

**PERFORMANCE MANAGEMENT OF
SUSTAINABLE FREIGHT TRANSPORTATION: A
STUDY OF SELECT ISSUES**

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STUDY OF SELECT ISSUES**

by

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CERTIFICATE

This is to certify that the thesis entitled “**Performance Management of Sustainable Freight Transportation: A Study of Select Issues**” being submitted by Devendra Kumar Pathak to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy (Ph.D.)** is a bonafide record of original research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has attained the requisite standard required for Ph.D. degree from Indian Institute of Technology Delhi. The results presented in this thesis have not been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

An energy-efficient, cost-effective, safe, and reliable freight transportation (FT) system is of utmost prominence to meet the burgeoning demands of the industry. FT plays an essential role in the growth of the regional economy, shaping smart cities, generating employment and large revenues. However, there are several negative externalities associated with freight transportation and the adverse impacts of the transport sector on climate as well as energy consumption are also well reported. It is evident that sustainable freight transportation (SFT) would substantially affect global sustainability. This encourages us to study the sustainability performance of the transport and logistics sector. Moreover, recent studies on sustainability bring out that at present times, organizations need to think beyond the traditional triple bottom line (3BL) concept of sustainability. Consequently, it becomes prudent to develop a comprehensive performance evaluation framework (PEF) based on an aggregated sustainability index to assess the sustainability performance of FT systems. Moreover, to be competitive in the prevailing dynamic market requirements, it also becomes prudent for freight operators to analyze the interaction between competitive priorities and sustainability performance. The consistently reducing modal share of rail freight transportation has emerged as a key concern to the policy-makers. The recent studies signify the importance of modal shift as a decarbonizing strategy and elucidate the potential of modal shift to attain sustainability in the freight transport sector. As several negative environmental and social externalities are associated with road freight transportation, it presents a major threat to the sustainability of the planet earth. Consequently, the utilization of dedicated freight corridors (DFCs) would be essential to decarbonize freight shipping and hence to achieve sustainability in FT.

In the last decade, globalization and growing concerns related to resource depletion and climate change have increased the importance of sustainability in businesses. Accordingly, the pressing need to embrace sustainability into the logistics operations solicits the attention of logistics professionals to develop an instrument for measuring sustainable logistics performance (SLP). Moreover, the issue of analyzing the impact of green innovation (GI) practices and sustainable training (ST) on firm performance has gained substantial attention from researchers in the domain of logistics and environmental management research. In today's competitive business environment, the key research issue that remains unexplored is to analyze the potential impact of GI and ST on SLP of logistics service providers (LSPs).

In order to address the aforesaid key issues, this research is carried out in three phases and consists of five research objectives. The first phase of this research attempts to identify critical success factors (CSFs) affecting the performance of SFT by reviewing the extant literature and performing a Delphi study. This study proposes a comprehensive PEF to assess the sustainability performance of FT systems by utilizing total interpretive structure modeling (TISM), fuzzy analytical hierarchy process (FAHP), and 0/1 rating score. Subsequently, the applicability of the proposed framework is also demonstrated through a case example. Afterward, the first phase of this research also attempts to utilize the concept of transition management theory to identify enablers of DFCs for the transition from road to rail FT. This study utilizes exploratory factor analysis (EFA) to empirically validate the three-level transition management framework for the enablers of DFCs. Subsequently, TISM is employed to delineate the inter-relationships among these enablers to decarbonize FT and achieve sustainability in the freight transport sector.

In the second phase of this research, an integrated performance assessment model is developed to assess the identified CSFs of SFT systems on the basis of the competitive priorities of the transport sector. A unified approach consisting of fuzzy group decision making (FGDM), fuzzy evidential reasoning algorithm (FERA), and expected utility theory is utilized to attain the specified objective. Subsequently, weight changing analysis is carried out to analyze the effect of variations in the weight of each competitive priorities on the competitive performance score (CPS) of six dimensions of SFT. Eventually, sensitivity analysis is also performed to check the robustness of the proposed model.

