

**THROUGHPUT FORECASTING, BLOCKCHAIN AND
SOCIAL MEDIA AFFORDANCES IN CONTAINER SUPPLY
CHAIN INDUSTRY: A MIXED METHOD STUDY**

By

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DEDICATED TO MY BELOVED MOTHER,

TARUNA SHANKAR

ज्ञान पाप हो जाता है अगर उद्देश्य शुभ ना हो।

CERTIFICATE

This is to certify that the thesis entitled “**Throughput Forecasting, Blockchain and Social Media Affordances in Container Supply Chain Industry: A Mixed Method Study**” being submitted by Sonali Shankar 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 the thesis, which has reached the requisite standard.

The results contained 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

An information system (IS) collects data from various business processes and analyzes them for strategic, tactical, and operational decision-making. The growing availability of large data and recent advances in machine learning have enabled IS driven solutions in solving the problems in the operations and supply chain management field. Traditionally, problems of supply chain management were largely tackled through mathematical modeling and optimization and, in a few cases, through empirical studies. In recent years, the focus of research is using cutting-edge technologies like artificial intelligence, blockchain technology, and data analytics for solving the business problems. The integration of IS has the potential to derive rules for effective directions and optimization of the operations and supply chain management practices.

The present thesis examines issues touching upon the interaction of IS and container supply chain areas. The inter-continental transportation of cargo is carried out in standardized units of transfer known as containers. The container supply chain is one of the most crucial supply chains for globalization and involves a large number of stakeholders like port authority, shipping liners, freight forwarders, 3PL (third party logistics) and others. Efficient use of IS tools and techniques can render huge cost benefits for the entire container supply chain. The thesis uses a mixed-method approach to study three elements of information systems, namely, *process* (machine learning-based forecasting process), *technology* (blockchain technology), and *people* (container logistics industry responses or people via social media) in the context of the container supply chain.

Decision-makers use data-based models to extrapolate the patterns in historical data to get insights about the future, incorporate into the optimization models to derive effective solutions for the business problems. Deriving insights about future outcomes is known as predictive analytics. The process of forecasting is used at all three decision levels (strategic, tactical, and operational) for better management of capital, resources, and manpower. In this study, a new process of forecasting using machine learning-based models is explored, and a deep learning-based (long short-term memory network, LSTM) predictive analytics model is developed for container throughput forecasting.

The research work is extended by accommodating the influence of external variables on container throughput forecasting. In doing so, a novel deep learning-based hybrid forecasting model (ARIMAX-LSTM) is proposed that takes into account the influence of 19 factors delineated by Triple-Bottom-Line (environment, economic, and social).

The thesis focuses on an emerging technology, blockchain and its potential adoption or use in the container logistics industry. It uses qualitative research to collect and analyze the data. Qualitative approach is considered suitable as the extant research is limited and objective was exploratory in nature. The extant literature shares a very limited use cases of blockchain in the container supply chain available on an open platform. Data were collected using in-depth, semi-structured interviews with 18 experts from the container supply chain and blockchain industries. Braun & Clarke's (2006) step-wise method was utilized for thematic analysis. This led to the identification of major themes from the data responses. This study also uses secondary data provided by the experts that are relevant for the study. Theory of affordances is employed to analyze the data and determine the potential solutions to the contemporary challenges of container supply chain using blockchain technology. This

study extends the theory of affordances while studying the success and failure of the technology used in an organization.

After studying the technology and process components, the thesis looks at the people component by studying responses of the container logistics firms to COVID 19, using social media analytics. The COVID19 pandemic has influenced the lives of people all around the globe, directly or indirectly. The impact on the logistics industry was significant, and how did these firms respond to the same with respect to the customers. Social media analytics is carried out using machine learning techniques to determine the emergence of social media affordances during the pandemic. The theory of affordances is employed to study the tweets of container logistics firms listed in Fortune-500 and Alphaliner-100 lists. A total of 48 firms were considered for the analysis. An initial set of data resulted in over 14000 tweets collected over a period of 3 months when the first wave of Covid19 was at its peak. The study presents the synthesis of the a) information dissemination, b) emerging roles of the container logistics firms, and; c) social media affordances and collective engagement of the firms during the pandemic.

The proposed models and methodologies have numerous applications across supply chains of various industries, such as food, agriculture, pharmaceutical, and others.

