

PERFORMANCE MANAGEMENT SYSTEM FOR SUSTAINABLE FREIGHT TRANSPORTATION

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PERFORMANCE MANAGEMENT SYSTEM FOR SUSTAINABLE FREIGHT TRANSPORTATION

by

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CERTIFICATE

This is to certify that the thesis entitled “**Performance Management System for Sustainable Freight Transportation System**” being submitted by **Vijayta Fulzele** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy** is a bonafide record of original research work carried out by her. She has worked under my supervision and has fulfilled the requirements for the submission of thesis, which has reached the requisite standard for Ph.D. degree of this institute. The results presented in this thesis have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

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ABSTRACT

Since the last one decade, the concept of sustainability is progressively gaining global attention as it not only improves environmental and social performances but also has positive impact on the overall profitability of the firm. The concept requires proportionate blending of the economic goals along with the environmental responsibility and societal equity. A major amount of responsibility lies with freight transportation sector. This is because transportation sector is a major source of greenhouse gas (GHG) emissions and energy consumption worldwide. Thus, there is a need to transform freight transportation policy towards a sustainable freight transportation paradigm. A sustainable freight transportation, generally, comprises of movement of goods with a broader perspective of improving operational and costs efficiencies while considering environmental and social impact of freight transportation process. However, the key challenge lies in reducing the negative externalities of freight transportation on environment and society.

One of the ways to integrate sustainability principles into freight transportation process is by developing performance management system. Such system sets the corporate goals, defines key metrics, periodically measures, evaluates, and analyzes firm's performance, and provides an opportunity of continuous improvement on the three dimensions of sustainability. Implementation of performance management system will ensure that decisions are well aligned with the sustainability principles. This is further supported by an adage "if there is no measurement, there will be no improvement". Since past many years, the researchers have witnessed immense growth in the performance measurement literature in the context of sustainable supply chain management area. However, issues related to sustainability performance for freight transportation system are often undermined in the literature. Currently, there are no well-accepted performance evaluation

system and broad range of performance metrics that can measure economic, environmental and social performances of the organization.

This research, thus, is carried out in three-phases to fill the above-mentioned gap in the literature. This study pre-dominantly addresses performance management issue in the sustainable freight transportation context. The first phase of this research is Exploratory Phase, which proposes a conceptual performance management system framework for sustainable freight transportation. A Soft-System Methodology has been adopted that accommodates holistic perspectives of various stakeholders while designing the framework. The proposed framework highlights the need of identifying key performance indicators, measuring the performance, and continuous improvement in the performance under each dimension of sustainability at the organizational level. The framework acted as a roadmap for the thesis with the aim to integrate sustainability in the freight operations through performance management system.

The second phase of the research is Performance Assessment phase. In this phase, a hybrid decision model has been used to present critical KPIs for Sustainable Freight Transportation (SFT). Initially, total ninety-nine were identified through an extensive literature review. These KPIs were classified into three dimensions of sustainability. Fuzzy Delphi Method (FDM) has been used to obtain a relevant list of KPIs for the freight industry from the identified ninety-nine KPIs. Next, KPIs were categorized into the driver, dependent, linkage and autonomous KPIs by identifying underlying relationships using Total Interpretive Structural Modeling (TISM). Finally, autonomous KPIs were removed from the lists and the remaining KPIs under each dimension were prioritized using Consensus Model (CM). KPIs identified in this phase could serve as reference indicators to establish an appropriate sustainable performance appraisal in the freight organization. Further, a performance index has been developed in this phase using the identified relevant key

performance indicators (KPIs). It essentially, measures the current sustainability health of the freight system and identifies weaknesses in different dimensions of the system. A Fuzzy Evidential Reasoning Algorithm (FERA) has been used to develop the performance index by aggregating subjective judgments with crisp quantitative values.

The third phase of the research is the Sustainability Adoption phase, which deals with improving the sustainability performance of freight transporters to remain competitive in the market. In this phase, best sustainability practices specific to freight transporters have been identified to enhance the organizational performance. An integrated approach by combining intuitionistic fuzzy number with graph theoretic and matrix approach have been used to prioritize the sustainability practices. In this study, it was found that top management commitment and multi-modal freight transportation have highest impact on the overall organizational performance. Therefore, a subsequent study was conducted to select best transportation mode, or a combination of modes based on various criteria to carry shipments from origin to destination. In this objective an integrated grey relational analysis based intuitionistic fuzzy multi-criteria decision-making process (GRA-IFP) and fuzzy multi-objective linear programming (FMOLP) model have been used. GRA-IFP has been applied first to assign weights to multiple criteria. These weights are further used in fuzzy multi-objective linear programming to finally select modes and estimate distances to be travelled by each mode. Three scenarios have been developed for analyzing sensitivity of decision variables with the variations in parameters under relevant conditions.