The third phase of this research attempts to develop and validate an instrument to measure SLP by extending the existing instrument of measuring logistics performance as proposed by Fugate et al. (2010). The outcomes of EFA and confirmatory factor analysis (CFA) disclose that SLP can be operationalized as a second-order construct model comprising of five dimensions, namely, (a) logistics effectiveness; (b) logistics efficiency; (c) logistics differentiation; (d) environmental performance; and (e) social performance. Subsequently, this phase also draws upon the sustainable human resource management (SHRM) and the natural resource-based view (NRBV) of the firm to empirically investigate the effect of GI and ST on SLP of LSPs. This study also investigates the mediating role of ST on the relationship between GI and SLP. EFA is utilized to compute the factor loading of all items and examine the reliability of the proposed scale for SLP, GI, and ST. CFA is utilized to examine the construct validity and model fit indices of the measurement model. Afterward, structural equation modeling (SEM) is utilized to examine the proposed path model and hypothesis.

The outcomes of this research bring out that logistics practitioners should now focus on the three emerging dimensions (i.e., ‘efficiency’, ‘employing advanced technology’, and ‘safety’ dimension) along with the traditional dimensions of sustainability (i.e., ‘economic’, ‘environmental’, and ‘social’) for the development of a comprehensive PEF for SFT systems. Eventually, this research proposes a comprehensive sustainability performance index (SPI) based PEF to assess the sustainability performance of different freight operators and thus facilitate decision-makers in selecting the best freight operator based on their SPI score. This research facilitates policy-makers to utilize a three-level transition management framework to realize changes in the transport infrastructure to decarbonize freight shipping and achieve sustainability in the freight transport sector. This research contributes to the FT literature by identifying and modeling CSFs of SFT and developing an integrated performance assessment model that facilitates logistics managers in identifying key CSFs, which lead to achieve higher CPS value. This research also contributes to the body of the existing literature by identifying the key items and constructs to measure SLP. The outcomes of this research also apprise logistics professionals about the significance of three constructs (i.e., logistics effectiveness, environmental performance, and social performance) of SLP, in understanding the sustainability issues related to logistics activities, due to their higher path estimate. Eventually, by integrating the NRBV and SHRM, this research facilitates logistics professionals to understand the influence of GI and ST on SLP and signifies that ST completely mediates the relationship between GI and SLP for the Indian logistics sector.

सार

एक ऊर्जा-कुशल, लागत प्रभावी, सुरक्षित और विश्वसनीय माल परिवहन (एफटी) प्रणाली उद्योग जगत की बढ़ती मांगों को पूरा करने के लिए अत्यंत प्रमुख है। एफटी क्षेत्रीय अर्थव्यवस्था के विकास में एक महत्वपूर्ण भूमिका निभाता है, स्मार्ट शहरों को आकार देने, रोजगार और बड़े राजस्व का सृजन करता है। हालांकि, माल परिवहन से जुड़ी कई नकारात्मक बाहरी चीजें हैं और जलवायु पर परिवहन क्षेत्र के प्रतिकूल प्रभाव के साथ-साथ ऊर्जा की खपत भी अच्छी तरह से बताई गई है। यह स्पष्ट है कि सतत माल परिवहन (एसएफटी) वैश्विक स्थिरता को काफी प्रभावित करेगा। यह हमें परिवहन और संचालन क्षेत्र के स्थिरता प्रदर्शन का अध्ययन करने के लिए प्रोत्साहित करता है। इसके अलावा, स्थिरता पर हाल के अध्ययनों से पता चलता है कि वर्तमान समय में, संगठनों को स्थिरता के पारंपरिक ट्रिपल बॉटम लाइन (3 बीएल) की अवधारणा से परे सोचने की जरूरत है। नतीजतन, एफटी सिस्टम के स्थिरता प्रदर्शन का आकलन करने के लिए एक समग्र स्थिरता सूचकांक के आधार पर एक व्यापक प्रदर्शन मूल्यांकन रूपरेखा (पीईएफ) विकसित करना समझदारी है। इसके अलावा, प्रचलित गतिशील बाजार की जरूरतों में प्रतिस्पर्धी होने के लिए, यह भी माल परिवहन ऑपरेटरों के लिए प्रतिस्पर्धी प्राथमिकताओं और स्थिरता प्रदर्शन का विश्लेषण करने के लिए विवेकपूर्ण हो जाता है। रेल माल परिवहन में लगातार कम होती हिस्सेदारी के कारण नीति निर्माताओं के लिए एक महत्वपूर्ण चिंता का विषय बन गया है। हाल के अध्ययनों से डीकार्बोनाइजिंग रणनीति के रूप में मोडल शिफ्ट के महत्व का संकेत मिलता है और माल परिवहन क्षेत्र में स्थिरता प्राप्त करने के लिए मोडल शिफ्ट की क्षमता को स्पष्ट करता है। जैसा कि कई नकारात्मक पर्यावरणीय और सामाजिक बाहरी चीजें सड़क माल परिवहन से जुड़ी हैं, यह ग्रह पृथ्वी की स्थिरता के लिए एक बड़ा खतरा प्रस्तुत करता है। नतीजतन, फ्रेट शिपिंग को डीकार्बोनाइज करने के लिए डेडिकेटेड फ्रेट कॉरिडोर (डीएफसी) का उपयोग आवश्यक होगा और इससे एफटी में स्थिरता प्राप्त होगी।

