

# **MODELLING RISK ISSUES IN PORT LOGISTICS**

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# **MODELLING RISK ISSUES IN PORT LOGISTICS**

by

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## CERTIFICATE

The Thesis entitled “**Modelling Risk Issues in Port Logistics**”, being submitted by **Mr. Bishal Dey Sarkar** to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy (Ph.D.)** is a record bona fide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has attained the standard required for a Ph.D. degree from the 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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“We don’t accomplish anything in this world alone”

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## **ABSTRACT**

The fourth industrial revolution is bringing about a series of technologies like Internet of Things (IoT), artificial intelligence (AI), blockchain, cloud computing, cyber-physical systems, smart manufacturing, sensors etc., in supply chain networks. Port Logistics is a crucial element of supply chain networks and it is inevitably affected by these significant changes. Port and shipping are considered as the key factors for the development and economic growth of a country. Port is not only a linkage between sea and land but it is also an economic concept. It can accommodate warehouses, logistics facilities, cities and industrial complexes that serves coastal and overseas traffic. Port Logistics is a term used to describe logistics and distribution services based at the ports where goods arrive.

Port logistics has been an important component of the Indian economy, accounting for more than 90% of Export/Import (EXIM) trade by volume and 72% by value. More than 1 billion tons of cargo was handled across 200 ports during the financial year 2015. In recent years, global transportation network evolves a lot and led to a situation where Indian ports lacks in necessary draft to handle the largest vessels, inefficiency due to poor hinterland connectivity through highways, road, rail, inland waterways and coastal shipping, inadequate cargo-handling equipment and machinery, inadequate navigational aids, lack of technical expertise and lack of facilities and IT systems. It is, therefore, necessary to assess the inefficiencies in the port logistics to ensure effective operation of ports. This requires a proper understanding of the barriers/inhibitors affecting the port logistics in Industry 4.0 era for emerging economies, risks associated with those barriers, their effect on different economic, environmental and operational criteria and various mitigation strategies to deal with the same. Analysis of previous research in context of Port Logistics highlighted the following areas, which needed further study which were taken up as research objectives:

- To develop a systematic framework for operational and technical issues in port logistics and to study port logistics performance in an Indian shipping port.
- To identify and model various barriers/inhibitors present in port logistics while using smart emerging technologies in the Industry 4.0 era.
- To do the severity analysis and risk profiling of the barriers/inhibitors involved in port logistics in the Industry 4.0 era.
- To develop a model to study the impact of the COVID-19 pandemic on port logistics and the Indian economy.

The first part of the study deals with the development of a comprehensive framework for managing port logistics issues. Issues related to loading/unloading, transit, storage (warehouse), customs clearance, regulatory authorities, port management unit and inland transport connection providers are studied. The study provides a conceptual model along with a final implementable model that would help concerned authorities such as state government, central government and policy-makers to have a profound understanding of the issues and challenges faced at different phases of port logistics. Further, the study aims to study the port logistics performance of an Indian Container Shipping Port which has posted a negative Compound Annual Growth Rate (CAGR) of 0.7 per cent for total traffic in the FY2012 – FY2016.

In the second part of the study, for emerging economies identification of key barriers for port logistics in Industry 4.0 era is carried out. It uses Total Interpretive Structural Modelling and Stakeholder's theory to develop a hierarchical model. It senses the significance of each stakeholder to understand and model the driver and dependence relationships between the barriers. Further, it classifies the barriers into the eight-levels hierarchical model. MICMAC analysis has been used to categorize the identified barriers into four clusters. Finding reveals some of the transitive and significant links, which helps stakeholders to sense the significant areas which need higher attention to restrict the port logistics barriers.

The third part of the research deals with the development of a quantification model to help decision-makers in achieving sustainability in port logistics in the era of Industry 4.0. The model ranks the barriers based on various criteria such as environment, economic and operational. The study is conducted in various phases. In the first phase, ERA is used to obtain the severity value and prioritize the barriers on various criteria. Further, fuzzy set theory is used to remove the vagueness in decision making and expected utility theory is used to obtain the crisp values of the barriers. In the second phase, a new approach has been proposed by changes the importance of criteria to develop a continuum of scenarios and to study the changing behavior of the barriers. Lastly, by identifying various risks associated with barriers of port logistics in Industry 4.0 era and categorize them into subparts based on their intensity.

The last part of the research is focused on developing a scenario-based interval-input-output model to analyze the risk of the COVID-19 pandemic on port logistics and the Indian economy. COVID-19 pandemic is considered as a disruption, which causes explicit threats to the economy of the country. The study investigates how different sectors are interconnected with each other, to analyze the effect of disruptions on matrices like inoperability and economic loss and studies how the effect of disruption propagates from one sector to other sectors.