The research finally concludes with the summary and key findings derived from the research. The proposed performance management system framework can broadly guide freight transporters to measure, evaluate and monitor the performance. A standardized list of critical KPIs can help freight transporters to decipher their strengths and weaknesses. The complete process of

developing performance index facilitates freight transporters to evaluate their performances on each dimension of sustainability. The list of sustainability practices can help prioritizing the focus of freight transporters towards the sustainability practices that have higher impact on overall organizational performance. This research contributes to the area of sustainable freight transportation by providing a roadmap and quantitative models to freight transporters, thus, facilitating the integration of sustainability into freight operations through the performance management system.

सार

पिछले एक दशक से, स्थिरता की अवधारणा उत्तरोत्तर वैश्विक रूप से ध्यान आकर्षित कर रही है क्योंकि इससे न केवल पर्यावरण और सामाजिक प्रदर्शन में सुधार होता है, बल्कि इससे फर्म की समग्र लाभप्रदता पर भी सकारात्मक प्रभाव पड़ता है। इस अवधारणा के लिए पर्यावरणीय जिम्मेदारी और सामाजिक इकिटी के साथ-साथ आर्थिक लक्ष्यों का आनुपातिक सम्मिश्रण आवश्यक है। माल परिवहन क्षेत्र के साथ जिम्मेदारी की एक बड़ी राशि निहित है। ऐसा इसलिए है क्योंकि परिवहन क्षेत्र दुनिया भर में ग्रीनहाउस गैस (जीएचजी) उत्सर्जन और ऊर्जा खपत का एक प्रमुख स्रोत है। इस प्रकार, माल परिवहन नीति को एक स्थायी माल परिवहन प्रतिमान में बदलने की आवश्यकता है। एक टिकाऊ माल परिवहन, आम तौर पर माल के परिवहन के पर्यावरण और सामाजिक प्रभाव पर विचार करते हुए परिचालन और लागत क्षमता में सुधार के व्यापक दृष्टिकोण के साथ माल की आवाजाही शामिल है। हालांकि, प्रमुख चुनौती पर्यावरण और समाज पर माल परिवहन के नकारात्मक प्रभावों को कम करने में निहित है।

माल परिवहन प्रक्रिया में स्थिरता सिद्धांतों को एकीकृत करने के तरीकों में से एक प्रदर्शन प्रबंधन प्रणाली विकसित करना है। इस तरह की प्रणाली कॉर्पोरेट लक्ष्यों को निर्धारित करती है, प्रमुख मैट्रिक्स को परिभाषित करती है, समय-समय पर उपायों का मूल्यांकन करती है, और फर्म के प्रदर्शन का विश्लेषण करती है, और स्थिरता के तीन आयामों पर निरंतर सुधार का अवसर प्रदान करती है। प्रदर्शन प्रबंधन प्रणाली का कार्यान्वयन यह सुनिश्चित करेगा कि निर्णय स्थिरता सिद्धांतों के साथ अच्छी तरह से गठबंधन किए गए हैं। यह आगे एक कहावत द्वारा समर्थित है "अगर कोई माप नहीं है, तो कोई सुधार नहीं होगा"। पिछले कई वर्षों से, शोधकर्ताओं ने टिकाऊ आपूर्ति श्रृंखला प्रबंधन क्षेत्र के संदर्भ में प्रदर्शन माप साहित्य में भारी वृद्धि देखी है। हालांकि, माल परिवहन प्रणाली के लिए स्थिरता प्रदर्शन से संबंधित मुद्दों को अक्सर साहित्य में कम आंका जाता है। वर्तमान में, कोई अच्छी तरह से स्वीकार किए जाते हैं प्रदर्शन मूल्यांकन प्रणाली और प्रदर्शन मैट्रिक्स की व्यापक रेंज है जो संगठन के आर्थिक, पर्यावरण और सामाजिक प्रदर्शन को माप सकते हैं।