पिछले दशक में, वैश्वीकरण और संसाधन में कमी और जलवायु परिवर्तन से संबंधित चिंताओं ने व्यवसायों में स्थिरता के महत्व को बढ़ा दिया है। तदनुसार, लॉजिस्टिक्स ऑपरेशंस में स्थिरता को अपनाने की जरूरत है, जिससे लॉजिस्टिक्स प्रोफेशनल्स का ध्यान सतत लॉजिस्टिक्स परफॉर्मेंस (एसएलपी) को मापने के लिए इंस्ट्रूमेंट डेवलप करने पर हो। इसके अलावा, फर्म के प्रदर्शन पर ग्रीन इनोवेशन (जीआई) प्रथाओं और सतत प्रशिक्षण (एसटी) के प्रभाव का विश्लेषण करने के मुद्दे ने संचालन और पर्यावरण प्रबंधन अनुसंधान के क्षेत्र में शोधकर्ताओं का काफी ध्यान आकर्षित किया है। आज के प्रतिस्पर्धी कारोबारी माहौल में, प्रमुख अनुसंधान मुद्दा जो अस्पष्ट बना हुआ है वह है संचालन सेवा प्रदाताओं (एलएसपी) के एसएलपी पर जीआई और एसटी के संभावित प्रभाव का विश्लेषण करना।

उपरोक्त प्रमुख मुद्दों को संबोधित करने के लिए, इस शोध को तीन चरणों में किया जाता है और इसमें पाँच अनुसंधान उद्देश्य होते हैं। इस शोध का पहला चरण महत्वपूर्ण सफलता कारकों (सीएसएफ) की पहचान करने का प्रयास करता है, जो एसएफटी के प्रदर्शन को प्रभावित कर रहे हैं। यह अध्ययन संपूर्ण व्याख्यात्मक संरचना मॉडलिंग (टीआईएसएम), फ़ज़ी विश्लेषणात्मक पदानुक्रम प्रक्रिया (एफ एचपी), और 0/1 रेटिंग स्कोर का उपयोग करके एफटी सिस्टम के स्थिरता प्रदर्शन का आकलन करने के लिए एक व्यापक पीईएफ़ का प्रस्ताव करता है। इसके बाद, प्रस्तावित फ्रेमवर्क की प्रयोज्यता को एक उदाहरण के माध्यम से भी प्रदर्शित किया जाता है। बाद में, इस शोध का पहला चरण सड़क से रेल एफटी स्थानांतरण के लिए डीएफसी के इनेबलर्स की पहचान करने के लिए स्थानांतरण प्रबंधन सिद्धांत की अवधारणा का उपयोग करने का भी प्रयास करता है। यह अध्ययन डीएफसी के इनेबलर्स के लिए तीन स्तरीय स्थानांतरण प्रबंधन ढांचे को अनुभवजन्य रूप से मान्य करने के लिए खोज कारक विश्लेषण (ईएफए) का उपयोग करता है। इसके बाद, एफटी को डीकार्बोनाइज करने और माल परिवहन क्षेत्र में स्थिरता प्राप्त करने के लिए इन इनेबलर्स के बीच अंतर-संबंधों को परिसीमित करने के लिए टीआईएसएम कार्यरत है।