This study concludes by deriving learnings from different phases and synthesis of research results. Major contributions and significant findings made through this research were also summarized. Various implications and contributions in the domain of port logistics for concerned policy-makers and decision-makers were also discussed. At last, the limitation of research and the scope of future research was also discussed.

**Keywords:** Port logistics, Container Shipping Port, Barriers, Risk profiling, Severity Analysis, TISM, FERA, SSM, SAP-LAP, Input-Output Modelling, Interval Programming, Economic Loss, Inoperability

## सार

चौथी औद्योगिक क्रांति आपूर्ति श्रृंखला नेटवर्क में इंटरनेट ऑफ थिंग्स (IoT), आर्टिफिशियल इंटेलिजेंस (AI), ब्लॉकचेन, क्लाउड कंप्यूटिंग, साइबर-फिजिकल सिस्टम, स्मार्ट मैनुफैक्चरिंग, सेंसर आदि जैसी तकनीकों की एक श्रृंखला ला रही है। बंदरगाह रसद आपूर्ति श्रृंखला नेटवर्क का एक महत्वपूर्ण तत्व है और यह इन महत्वपूर्ण परिवर्तनों से अनिवार्य रूप से प्रभावित होता है। किसी देश के विकास और आर्थिक विकास के लिए बंदरगाह और नौवहन को प्रमुख कारक माना जाता है। बंदरगाह न केवल समुद्र और भूमि के बीच एक कड़ी है बल्कि यह एक आर्थिक अवधारणा भी है। यह गोदामों, रसद सुविधाओं, शहरों और औद्योगिक परिसरों को समायोजित कर सकता है जो तटीय और विदेशी यातायात की सेवा करते हैं। बंदरगाहों को वैश्विक परिवहन नेटवर्क और एक जंक्शन के रूप में माना जाता है जहां यह परिवहन के अन्य साधनों से मिलता है। बंदरगाह रसद एक शब्द है जिसका उपयोग उन बंदरगाहों के आधार पर रसद और वितरण सेवाओं का वर्णन करने के लिए किया जाता है जहां माल आता है।

बंदरगाह रसद भारतीय अर्थव्यवस्था का एक महत्वपूर्ण हिस्सा रहा है। यह 90% से अधिक निर्यात / आयात व्यापार को मात्रा द्वारा और 72% मूल्य से स्थानांतरित करने के लिए जिम्मेदार है। वित्तीय वर्ष 2015 में, 1 बिलियन टन से अधिक कार्गो को 200 विभिन्न बंदरगाहों द्वारा संभाला गया था। वैश्विक परिवहन नेटवर्क की जटिलता एक ऐसी स्थिति पैदा करती है जहां भारत में सुविधाओं और आईटी प्रणालियों का अभाव है, तकनीकी विशेषज्ञता की कमी है, अपर्याप्त समुद्री मार्ग पथ प्रदर्शन की कमी है, कार्गो-हैंडलिंग उपकरण और मशीनरी का अभाव है और सबसे बड़े जहाजों को संभालने के लिए आवश्यक गहराई में कमी है। इसके लिए चौथी औद्योगिक क्रांति में उभरती अर्थव्यवस्थाओं के लिए बंदरगाह रसद को प्रभावित करने वाले अवरोधों/अवरोधकों की उचित समझ की आवश्यकता है, उन बाधाओं से जुड़े

जोखिम, आर्थिक, पर्यावरणीय और परिचालन मानदंड जैसे विभिन्न दृष्टिकोणों पर उनके प्रभाव। इसके अलावा, बाधाओं से निपटने के लिए विभिन्न शमन रणनीतियों की पहचान करना आवश्यक है।

बंदरगाह रसद के संदर्भ में पिछले शोध के विश्लेषण में निम्नलिखित क्षेत्रों पर प्रकाश डाला गया है। उन क्षेत्रों में आगे अध्ययन की आवश्यकता है और उन्हें अनुसंधान उद्देश्यों के रूप में लिया गया है।

- भारतीय शिपिंग पोर्ट के प्रदर्शन का अध्ययन करना और भारत में पोर्ट लॉजिस्टिक मुद्दों और चुनौतियों का एक व्यवस्थित ढांचा विकसित करना।
- चौथी औद्योगिक क्रांति के युग में उभरती प्रौद्योगिकियों का उपयोग करते हुए बंदरगाह रसद में मौजूद विभिन्न बाधाओं / अवरोधकों की पहचान और मॉडल करना।
- चौथी औद्योगिक क्रांति के युग में बंदरगाह रसद में शामिल बाधाओं/अवरोधकों का गंभीरता विश्लेषण और जोखिम रूपरेखा करना।
- बंदरगाह रसद और भारतीय अर्थव्यवस्था पर COVID-19 महामारी के प्रभाव का अध्ययन करने के लिए एक मॉडल विकसित करना।