सार

एक सूचना प्रणाली (आईएस) विभिन्न व्यावसायिक प्रक्रियाओं से डेटा एकत्र करती है और रणनीतिक, सामरिक और परिचालन निर्णय लेने के लिए उनका विश्लेषण करती है। बड़े आँकड़ों की बढ़ती उपलब्धता और मशीन लर्निंग के क्षेत्र में हाल ही का प्रगति ने संचालन और आपूर्ति श्रृंखला प्रबंधन क्षेत्र में समस्याओं के लिए सूचना प्रणाली-आधारित समाधान विकसित करने पर संगठनों का ध्यान आकर्षित किया है। परंपरागत रूप से, आपूर्ति श्रृंखला प्रबंधन की समस्याओं को बड़े पैमाने पर गणितीय मॉडलिंग और अनुकूलन के माध्यम से और कुछ मामलों में अनुभवजन्य अध्ययनों के माध्यम से निपटाया जाता था। हाल के वर्षों में, अनुसंधान का ध्यान मशीन लर्निंग (कृत्रिम बुद्धिमत्ता), ब्लॉकचैन प्रौद्योगिकी, डेटा विश्लेषण जैसी अत्याधुनिक तकनीकों का उपयोग करके आपूर्ति श्रृंखला प्रबंधन की व्यावसायिक समस्याओं को हल करने की ओर बढ़ रहा है। आपूर्ति श्रृंखला प्रबंधन के लिए सूचना प्रणालियों के एकीकरण में संचालन और आपूर्ति श्रृंखला के प्रभावी अनुकूलन के लिए नियम प्राप्त करने की क्षमता है।

यह अध्ययन आईएस और कंटेनर आपूर्ति श्रृंखला क्षेत्रों की बातचीत से संबंधित मुद्दों की जांच करती है। माल के अंतर-महाद्वीपीय परिवहन को कंटेनर के रूप में ज्ञात स्थानांतरण की मानकीकृत इकाइयों में किया जाता है। कंटेनर आपूर्ति श्रृंखला वैश्वीकरण के लिए सबसे महत्वपूर्ण आपूर्ति श्रृंखलाओं में से एक है और इसमें बड़ी संख्या में हितधारक शामिल हैं जैसे पोर्ट अथॉरिटी, शिपिंग लाइनर्स, फ्रेट फारवर्डर, 3PL (थर्ड पार्टी लॉजिस्टिक्स), आदि। सूचना प्रणाली उपकरणों और तकनीकों का कुशल उपयोग संपूर्ण कंटेनर आपूर्ति श्रृंखला के लिए भारी लाभ प्रदान कर सकता है। नतीजतन, यह निबंध सूचना प्रणाली के तीन तत्वों, अर्थात् प्रक्रिया (मशीन लर्निंग-आधारित पूर्वानुमान प्रक्रिया), प्रौद्योगिकी (ब्लॉकचैन प्रौद्योगिकी), और लोगों (सोशल मीडिया के माध्यम से कंटेनर आपूर्ति श्रृंखला के लोग), को कंटेनर आपूर्ति श्रृंखला संदर्भ में अध्ययन करने के लिए एक मिश्रित-विधि दृष्टिकोण का उपयोग करती है।

निर्णयकर्ता भविष्य के बारे में अंतर्दृष्टि प्राप्त करने के लिए डेटा-आधारित मॉडल विकसित करते हैं और फिर व्यावसायिक समस्याओं का प्रभावी समाधान प्राप्त करने के लिए अंतर्दृष्टि का उपयोग अनुकूलन मॉडल में करते हैं। भविष्य के परिणामों के बारे में अंतर्दृष्टि प्राप्त करना भविष्य कहनेवाला विश्लेषण के रूप में जाना जाता है। पूंजी, संसाधनों और जनशक्ति के बेहतर प्रबंधन के लिए सभी तीन निर्णय स्तरों (रणनीतिक, सामरिक और परिचालन) पर पूर्वानुमान की यह प्रक्रिया का उपयोग किया जाता है। इस अध्ययन में मशीन लर्निंग-आधारित मॉडल का उपयोग करके पूर्वानुमान की नई प्रक्रिया का पता लगाया गया है, और कंटेनर थ्रूपुट पूर्वानुमान के लिए एक डीप लर्निंग -आधारित (दीर्घकालिक अल्पकालिक स्मृति संजाल) भविष्य कहनेवाला विश्लेषण मॉडल विकसित किया गया है। कंटेनर थ्रूपुट पूर्वानुमान पर बाहरी पर्यावरण के प्रभाव को समायोजित किया गया है। ऐसा करने के लिए, एक डीप लर्निंग-आधारित हाइब्रिड पूर्वानुमान मॉडल प्रस्तावित किया है जो ट्रिपल-बॉटम-लाइन (पर्यावरण, आर्थिक और सामाजिक) द्वारा चित्रित 19 कारकों के प्रभाव को ध्यान में रखता है।