इस प्रकार, इस शोध को साहित्य में उपर्युक्त अंतर को भरने के लिए तीन चरणों में किया जाता है। यह अध्ययन पूर्व-माल ढुलाई के संदर्भ में प्रदर्शन प्रबंधन के मुद्दे को प्रमुखता से संबोधित करता है। इस शोध का पहला चरण एक्सप्लोरेटरी चरण है, जो टिकाऊ माल परिवहन के लिए एक वैचारिक प्रदर्शन प्रबंधन प्रणाली की रूपरेखा प्रस्तुत करता है। एक सॉफ्ट-सिस्टम मथोडोलॉजी को अपनाया गया है जो रूपरेखा तैयार करते समय विभिन्न हितधारकों के समग्र दृष्टिकोण को समायोजित करता है। प्रस्तावित रूपरेखा संगठनात्मक स्तर पर स्थिरता के प्रत्येक आयाम के तहत प्रदर्शन को मापने, प्रदर्शन को मापने और प्रदर्शन में निरंतर सुधार की

पहचान करने की आवश्यकता पर प्रकाश डालती है। प्रदर्शन प्रबंधन प्रणाली के माध्यम से माल ढुलाई कार्यों में स्थिरता को एकीकृत करने के उद्देश्य से थीसिस के लिए रूपरेखा के रूप में कार्य किया।

शोध का दूसरा चरण प्रदर्शन मूल्यांकन चरण है। इस चरण में, सतत फ्रेट ट्रांसपोर्टेशन (SFT) के लिए महत्वपूर्ण KPI प्रस्तुत करने के लिए एक हाइब्रिड निर्णय मॉडल का उपयोग किया गया है। प्रारंभ में, कुल निन्यानबे की पहचान एक व्यापक साहित्य समीक्षा के माध्यम से की गई थी। इन KPI को स्थिरता के तीन आयामों में वर्गीकृत किया गया था। फ़ज़ी डेल्फ़ी विधि (एफडीएम) का उपयोग पहचाने गए निन्यानबे केपीआई से माल उद्योग के लिए केपीआई की एक प्रासंगिक सूची प्राप्त करने के लिए किया गया है। इसके बाद, KPI को ड्राइवर, आश्रित, लिंकेज और ऑटोनॉमस KPI में वर्गीकृत किया गया था, जो कुल इंटरएक्टिव स्ट्रक्चरल मॉडलिंग (TISM) का उपयोग करके अंतर्निहित संबंधों की पहचान करता है। अंत में, स्वायत्त KPI को सूचियों से हटा दिया गया था और प्रत्येक आयाम के तहत शेष KPI को आम सहमति मॉडल (CM) का उपयोग करके प्राथमिकता दी गई थी। इस चरण में पहचाने गए KPI माल संगठन में एक उपयुक्त स्थायी प्रदर्शन मूल्यांकन स्थापित करने के लिए संदर्भ संकेतक के रूप में काम कर सकते हैं। इसके अलावा, इस चरण में एक पहचान सूचकांक विकसित किया गया है जो कि पहचाने गए प्रासंगिक प्रमुख प्रदर्शन संकेतक (KPI) का उपयोग करता है। यह अनिवार्य रूप से, माल प्रणाली के वर्तमान स्थिरता स्वास्थ्य को मापता है और प्रणाली के विभिन्न आयामों में कमजोरियों की पहचान करता है। एक फ़ज़ी एविडेंशियल रीज़निंग अल्गोरिथम (फेरा) का उपयोग कुरकुरा मात्रात्मक मानों के साथ व्यक्तिपरक निर्णय एकत्र करके प्रदर्शन सूचकांक को विकसित करने के लिए किया गया है।

शोध का तीसरा चरण सस्टेनेबिलिटी एडॉप्शन चरण है, जो बाजार में प्रतिस्पर्धी बने रहने के लिए माल ढुलाई के स्थायित्व के प्रदर्शन को बेहतर बनाने से संबंधित है। इस चरण में, संगठनात्मक प्रदर्शन को बढ़ाने के लिए माल ढुलाई के लिए विशिष्ट सर्वोत्तम स्थिरता प्रथाओं की पहचान की गई है। ग्राफ प्रमेय और मैट्रिक्स दृष्टिकोण के साथ अंतर्ज्ञानवादी फज़ी संख्या के संयोजन द्वारा एक एकीकृत दृष्टिकोण का उपयोग स्थिरता प्रथाओं को प्राथमिकता देने के लिए किया गया है। इस अध्ययन में, यह पाया गया कि शीर्ष प्रबंधन प्रतिबद्धता और मल्टी-मोडल माल ढुलाई परिवहन का समग्र संगठनात्मक प्रदर्शन पर सबसे अधिक प्रभाव पड़ता है। इसलिए, परिवहन के लिए गंतव्य से ले जाने के लिए विभिन्न मानदंडों के आधार पर सर्वोत्तम परिवहन मोड, या मोड के संयोजन का चयन करने के लिए एक बाद का अध्ययन किया गया था। इस उद्देश्य में एक एकीकृत ग्रे रिलेशनल विश्लेषण आधारित अंतर्ज्ञानवादी फज़ी मल्टी-मापदंड निर्णय लेने की प्रक्रिया (GRA-IFP) और फज़ी मल्टी-ऑब्जेक्टिव लीनियर प्रोग्रामिंग (FMOLP) मॉडल का उपयोग किया गया है। GRA-IFP को कई मानदंडों के लिए भार असाइन करने के लिए पहले लागू किया गया है। इन वज़नों का उपयोग फ़ज़ी मल्टी-ऑब्जेक्टिव लीनियर प्रोग्रामिंग में किया जाता है ताकि अंत में मोड का चयन किया जा सके और प्रत्येक मोड