अध्ययन का पहला भाग पोर्ट लॉजिस्टिक मुद्दों और चुनौतियों के प्रबंधन के लिए एक व्यापक ढांचे के विकास से संबंधित है। इस शोध में लोडिंग / अनलोडिंग, ट्रांजिट, स्टोरेज (वेयरहाउस), सीमा शुल्क निकासी, नियामक प्राधिकरण, पोर्ट मैनेजमेंट यूनिट और अंतर्देशीय परिवहन कनेक्शन प्रदाताओं से संबंधित मुद्दों और चुनौतियों का अध्ययन किया गया है। अध्ययन एक अंतिम कार्यान्वयन मॉडल के साथ एक वैचारिक मॉडल प्रदान करता है जो राज्य सरकार, केंद्र सरकार और नीति-निर्माताओं जैसे संबंधित अधिकारियों को विभिन्न चरणों में भारतीय बंदरगाह रसद प्रणाली द्वारा सामना किए गए मुद्दों और चुनौतियों की गहन समझ रखने में मदद करता है। इसके अलावा, अध्ययन का उद्देश्य एक भारतीय कंटेनर शिपिंग पोर्ट के बंदरगाह रसद प्रदर्शन का अध्ययन करना है, जिसने वित्त वर्ष 2012 - वित्त वर्ष

2016 में कुल यातायात के लिए -0.7 प्रतिशत की नकारात्मक चक्रवृद्धि वार्षिक वृद्धि दर (CAGR) पोस्ट की है।

अध्ययन के दूसरे भाग में, उभरती अर्थव्यवस्थाओं के लिए चौथी औद्योगिक क्रांति के युग में बंदरगाह रसद की प्रमुख बाधाओं का पहचान किया गया है। यह श्रेणीबद्ध मॉडल विकसित करने के लिए TISM और स्टेकहोल्डर के सिद्धांत का उपयोग करता है। यह प्रत्येक हितधारक के महत्व को पहचानता है। बाधाओं के बीच ड्राइविंग शक्ति और निर्भरता संबंधों को समझने और मॉडल करने के लिए। इसके अलावा, यह आठ-स्तरीय पदानुक्रमित मॉडल में बाधाओं को वर्गीकृत करता है। MICMAC विश्लेषण का उपयोग पहचान किए गए अवरोधों को चार समूहों में वर्गीकृत करने के लिए किया गया है। खोज से कुछ सकर्मक और महत्वपूर्ण लिंक का पता चलता है, जो हितधारकों को उन महत्वपूर्ण क्षेत्रों को समझने में मदद करता है, जिन्हें बंदरगाह रसद बाधाओं को रोकने के लिए उच्च ध्यान देने की आवश्यकता है।

शोध का तीसरा हिस्सा चौथी औद्योगिक क्रांति के युग में बंदरगाह रसद में स्थिरता प्राप्त करने में निर्णय लेने वालों की मदद करने के लिए एक परिमाणीकरण मॉडल के विकास से संबंधित है। मॉडल पर्यावरण, आर्थिक और परिचालन जैसे विभिन्न मानदंडों के आधार पर बाधाओं को रैंक करता है। अध्ययन विभिन्न चरणों में आयोजित किया जाता है, पहले चरण में, ईआरए का उपयोग गंभीरता मूल्य प्राप्त करने और विभिन्न मानदंडों पर बाधाओं को प्राथमिकता देने के लिए किया गया है। इसके अलावा, फजी सेट सिद्धांत का उपयोग निर्णय लेने में अस्पष्टता को दूर करने के लिए किया जाता है और अपेक्षित उपयोगिता सिद्धांत का उपयोग बाधाओं के कुरकुरा मूल्यों को प्राप्त करने के लिए किया गया है। दूसरा चरण परिदृश्यों के एक निरंतरता को विकसित करके बाधाओं के बदलते व्यवहार और अन्योन्याश्रयता से संबंधित है। अंत में, चौथी औद्योगिक क्रांति के युग में बंदरगाह रसद की बाधाओं से जुड़े विभिन्न जोखिमों की पहचान करके और उनकी तीव्रता के आधार पर उन्हें उप-भागों में वर्गीकृत किया गया है।

