transportation system (ITS)' (EM-4),

‘personnel training’ (EC-2), ‘adoption of safety standards’ (SA-5), and ‘efficient transport operations’ (EF-4). Their CPS value is 0.833, 0.829, 0.806, and 0.791, respectively.

The outcomes of this study reveal (as depicted in Table 9) that none of the CSFs come under the category of ‘not significant at all’. Therefore, all the identified CSFs of SFT are essential while assessing the overall competitive performance of an SFT system. As depicted in Figure 3, it is evident that eight CSFs (represented by blue color) are significant that achieve higher CPS value. These CSFs in the descending order of their CPS value are as follows: ‘intelligent transportation system’ (EM-4), ‘personnel training’ (EC-2), ‘adoption of safety standards’ (SA-5), ‘efficient transport operations’ (EF-4), ‘operating cost’ (EC-1), ‘top management support for ICT usage’ (EM-5), ‘quality management’ (EF-2), and ‘cargo security’ (SA-3). As six CSFs out of eight significant CSFs are from the three emerging sustainability factors (i.e., EM, EF, and SA), this finding ascertains the significance of three emerging sustainability dimensions in achieving higher competitive performance by a freight transport system. This outcome also corroborates an earlier study (Pathak et al., 2019), which brings out the significance of these three emerging sustainability factors in the performance assessment of SFT systems.

The next 18 CSFS (represented by yellow color) are of a moderately significant category that also requires attention for achieving a higher competitive advantage. These CSFs include ‘SA-4’, ‘EF-6’, ‘EM-3’, ‘EC-5’, ‘SO-5’, ‘EC-4’, ‘EM-2’, ‘SA-1’, ‘EM-1’, ‘EF-1’, ‘SO-4’, ‘EF-5’, ‘SA-2’, ‘EF-3’, ‘SO-1’, ‘EN-7’, ‘EC-3’, and ‘SO-6’ in the descending order of their CPS value. The remaining eight CSFs (represented by green color), i.e., ‘SO-3’, ‘EN-4’, ‘EN-1’, ‘EN-3’, ‘SO-2’, ‘EN-5’, ‘EN-2’, and ‘EN-6’ are categorized as slightly significant due to their lower CPS value.

The outcomes of sensitivity analysis reveal that the utilization of axioms assists in pinpointing the key sustainability CSFs that significantly affect the competitive performance of a freight operator (i.e., LSPs, carriers) and to enhance its robustness in the hypercompetitive marketplace. As all three axioms of sensitivity analysis are completely satisfied (John et al., 2014; Wan et al., 2019; Yang et al., 2009), it exhibits the robustness of the developed FERA-based performance assessment framework for SFT systems based on competitive priorities. Figure 4 graphically represents the results of sensitivity analysis for all CSFs and it is outlined in such a way that the variation (i.e., the difference between original CPS value and CPS value when aggregated normalized belief degree is reduced by 30%) decreases while moving from left hand side to the right hand side (i.e., from ‘accident rate’ (SA-1) to ‘visual intrusion’ (EN-6)). Therefore, it is clear from Figure 4 that the maximum variations occur in the CPS value of ‘accident rate’ (SA-1), ‘drivers’ efficiency’ (EF-3), and ‘injury severity level’ (SA-2). It denotes that

the proposed model is more sensitive to ‘accident rate’ (SA-1), ‘drivers’ efficiency’ (EF-3), and ‘injury severity level’ (SA-2) than to the other CSFs. The outcome of the sensitivity analysis further confirms the significance of ‘safety’ and ‘efficiency’ sustainability dimensions in the freight transport sector for achieving better competitive performance. Wang (2019) brings out the significance of the safety dimension in assessing road transport sustainability. Furthermore, due to the higher sensitivity, ‘complying with government regulations for green practices implementation’ (EN-7), ‘loading factor’ (EC-3), ‘drivers’ healthcare’ (SO-6), and ‘traffic clogging’ (SO-1) are the critical CSFs affecting the overall competitive performance.