द्वारा यात्रा की जाने वाली दूरी का अनुमान लगाया जा सके। प्रासंगिक परिस्थितियों में मापदंडों में बदलाव के साथ निर्णय चर की संवेदनशीलता का विश्लेषण करने के लिए तीन परिदृश्य विकसित किए गए हैं।

अनुसंधान अंत में अनुसंधान से प्राप्त सारांश और प्रमुख निष्कर्षों के साथ समाप्त होता है। प्रस्तावित प्रदर्शन प्रबंधन प्रणाली की रूपरेखा मोटे तौर पर माल ढुलाई करने वालों का मार्गदर्शन करने, मूल्यांकन और निगरानी करने के लिए मार्गदर्शन कर सकती है। महत्वपूर्ण KPI की एक मानकीकृत सूची माल ढुलाईकर्ताओं को अपनी ताकत और कमजोरियों को समझने में मदद कर सकती है। प्रदर्शन सूचकांक विकसित करने की पूरी प्रक्रिया स्थिरता के प्रत्येक आयाम पर उनके प्रदर्शन का मूल्यांकन करने के लिए माल ढुलाई की सुविधा प्रदान करती है। स्थिरता प्रथाओं की सूची स्थिरता व्यवहारों के प्रति माल परिवहन के फोकस को प्राथमिकता देने में मदद कर सकती है जो समग्र संगठनात्मक प्रदर्शन पर अधिक प्रभाव डालते हैं। यह शोध माल ढुलाई के लिए रोडमैप और मात्रात्मक मॉडल प्रदान करके टिकाऊ माल परिवहन के क्षेत्र में योगदान देता है, इस प्रकार, प्रदर्शन प्रबंधन प्रणाली के माध्यम से माल ढुलाई कार्यों में स्थिरता के एकीकरण की सुविधा प्रदान करता है।

TABLE OF CONTENTS

CERTIFICATE	I
ACKNOWLEDGEMENTS	II
ABSTRACT	IV
CONTENTS	XI
LIST OF FIGURES	XVI
LIST OF TABLES	XVIII
LIST OF ABBREVIATIONS	XXII

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND	1
1.2 FEATURES OF SUSTAINABLE FREIGHT TRANSPORTATION	3
1.3 NEED OF SUSTAINABLE FREIGHT TRANSPORTATION	5
1.4 SCOPE OF THE STUDY	7
1.5 PERFORMANCE MEASUREMENT SYSTEM FOR SUSTAINABLE FREIGHT TRANSPORTATION	10
1.6 MOTIVATIONS FOR RESEARCH	13
1.7 RESEARCH QUESTIONS AND RESEARCH OBJECTIVES	15
1.8 RESEARCH METHODOLOGY	15
1.9 RESEARCH FRAMEWORK	18
1.10 ORGANIZATION OF THESIS	19
1.11 CHAPTER SUMMARY	20

CHAPTER 2. LITERATURE REVIEW ON SUSTAINABLE FREIGHT TRANSPORTATION

2.1 INTRODUCTION	21
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2.2	NEED OF SUSTAINABILITYIN FREIGHT TRANSPORTATION	23
2.3	MULTI-MODAL FREIGHT TRANSPORTATION	26
2.4	SUSTAINABLE URBAN FREIGHT TRANSPORTATION	29
2.5	SUSTAINABLITY PRACTICES FOR FREIGHT TRANSPORTATION	32
2.6	PERFORMANCE MANAGEMENT IN SUSTAINABLE FREIGHT TRANSPORTATION	36
2.6.1	SUSTAINABILITY ACCOUNTING	39
2.6.2	SUSTAINABILITY ASSESSMENT	43
2.6.3	SUSTAINABILITY REPORTING	45
2.7	GAPS IN LITERATURE	55
2.8	CHAPTER SUMMARY	57