इस शोध के दूसरे चरण में, परिवहन क्षेत्र की प्रतिस्पर्धी प्राथमिकताओं के आधार पर एसएफटी सिस्टम की पहचान किए गए सीएसएफ का आकलन करने के लिए एक एकीकृत प्रदर्शन मूल्यांकन मॉडल विकसित किया गया है। फ़ज़ी ग्रुप डिजीजन मेकिंग (एफ जीडीएम), फ़ज़ी एविडेंसियल रीज़निंग अल्गोरिद्म (एफ ईआरए), और अपेक्षित उपयोगिता सिद्धांत से मिलकर एक एकीकृत दृष्टिकोण निर्दिष्ट उद्देश्य को प्राप्त करने के लिए उपयोग किया जाता है। इसके बाद, एसएफटी के छह आयामों के प्रतिस्पर्धी प्रदर्शन स्कोर (सीपीएस) पर प्रत्येक प्रतिस्पर्धी प्राथमिकताओं के महत्व में भिन्नता के प्रभाव का विश्लेषण करने के लिए महत्व परिवर्तन विश्लेषण किया जाता है। आखिरकार, प्रस्तावित मॉडल की दृढ़ता की जांच करने के लिए संवेदनशीलता विश्लेषण भी किया जाता है।

इस शोध के तीसरे चरण में फुगते एट अल. (2010) द्वारा प्रस्तावित लॉजिस्टिक्स प्रदर्शन को मापने के मौजूदा इंस्ट्रूमेंट को विस्तार कर एसएलपी को मापने के लिए एक उपकरण को विकसित करने और मान्य करने का प्रयास किया गया है। ईएफए और पुष्टिकरण कारक विश्लेषण (सीएफए) के परिणामों से पता चलता है कि एसएलपी को दूसरे क्रम के निर्माण मॉडल के रूप में संचालित किया जा सकता है जिसमें पांच आयाम शामिल हैं, अर्थात् (ए) संचालन प्रभावशीलता; (बी) संचालन दक्षता; (सी) संचालन भेदभाव; (डी) पर्यावरण प्रदर्शन; और (ई) सामाजिक प्रदर्शन। इसके बाद, यह चरण सतत मानव संसाधन प्रबंधन (एस एचआरएम) और फर्म के प्राकृतिक संसाधन-आधारित दृष्टिकोण (एन आरबीवी) को भी आकर्षित करता है ताकि एलएसपी के एसएलपी पर जीआई और एसटी के प्रभाव का अनुभव किया जा सके। यह अध्ययन जीआई और एसएलपी के बीच संबंधों

पर एसटी की मध्यस्थता भूमिका की भी जांच करता है। ईएफए का उपयोग सभी आइटम के कारक लोडिंग की गणना करने और एसएलपी, जीआई और एसटी के लिए प्रस्तावित पैमाने की विश्वसनीयता की जांच करने के लिए किया जाता है। सीएफए का उपयोग माप मॉडल के निर्माण वैधता और मॉडल फिट सूचकांकों की जांच करने के लिए किया जाता है। बाद में, प्रस्तावित पाथ मॉडल और परिकल्पना की जांच करने के लिए संरचनात्मक समीकरण मॉडलिंग (एसईएम) का उपयोग किया जाता है।

इस शोध के नतीजे बताते हैं कि लॉजिस्टिक्स प्रोफेशनल्स को एसएफटी सिस्टम के लिए एक व्यापक पीईएफ के विकास के लिए अब स्थिरता के पारंपरिक आयामों (यानी, 'आर्थिक', 'पर्यावरण' और 'सामाजिक') के साथ-साथ तीन उभरते आयामों (जैसे, 'दक्षता', 'उन्नत तकनीक को रोजगार देना' और 'सुरक्षा' आयाम) पर ध्यान केंद्रित करना चाहिए। आखिरकार, यह शोध विभिन्न माल ऑपरेटर्स के स्थिरता प्रदर्शन का आकलन करने के लिए व्यापक स्थिरता प्रदर्शन सूचकांक (एसपीआई) आधारित पीईएफ का प्रस्ताव करता है और इस प्रकार एसपीआई स्कोर के आधार पर सर्वश्रेष्ठ माल ऑपरेटर का चयन करने में निर्णयकर्ताओं को सुविधा प्रदान करता है। यह शोध नीति-निर्माताओं को माल परिवहन को डीकार्बोनाइज करने और माल परिवहन क्षेत्र में स्थिरता प्राप्त करने के लिए परिवहन आधारिक संरचना में बदलाव करने के लिए तीन-स्तरीय स्थानांतरण प्रबंधन ढांचे का उपयोग करने की सुविधा प्रदान करता है। यह शोध एसएफटी के सीएसएफ की पहचान और मॉडलिंग करके एफटी साहित्य में योगदान देता है और एक एकीकृत प्रदर्शन मूल्यांकन मॉडल विकसित करता है जो जरूरी सीएसएफ की पहचान करने में लॉजिस्टिक्स प्रबंधकों को सुविधा प्रदान करता है, जिससे उच्च सीपीएस मूल्य प्राप्त होता है। यह शोध मौजूदा साहित्य की मुख्य आइटम और फ़ैक्टर की पहचान करके एसएलपी को मापने में भी योगदान देता है। इस शोध के परिणामों ने संचालन पेशेवरों को एसएलपी के तीन फ़ैक्टर (यानी, संचालन प्रभावशीलता, पर्यावरण प्रदर्शन, और सामाजिक प्रदर्शन) के महत्व के बारे में भी बताया, उनके उच्च पाथ अनुमान के कारण, संचालन गतिविधियों से संबंधित स्थिरता के मुद्दों को समझने में। आखिरकार, एन आरबीवी और एस एचआरएम को एकीकृत करके, यह शोध एसएलपी पर जीआई और एसटी के प्रभाव को समझने के लिए संचालन पेशेवरों को सुविधा प्रदान करता है और यह दर्शाता है कि एसटी भारतीय संचालन क्षेत्र के लिए जीआई और एसएलपी के बीच संबंधों को पूरी तरह से मध्यस्थता करता है।