While performing the changing weight analysis, in the base model (i.e., when all competitive priorities are given equal importance), ‘employing advanced technology dimension’ (EM) achieves the highest CPS, and ‘environmental dimension’ (EN) attains the lowest CPS (refer to Table 13). The outcomes of different weight allocation scenarios reveal that ‘EM’, ‘SA’, and ‘EC’ factors of sustainability achieve higher CPS value whereas ‘EN’ and ‘SO’ achieve lower CPS value. Therefore, we can deduce that these factors (i.e., ‘EM’, ‘SA’, and ‘EC’) and their respective CSFs are the key elements that lead to attain higher competitive advantage. The top management should focus on these CSFs on a higher priority basis to remain competitive in the hypercompetitive market place. These findings, along with the outcomes of sensitivity analysis, depict the robustness of the developed model and signify that the variations in the weight of competitive priorities will not invalidate the findings of the developed framework. In sum, this research contributes to the literature on SFT as the existing studies significantly lack to analyze the sustainability performance of freight transport based on competitive priorities (Galeazzo and Klassen, 2015; Lin and Tseng, 2016). The exploration of the interaction between sustainability performance and competitive priorities has significant implications for logistics professionals in decision-making as well as performance management literature (e.g., Laari et al., 2018).

8 CONCLUSION AND SCOPE FOR FUTURE WORK

This study proposes a comprehensive performance assessment framework (PAF) based on competitive priorities for SFT systems by utilizing an integrated approach consisting of fuzzy group decision-making (FGDM), fuzzy evidential reasoning algorithm (FERA), and expected utility theory. As discussed, FERA utilizes the concepts of FST and ERA. This framework assesses the identified (i.e., 34) CSFs that influence the performance of SFT based on competitive priorities. These CSFs are categorized into six sustainability dimensions (i.e., ‘economic’ (EC), ‘environmental’ (EN), ‘employing advanced technology’ (EM), ‘efficiency’ (EF), ‘safety’ (SA), and ‘social’ (SO)). Further,

‘delivery of quality services’ (DQ), ‘innovation’ (IN), ‘cost’ (CO), and ‘flexibility’ (FL) are considered as the key competitive priorities for the transportation sector. This study also demonstrates the use of an improved and efficient methodology proposed by Chen (1998) for aggregation of fuzzy opinions. A case example of the FT sector in India is considered to exhibit the appositeness of the developed framework. The proposed competitive performance score (CPS) based PAF for SFT systems assists in managing the uncertainties involved in the decision-making. Eventually, this research also analyzes the effect of variations in the weight of each competitive priorities on the CPS value of six dimensions of SFT. The proposed model is a significant step forward for an organization to emphasize sustainability factors for improving its competitive performance.

This study has significant implications for both logistics professionals and researchers. The outcomes of the proposed model highlight the importance of each sustainability CSF in attaining better competitive performance by freight operators. This study highlights the four key competitive priorities of the transport sector (i.e., ‘DQ’, ‘IN’, ‘CO’, and ‘FL’) and signifies the importance of sustainability as well as competitive priorities while assessing the performance of an FT system. Presently, this knowledge has become essential for logistics professionals and decision-makers to develop the required strategies that encompass sustainability and will lead to improving the competitive performance of an FT system. This study also appraises logistics professionals about the key sustainability dimensions (i.e., ‘EM’, ‘SA’, and ‘EC’) that lead to attain higher competitive advantage under different weight allocation scenarios.

The novelty of this research lies in developing a framework for sustainability performance assessment based on competitive priorities under uncertainties, identifying key CSFs that are crucial to improve competitive performance, and proposing a CPS-based PAF for SFT systems. The CPS value acts as an objective tool for evaluating the competitive performance of an SFT system. This CPS-based PAF facilitates logistics professionals to pinpoint the most and least significant CSFs that affect the overall competitive performance. Furthermore, the methodological facets elucidated in this research have significant insinuations for researchers as well as practitioners. There are some limitations of the proposed framework. First, this research develops a comprehensive PAF to assess the sustainability performance of freight operators (i.e., LSPs and carriers) involved in rail-based and road-based multi-modal FT. Second, the findings of this research cannot be directly utilized for temperature-controlled transportation that includes the shipping of perishable goods. Moreover, as the transport sector faces environmental regulations that vary from one country to another, the generalization of the findings to

the logistics sector in other countries very different from India should be undertaken with caution. As scope for future research, the impact of considering more experts on the aggregated outcomes can be examined. Future studies may perform this analysis for an individual freight operator, and its overall sustainability CPS value can be calculated by aggregating normalized belief degrees for six dimensions of sustainability. In this research, we have consulted experts associated with the Indian transport and logistics sector. Future research can be done for developed countries, and a comparison analysis can also be performed. The obtained results and suggested methodology can be further extended and adapted by the top management of an organization according to its specific characteristics.

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Appendix-I

Sample Calculation representing Aggregation part of ERA

We represent the computation for aggregation of belief degree for ‘personnel training’ (EC-2) on the basis of four competitive priorities (please refer to Table 7).