CHAPTER 3. PERFORMNACE MANAGEMENT FRAMEWORK FOR SUSTAINABLE FREIGHT TRANSPORTATION

3.1	INTRODUCTION	58
3.2	PROBLEM STATEMENT IN THE CONTEXT OF SUSTAINABLE FREIGHT TRANSPORTATION SYSTEM	61
3.3	METHODOLOGY	63
3.4	APPLICATION OF SOFT SYSTEM METHODOLOGY IN SUSTIANABLE FREIGHT TRANSPORTATION	66
3.5	DISCUSSION	87
3.6	CHAPTER SUMMARY	89

CHAPTER 4. A HYBRID DECISION MODEL FOR SELECTING AND PRIORITIZING KEY PERFORMANCE INDICATORS FOR SUSTAINABLE FREIGHT TRANSPORTATION

4.1	BACKGROUND	90
4.2	PROBLEM STATEMENT	91
4.3	HYBRID MULTI-CRITERIA DECISION-MAKING APPROACH	96
4.4	DATA COLLECTION	100
4.5	AN APPLICATION OF PROPOSED HYBRID DECISION MODEL	100

4.5.1 STAGE I: FUZZY DELPHI METHOD	101
4.5.2 STAGE II: TOTAL INTERPRETIVE STRUCTURAL MODELING	105
4.5.3 STAGE III: CONSENSUS MODEL	114
4.5.3.1 ALGORITHM FOR CONSENSUS MODEL FOR SUSTAINABLE FREIGHT TRANSPORTATION	115
4.5.3.2 ESTIMATION OF RELATIVE WEIGHTS OF KPIS USING CONSENSUS MODEL	122
4.6 RESULTS AND MANAGERIAL IMPLICATIONS	129
4.7 CHAPTER SUMMARY	136

CHAPTER 5. PERFORMANCE MEASUREMENT OF SUSTAINABLE FREIGHT TRANSPORTATION

5.1 BACKGROUND	137
5.2 PROBLEM STATEMENT	138
5.3 METHODOLOGY	142
5.4 AN APPLICATION OF THE PROPOSED FERA METHODOLOGY TO DEVELOP PERFORMANCE INDEX	151
5.5 RESULTS AND DISCUSSIONS	157
5.6 SENSITIVITY ANALYSIS	159
5.6.1 BALANCED SCORECARD-BASED SENSITIVITY ANALYSIS	159
5.6.2 TYPE-II SENSITIVITY ANALYSIS	162
5.7 CHAPTER SUMMARY	163

CHAPTER 6. IMPROVING FREIGHT TRANSPORTATION PERFORMANCE THROUGH SUSTAINABILITY PRACTICES

6.1 INTRODUCTION	165
6.2 PROBLEM STATEMENT	167
6.3 THEORY OF PRACTICE-BASED VIEW	168
6.4 AN INTEGRATED APPROACH BASED ON GRAPH THEORY AND INTUITIONISTIC FUZZY NUMBERS	169
6.4.1 PRELIMINARIES OF INTUITIONISTIC FUZZY SET (IFS) THEORY	172
6.4.2 GRAPH THEORY APPROACH	173
6.4.3 SUSTAINABILITY PRACTICES ASSESSMENT MODEL	174

6.5 APPLICATION OF THE PROPOSED IFNs-GTMA BASED MODEL FOR EVALUATING SUSTAINABILITY PRACTICES FOR FREIGHT TRANSPORTATION SYSTEM	185
6.6 RESULTS AND DISCUSSION	203
6.7 CHAPTER SUMMARY	206

CHAPTER 7. A MODEL FOR THE SELECTION OF MODES IN THE CONTEXT OF SUSTAINABLE FREIGHT TRANSPORTATION

7.1 BACKGROUND	207
7.2 PROBLEM STATEMENT	209
7.3 METHODOLOGY	213
7.3.1 GREY RELATIONAL ANALYSIS BASED INTUITIONISTIC FUZZY MULTI-CRITERIA DECISION-MAKING PROCESS (GRA-IFP)	213
7.3.1.1 STEP-WISE METHODOLOGY	214
7.3.2 FUZZY MULTI-OBJECTIVE LINEAR PROGRAMMING	217
7.4 MULTI-MODE SELECTION MODEL	221
7.5 A CASE ILLUSTRATION	223
7.6 FUZZY MULTI-OBJECTIVE LINEAR PROGRAMMING	228
7.7 RESULTS & DISCUSSIONS	232
7.8 SCENARIO BUILDING AND SENSITIVITY ANALYSIS	236
7.9 CHAPTER SUMMARY	240