अनुसंधान का अंतिम भाग बंदरगाह रसद और भारतीय अर्थव्यवस्था पर COVID-19 महामारी के जोखिम का विश्लेषण करने के लिए परिदृश्य आधारित अंतराल-इनपुट-आउटपुट मॉडल विकसित करने पर केंद्रित है। COVID-19 महामारी को एक व्यवधान के रूप में माना जाता है, जो देश की अर्थव्यवस्था के लिए स्पष्ट खतरे का कारण बनता है। अध्ययन इस बात की जाँच करता है कि विभिन्न क्षेत्र एक दूसरे से कैसे जुड़े हैं और यह जाँच करता है कि कैसे विघटन का प्रभाव एक क्षेत्र से दूसरे क्षेत्रों तक फैलता है। विघटन के प्रभाव का अध्ययन करने के लिए यह अक्षमता और आर्थिक नुकसान जैसे मेट्रिक्स का उपयोग करता है।

अनुसंधान के इस भाग में संपूर्ण शोध, इसके प्रमुख योगदान और इस शोध के माध्यम से किए गए महत्वपूर्ण निष्कर्षों पर चर्चा करता है। इस शोध के माध्यम से संबंधित नीति-निर्माताओं और निर्णय-निर्माताओं के लिए बंदरगाह रसद के क्षेत्र में विभिन्न निहितार्थ और योगदान पर भी चर्चा की गई है। शोध अंत में, शोध की सीमा और भविष्य के अनुसंधान के दायरे पर भी चर्चा की गई है।

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## ABBREVIATIONS

AHP:	Analytic Hierarchy Process
ANCOVA:	Analysis of Covariance
ANOVA:	Analysis of Variance
ANP:	Analytic Network Process
ARIMA:	Autoregressive Integrated Moving Average
BAP:	Berth Allocation Problem
BCBA:	Brihanmumbai Custom Brokers Association
BI:	Bureau of Immigration
BMCT:	Bharat Mumbai Container Terminal
BPCL:	Bharat Petroleum Corporation Limited
BRP:	Behavioural Risk Profiling
CAGR:	Compound Annual Growth Rate
CCI:	Container Corporation of India Ltd
CFS:	Container Freight Stations
COVID:	Corona Virus Disease
CR:	Central Railway
CSLA:	Container Shipping Lines Association
DOE:	Design of Experiment
DPDS:	Direct Port Delivery System
EDI:	Electronic Data Interchange
ER:	Evidential Reasoning
ERA:	Evidential Reasoning Approach
EUT:	Expected Utility Theory
EXIM:	Export/Import
FERA:	Fuzzy-Evidential Reasoning Approach
FEU:	Forty-Foot Equivalent Unit
FFFAI:	Federation of Freight Forwarders' Associations in India
FST:	Fuzzy Set Theory
GAIN:	Galician Innovation Agency
GDP:	Gross Domestic Product
GPS:	Global Positioning System

ICC:	Indian Coastal Conference
ICD:	Inland Container Depots
ICT:	Information and Communications Technology
IHC:	Inland Hauling Charges
IIM:	Input-Output Modelling
IM:	Interdependency Matrix
IN:	Indian Navy
IP:	Interval Programming
IPPTA:	Indian Private Ports & Terminals Association
ISM:	Interpretive Structural Modelling
IT:	Information Technology
IWAI:	Inland Waterways Authority of India
JNPCT:	Jawaharlal Nehru Port Container Terminal
JNPT:	Jawaharlal Nehru Port Trust
KPI:	Key Performance Indicators
LPG:	Liberalization, Privatization, Globalization
MADA:	Multiple Attribute Decision Analysis
MANSA:	Maritime Association of Nationwide Shipping Agencies
MCDM:	Multiple-criteria decision-making
NHAI:	National Highways Authority of India
NPA:	National Port Authority
NSICT:	Nhava Sheva International Container Terminal
OCR:	Optical Character Recognition
OECD:	Organisation for Economic Cooperation and Development
ONE:	Ocean Network Express
ORA:	Organization Risk Analyser
PL:	Port Logistics
POL:	Petroleum, oil and lubricants
PTD:	Port Traffic Department
QCAP:	Quay Crane Assignment Problem
QCSP:	Quay Crane Scheduling Problem
RFID:	Radio-frequency identification
RMS:	Risk Management System

SAP-LAP:	Situation-Actor-Process-Learning-Action-Performance
SEM:	Structural Equation Model
SL:	Shipping Lines
SSM:	Soft System Methodology
SWIFT:	Single Window Interface for Trade
TAMP:	Tariff Authority for Major Ports
TEU:	Twenty-Foot Equivalent Unit
TFN:	Triangular Fuzzy Number
THC:	Terminal Handling Charges
TISM:	Total Interpretive Structural Modelling
TOPSIS:	Technique for Order of Preference by Similarity to Ideal Solution
UNCTAD:	United Nations Conference on Trade And Development
VIKOR:	VlseKriterijumska Optimizacija I Kompromisno Resenje
VUCA:	Volatile, Uncertain, Complex and Ambiguous