	VL	L	M	H	VH
DQ	0.000	0.000	0.128	0.433	0.439
IN	0.000	0.000	0.166	0.458	0.376
CO	0.000	0.000	0.082	0.400	0.518
FL	0.000	0.000	0.166	0.458	0.376

As these four attributes are assigned equal weightage, from Equation (9) $L=4$, and $\theta_1 = \theta_2 = \theta_3 = \theta_4 = 0.25$. Basis probability mass and residual probability mass are computed by using Equation (13) and (14a).

	$p_{n,i}$					$\tilde{p}_{H,i}$	$\tilde{p}_{H,i}$
DQ	0	0	0.032	0.1083	0.1098	0.75	0
IN	0	0	0.0415	0.1145	0.094	0.75	0
CO	0	0	0.0205	0.10	0.1295	0.75	0
FL	0	0	0.0415	0.1145	0.094	0.75	0

Using Equations (15) - (17), we compute the combined probability masses as follows. First, we aggregate *Delivery of quality services (DQ)* and *Innovation (IN)*.

$$NF_{I2} = [1 - (0 + \dots + 0 + 0.032 \times 0.1145 + 0.032 \times 0.094 + 0 + 0 + 0.1083 \times 0.094 + 0.1083 \times 0.0415 + 0 + 0 + 0.1098 \times 0.1145 + 0.1098 \times 0.0415)]^{-1} = 1.04$$

And aggregated probability masses values are as follows

$$p_{3,I2} = 1.04 \times [(0.032 \times 0.0415) + (0.0415 \times (0.75 + 0)) + (0.032 \times (0.75 + 0))] = 0.05871 \quad (\text{similarly, other values are calculated})$$

$p_{n,I2}$					$\tilde{p}_{H,I2}$	$\tilde{p}_{H,I2}$
0	0	0.0587	0.1866	0.1697	0.585	0

Now, we combine the above results for *Delivery of quality services (DQ)* and *Innovation (IN)* with *Cost (CO)*. $NF_{I3} = 1.066$

$p_{n,I3}$					$\tilde{p}_{H,I3}$	$\tilde{p}_{H,I3}$
0	0	0.061	0.2315	0.2398	0.4677	0

Now, we combine the above results for *Delivery of quality services (DQ)*, *Innovation (IN)*, and *Cost (CO)* with *Flexibility (FL)*.

$$NF_{I4} = 1.0887$$

$p_{n,l\ 4}$					$\bar{p}_{H,l\ 4}$	$\tilde{p}_{H,l\ 4}$
0	0	0.0737	0.2762	0.2682	0.3819	0

Further, by using Equations (18) and (19), aggregated normalized belief degrees of EC2 for all competitive priorities are computed as follows.

$$\beta_3 = \frac{0.0737}{1 - 0.3819} = 0.119 \text{ (similarly, other values are calculated)}$$

β_1	β_2	β_3	β_4	β_5	β_H
0	0	0.119	0.447	0.434	0

These results are the same as reported in Table 9.

Appendix-II

LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
CO	Cost
CPS	Competitive Performance Score
CSF	Critical Success Factor
CSI	Composite Sustainability Index
DEA	Data Envelopment Analysis
DQ	Delivery of Quality Services
EC	Economic Dimension
EDI	Electronic Data Interchange
EF	Efficiency Dimension
EM	Employing Advanced Technology Dimension
EN	Environmental Dimension
ERA	Evidential Reasoning Algorithm
FAHP	Fuzzy Analytical Hierarchy Process
FERA	Fuzzy Evidential Reasoning Algorithm
FGDM	Fuzzy Group Decision Making
FL	Flexibility
FST	Fuzzy Set Theory
FT	Freight Transportation
GSCM	Green Supply Chain Management
GTC	Green Transport Corridor
ICT	Information and Communication Technology
IDS	Intelligent Decision System
IN	Innovation
ITS	Intelligent Transportation System
KPI	Key Performance Indicators
LSP	Logistics Service Provider
MCDM	Multi-criteria Decision Making
PAF	Performance Assessment Framework
PMS	Performance Measurement System
SA	Safety Dimension
SEM	Structural Equation Modeling
SFT	Sustainable Freight Transportation
SO	Social Dimension
SPI	Sustainability Performance Index
TFN	Triangular Fuzzy Number
TISM	Total Interpretive Structure Modeling
UFT	Urban Freight Transportation