CHAPTER 8. SUMMARY OF RESEARCH FINDINGS AND CONCLUSIONS

8.1 INTRODUCTION	242
8.2 SUMMARY OF RESEARCH FINDINGS	243
8.2.1 PHASE I: EXPLORATORY PHASE	243
8.2.2 PHASE II: PERFORMANCE ASSESSMENT PHASE	244
8.2.3 PHASE III: SUSTAINABILITY ADOPTION PHASE	247
8.3 SIGNIFICANT IMPLICATIONS OF THE RESEARCH	249
8.3.1 IMPLICATIONS OF RESEARCH FOR ACADEMIA	249
8.3.2 IMPLICATIONS OF RESEARCH FOR PRACTITIONERS	250

8.4 LIMITATIONS OF THE RESEARCH	252
8.5 FUTURE SCOPE OF THE RESEARCH	253
8.6 CHAPTER SUMMARY	254
 REFERENCES	 256
ABOUT THE AUTHOR	285

LIST OF FIGURES

Figure 1.1. Different stages of freight transportation	1
Figure 1.2. Freight traffic via road and rail in India	7
Figure 1.3. Freight transportation cost as a percentage of GDP	10
Figure 1.4. Performance management system (PMS) for sustainable freight transportation	12
Figure 1.5. Research Framework	18
Figure 2.1. Publishing trend in the area of sustainable freight transportation	23
Figure 2.2. Key aspects of sustainability performance for freight transportation	39
Figure 3.1. Sustainability dimensions based on triple bottom line (TBL)	58
Figure 3.2. Different stages of Soft System Methodology	65
Figure 3.3. Symptoms Map	69
Figure 3.4. Rich picture for sustainable freight transportation	73
Figure 3.5. Initial Conceptual Map for Sustainable Freight Transportation	78
Figure 3.6. Final Implementable Model for Sustainable Freight Transportation	79
Figure 3.7. Performance Management Framework for Sustainable Freight Transportation	81
Figure 4.1. Schematic diagram of the proposed framework for performance of sustainable freight transportation	99
Figure 4.2. TISM-based Framework for Sustainable Freight Transportation	112
Figure 4.3. MICMAC Analysis of KPIs for sustainable freight transportation	113
Figure 4.4. Framework for Consensus Model Process	116
Figure 4.5. Graphical representation of weights of KPIs obtained using CM process	132
Figure 5.1. Framework for development of Performance Index based on FERA	140
Figure 5.2. Growth-Cost Matrix for FTS	145

Figure 5.3 Illustration of mapping process to transform TFNs to non-normalised Belief Degree structure	146
Figure 5.4. Balance scorecard-based Sensitivity Analysis	161
Figure 5.5. Sensitivity Analysis by weights	162
Figure 6.1. Practice-based view model for research	169
Figure 6.2. Flow-chart representing step-wise procedure adopted in the proposed Methodology	177
Figure 6.3. Digraph representing the importance relations among organizational performances	189
Figure 6.4. Digraph representing the positive and negative influences of sustainability practices on the organizational performances	190
Figure 7.1. Characteristics of Different Modes of Transportation	207
Figure 7.2. Multi-Modal Freight Transportation Process	208
Figure 7.3. Sustainable Framework considered in the study	212
Figure 7.4. Sensitivity analysis by changing weights of economic criteria	237
Figure 7.5. Sensitivity analysis by changing weights of environment criteria	238
Figure 7.6. Sensitivity analysis by changing weights of social criteria	239