कंटेनर आपूर्ति श्रृंखला में नई प्रौद्योगिकी (ब्लॉकचैन) का अध्ययन करने के लिए एक पद्धतिगत विकल्प के रूप में गुणात्मक शोध को चुना है। गुणात्मक दृष्टिकोण को उपयुक्त माना जा सकता है क्योंकि कंटेनर आपूर्ति श्रृंखला में लोग ब्लॉकचैन तकनीक से परिचित नहीं है, जोकि कंटेनर आपूर्ति श्रृंखला में ब्लॉकचैन के उपयोग के बहुत सीमित उदाहरण से स्पष्ट है। इस अध्ययन में कंटेनर आपूर्ति श्रृंखला और ब्लॉकचैन उद्योगों के अठारह विशेषज्ञों के अर्ध-संरचित साक्षात्कार को सम्मिलित किया है। विषयगत विश्लेषण के लिए चरण-वार पद्धति का उपयोग किया गया है। इससे डेटा प्रतिक्रियाओं से प्रमुख विषयों की पहचान हुई। इस अध्ययन में विशेषज्ञों द्वारा उपलब्ध कराए गए द्वितीयक आंकड़े भी शामिल हैं जो अध्ययन के लिए प्रासंगिक हैं। डेटा का विश्लेषण करने और ब्लॉकचैन प्रौद्योगिकी का उपयोग करके कंटेनर आपूर्ति श्रृंखला की समकालीन चुनौतियों के संभावित समाधान निर्धारित करने के लिए अफोर्डेस के सिद्धांत को नियोजित किया जाता है। यह अध्ययन एक संगठन में उपयोग की जाने वाली तकनीक की सफलता और विफलता का अध्ययन करने से लेकर संगठन में संबंधित चुनौतियों के लिए अनुवांशिक विश्लेषण प्रदान करता है व अफोर्डेस के सिद्धांत का विस्तार करता है।

इस अध्ययन में सोशल मीडिया विश्लेषण का उपयोग करने वाले लोगों के कंटेनर रसद फर्मों का अध्ययन भी शामिल है। इस अध्ययन की अवधि के दौरान कोविड-१९ महामारी की एक दुर्भाग्यपूर्ण घटना घटी। कोविड-19 महामारी ने प्रत्यक्ष या अप्रत्यक्ष रूप से दुनिया भर के लोगों के जीवन को प्रभावित किया है और यह उनके जीवन का एक महत्वपूर्ण अध्याय बन गया है। शोधकर्ताओं ने इस अध्ययन में भी महामारी के अध्याय को समायोजित करने का प्रयास किया है। महामारी के दौरान सोशल मीडिया के अफोर्डेंस के उद्भव को निर्धारित करने के लिए मशीन लर्निंग तकनीकों का उपयोग करके सोशल मीडिया विश्लेषण किया है। अफोर्डेंस के सिद्धांत को अध्ययन करने के लिए फॉर्च्यून-५०० और अल्फालाइनर-१०० सूचियों में सूचीबद्ध कंटेनर रसद फर्मों के ट्वीट्स का उपयोग किया गया है। विश्लेषण के लिए कुल 48 फर्मों पर विचार किया गया। 3 महीने की अवधि में 14000 से अधिक ट्वीट एकत्र किए गए। अध्ययन निम्नलिखित के संश्लेषण को प्रस्तुत करता है: क) सूचना प्रसार, ख) कंटेनर रसद फर्मों की उभरती भूमिकाएं, और; ग) महामारी के दौरान सोशल मीडिया के अफोर्डेंस और फर्मों की सामूहिक भागीदारी।

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LIST OF ABBREVIATION

ANN: Artificial neural network

AR: Autoregressive

ARIMA: Autoregressive integrated moving average

ARIMAX: Autoregressive integrated moving average with external regressors

ARMAE: Average relative mean absolute error

ARMAPE: Average relative mean absolute percentage error

ARME: Average relative mean error

ARMSE: Average relative mean squared error

B2B: Business-to-business

BC: Blockchain

CAE: Connective action episode

CE: Collective engagement

CF: Conversion factor

CFS: Container freight station

CL: Container logistics

CSC: Container supply chain

CT: Container throughput

DES: Double exponential smoothing

DM: Diebold and Mariano Test

DP: Dry port

EDI: Electronic data interchange

ES: Exponential smoothing

ETS: Error, trend and seasonality

FC: Facilitating condition

ICD: Inland container depot

ICT: Information and communications technology

IE: Information extraction

IR: Information retrieval

IS: Information systems

LSTM: Long short memory network

MA: Moving Average

MAE: Mean absolute error

MAPE: Mean absolute percentage error

ME: Mean error

PC1: Principal component one

PC2: principal component two

PCA: Principal components analysis

PLA: Port of Los Angeles

PSA: Port of Singapore authority

ReLU: Rectified linear unit

RMSE: Root mean squared error

RNN: Recurrent neural network

SARIMA: Seasonal autoregressive integrated moving average

SCM: Supply chain management

SES: Simple exponential smoothing

SVR: Support vector machine

TBATS: Trigonometric, box-cox transform, ARMA errors, trend and seasonal

TEU: Twenty equivalent unit

TPE: Tree-structured parzen estimator approach

UNCTAD: United Nations conference on trade and development

VAR: Vector autoregression

WMW: Wilcoxon-Mann-Whitney

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