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LIST OF ABBREVIATIONS

AGFI	Adjusted Goodness of Fit Index
AHP	Analytical Hierarchy Process
ANP	Analytic Network Process
ASV	Average Shared Variance
AVE	Average Variance Extracted
BSC	Balanced Scorecard
CAGR	Compounded Annual Growth Rate
CAIC	Consistent Akaike Information Criterion
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CITC	Corrected Item-total Correlation
CMIE	Centre for Monitoring Indian Economy
CO	Cost
CPS	Competitive Performance Score
CR	Composite Reliability
CSF	Critical Success Factor
DEA	Data Envelopment Analysis
DFC	Dedicated Freight Corridor
DKIC	Delhi-Kolkata Industrial Corridor
DMIC	Delhi-Mumbai Industrial Corridor
DQ	Delivery of Quality Services
EC	Economic Dimension
EDI	Electronic Data Interchange
EF	Efficiency Dimension
EFA	Exploratory Factor Analysis
EM	Employing Advanced Technology Dimension
EN	Environmental Dimension
ENP	Environmental Performance
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
GDP	Gross Domestic Product
GHRM	Green Human Resource Management
GI	Green Innovation
GPS	Global Positioning System
GSCM	Green Supply Chain Management
GST	Goods and Service Tax
HRM	Human Resource Management
ICT	Information and Communication Technology
IDS	Intelligent Decision System
IN	Innovation
ISM	Interpretive Structural Modeling
ITS	Intelligent Transportation System
KMO	Kaiser-Meyer-Olkin
LDN	Logistics Differentiation
LES	Logistics Effectiveness
LEY	Logistics Efficiency
LPI	Logistics Performance Index
LSP	Logistics Service Provider
MCDM	Multi-criteria Decision Making
MSV	Maximum Shared Variance
NGO	Non-governmental Organization
NRBV	Natural Resource-based View
PCA	Principal Component Analysis
PEF	Performance Evaluation Framework
PI	Physical Internet

PLS	Partial Least Square
PMS	Performance Measurement System
PNFI	Parsimony Normed Fit Index
RBV	Resource-based View
RFID	Radio Frequency Identification
RMSEA	Root-mean-square Error of Approximation
RST	Rough sets Theory
SA	Safety Dimension
SEM	Structural Equation Modeling
SFT	Sustainable Freight Transportation
SHRM	Sustainable Human Resource Management
SLP	Sustainable Logistics Performance
SO	Social Dimension
SOLP	Sustainability of Operational Logistics Performance
SOP	Social Performance
SPI	Sustainability Performance Index
SSCM	Sustainable Supply Chain Management
ST	Sustainable Training
TFN	Triangular Fuzzy Number
TISM	Total Interpretive Structure Modeling
TLI	Tucker Lewis Index
TOPSIS	Technique for Order Preference by Similarity to the Ideal Solution
TQM	Total Quality Management
UFT	Urban Freight Transportation
VRIN	Valuable, Rare, Inimitable, and Non-substitutable
3BL	Triple Bottom Line
3PL	Third-party Logistics