LIST OF TABLES

Table 1.1	Difference between the conventional freight transportation and sustainable freight transportation	4
Table 1.2	Logistics Performance Index (LPI) for different countries	9
Table 1.3	Comparison of India with other countries on efficiency indicators	10
Table 1.4	Research objectives and methodology mapping	16
Table 2.1	The proposed three-level keyword assembly structure	21
Table 2.2	Some studies emphasizing the need to measure sustainable performance	38
Table 2.3	List of articles addressing performance management issues in sustainable supply chain area	47
Table 2.4	List of articles addressing performance management issues in sustainable freight transportation area	53
Table 3.1	Different case organizations considered in this study	66
Table 3.2	Mapping of conflict areas to identify root causes	72
Table 3.3	CATWOE for the Sustainable Freight Transportation	76
Table 3.4	Root definitions formed from different world views	77
Table 4.1	List of KPIs for sustainable freight transportation	92
Table 4.2	Comparative analysis of similar MCDM techniques used in each stage of the present study	98
Table 4.3	List of selected KPIs using Fuzzy Delphi Method	104
Table 4.4	Final reachability matrix	108
Table 4.5	Final labels allocated to each KPI	111
Table 4.6	Individual Decision Matrices for Financial KPIs	123
Table 4.7	Clustering of DMs in Financial KPIs	125
Table 4.8	Weights of Key Performance Indicators (KPIs) for Sustainable Freight Transportation	128
Table 5.1	List of Key Performance Indicators of Sustainable Freight	141

Transportation	
Table 5.2 Transformation of linguistic variables to fuzzy triangular membership function	143
Table 5.3 Description of range of sustainability level and type of performers based on TFNs	144
Table 5.4 Example of transformation of TFNs into normalized belief degrees	147
Table 5.5 Comparative Analysis of Case Organizations	152
Table 5.6 Aggregation of assessment of sustainability by experts using TFNs	153
Table 5.7 Computation of Performance Index	155
Table 5.8 Performance Index for Case-I, Case-II and Case-III	156
Table 5.9 Balance scorecard-based Sensitivity Analysis with five scenarios	161
Table 5.10 Sensitivity Analysis by weights	163
Table 6.1 List of sustainability practices for freight transportation	170
Table 6.2 Comparative analysis different methodologies with the proposed Approach	176
Table 6.3 Conversion of linguistic variables into IFNs for the importance of decision makers	182
Table 6.4 Linguistic assessment and associated Intuitionistic Fuzzy Numbers	187
Table 6.5.1 Linguistic assessment by expert group 1 for relative importance among different measures of organizational performance	188
Table 6.5.2 Linguistic assessment by expert group 2 for relative importance among different measures of organizational performance	188
Table 6.5.3 Linguistic assessment by expert group 3 for relative importance among different measures of organizational performance	188
Table 6.5.4 Linguistic assessment by expert group 4 for relative importance among different measures of organizational performance	188
Table 6.5.5 Linguistic assessment by expert group 5 for relative importance among different measures of organizational performance	189
Table 6.6.1 Linguistic assessment by expert group 1 for positive influences of sustainability practices on the organizational performances	191
Table 6.6.2 Linguistic assessment by expert group 2 for positive influences of	191

sustainability practices on the organizational performances	
Table 6.6.3 Linguistic assessment by expert group 3 for positive influences of sustainability practices on the organizational performances	192
Table 6.6.4 Linguistic assessment by expert group 4 for positive influences of sustainability practices on the organizational performances	192
Table 6.6.5 Linguistic assessment by expert group 5 for positive influences of sustainability practices on the organizational performances	193
Table 6.6.6 Linguistic assessment by expert group 1 for negative influences of sustainability practices on the organizational performances	193
Table 6.6.7 Linguistic assessment by expert group 2, 3 and 4 for positive influences of sustainability practices on the organizational performances	194
Table 6.6.8 Linguistic assessment by expert group 5 for negative influences of sustainability practices on the organizational performances	195
Table 6.7 Modified intuitionistic preference relation matrices of expert group 2	196
Table 6.8 Modified intuitionistic preference relation matrices of expert group 3	196
Table 6.9 Modified intuitionistic preference relation matrices of expert group 5	196
Table 6.10 Importance of expert groups and their associated weights	197
Table 6.11 Linguistic assessment of importance of expert groups	197
Table 6.12 Aggregated Intuitionistic fuzzy relation matrix for relative importance among the different constructs of organizational performance	197
Table 6.13 Aggregated Intuitionistic fuzzy relation matrix for positive influence of sustainability practices on the organizational performance	198
Table 6.14 Aggregated Intuitionistic fuzzy relation matrix for negative influence of sustainability practices on the organizational performance	198
Table 6.15 De-fuzzified matrix for relative importance among different constructs of organizational performance	199
Table 6.16 De-fuzzified matrix for positive and negative influences of sustainability practices on the organizational performance	200
Table 6.17 Permanent function matrix representing positive influences of sustainability practices on the organizational performance	201

Table 6.18	Permanent function matrix representing negative influences of sustainability practices on the organizational performance	201
Table 6.19	Ranking of sustainability practices based on net positive influence over organizational performance	202
Table 7.1	Conversion of linguistic variable into intuitionistic fuzzy numbers	214
Table 7.2	Conversion of linguistic variables into IFNs for the importance of decision makers	215
Table 7.3	Summary of objective functions used in this study	223
Table 7.4	Aggregated intuitionistic fuzzy decision matrix (B)	225
Table 7.5	Distance Matrix (β)	226
Table 7.6	Grey Relational Coefficient Matrix (γ_{ij})	226
Table 7.7	Quantitative information on each criterion to select transportation mode	228
Table 7.8	Numerical example of multi-objective linear programming	229
Table 7.9	The dataset for calculation of membership function	230
Table 7.10	Formulation of Multi-Mode selection problem using Asymmetrical Approach	230
Table 7.11	Formulation of Multi-Mode selection problem using Symmetrical Approach	232
Table 7.12	Comparison between Asymmetrical and Symmetrical Approach	232
Table 7.13	Summary of Mode selection and Total distance allocation	235

LIST OF ABBREVIATIONS

FT	Freight transportation
FTS	Freight Transportation System
SFT	Sustainable Freight Transportation
3PL	Third-Party Logistics Service Providers
SCM	Supply Chain Management
TSP	Trans-shipment
GHG	Green-house Gas Emissions
NGO	Non-Governmental Organizations
UNCTAD	United Nation Conference on Trade and Development
USD	United States Dollar
NTDPC	National Transport Development Policy Committee
CAGR	Compounded Annual Growth Rate
FMCG	Fast-Moving Consumer Goods
IBEF	Indian Brand Equity Foundation
ASSOCHAM	Associated Chambers of Commerce & Industry of India
RO	Research Objective
TBL	Triple Bottom Line
PMS	Performance Management System
SSM	Soft-System Methodology
KPI(s)	Key Performance Indicator(s)
FDM	Fuzzy Delphi Method
TISM	Total Interpretive Structural Modeling
CM	Consensus Model
FERA	Fuzzy Evidential Reasoning Algorithm
IFN-GTMA	Intuitionistic Fuzzy Number-based Graph Theoretic Matrix Approach
GRA-IFP	Grey Relational Analysis Based Intuitionistic Fuzzy multi-criteria decision-making process
FMOLP	Fuzzy Multi-Objective Linear Programming
SSCM	Sustainable Supply Chain Management

LPI	Logistics Performance Index
EU	European Union
UK	United Kingdom
US	United States
GDP	Gross Domestic Product
NAPCC	National Action Plan on Climate Change
LEZ	Low Economic Zone
ITS	Intelligent Transportation System
LNG	Liquified Natural Gas
LCA	Life Cycle Assessment
VE	Value Engineering
ICT	Information and Communication Technologies
CL	Crowd Logistics
HDV	Heavy Duty Logistics
AFHS	Automated Freight Handling System
WSN	Wireless Sensor Networks
MCDM	Multi-Criteria Decision Making
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
DEMATEL	Decision Making Trial and Evaluation Laboratory
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
DEA	Data Envelopment Analysis
QFD	Quality function deployment
ELECTRE	ELimination Et Choix Traduisant la REalité
BSC	Balance Score Card
GSCM	Green Supply Chain Management
ERM	Enterprise Risk Management
CSR	Corporate Social Responsibility
SPA	Sustainable Performance Assessment
MRIO	Multi-Regional Input-Output

DCs	Dynamic Capabilities
IT	Information Technology
SEM	Structural Equation Modelling
ALNS	Adaptive Large Neighborhood Search
SC(s)	Supply Chain(s)
ADB	Asian development Bank
OR	Operational Research
PAN	Presence Across Nation
SLAs	Service Level Agreements
R&D	Research & Development
SCOR	Supply-Chain Operations Reference
PDCA	Plan Do Check Act
FTL	Full Truck Load
WMS	Waste Management System
VMI	Vendor Managed Inventory
TFNs	Triangular Fuzzy Numbers
GM	Geometric Mean
SSIM	Structural Self Interaction Matrix
MICMAC	Cross-Impact Matrix Multiplication Applied to the Classification
GCL	Group Consensus Level
LTL	Less-Than Truck Load
D-S	Dempster-Shafer
ERA	Evidential Reasoning Algorithm
FST	Fuzzy Set Theory
IFN	Intuitionistic Fuzzy Numbers
IFS	Intuitionistic Fuzzy Set
PBV	Practice-Based View
RBV	Resource-Based View
IFWA	Intuitionistic Fuzzy Weighted Averaging
CE	Circular Economy