

OPTIMIZING OPERATIONS USING BIG DATA: MODELS AND METHODOLOGIES

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OPTIMIZING OPERATIONS USING BIG DATA: MODELS AND METHODOLOGIES

by

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CERTIFICATE

This is to certify that the thesis entitled "**Optimizing Operations Using Big Data: Models And Methodologies**" being submitted by **Kuldeep Lamba** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy** is a bona fide record of original 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 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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(Kuldeep Lamba)

ABSTRACT

Big Data has been steadily gaining prominence in the last decade. It has been applied extensively in banking sectors, retail industries and government agencies for analyzing spending behavior of customers, security and fraud detection, sentiment analysis etc. However, Big Data application in Operations and Supply Chain Management (OSCM) is relatively new. Even though, most organizations expect huge benefits from Big Data applications in their supply chains, the actual use is much less and a fairly large number of firms fail to unveil its business value. Big Data involves huge volumes of data capturing and its accurate analysis. Information technology plays a vital role in it. The use of various information technology enabled infrastructure (e.g. enterprise resource planning (ERP), radio frequency identification (RFID), internet of things (IoT), cloud computing and electronic data interchange (EDI)) in OSCM enable a firm to effectively maintain control over its information, material and financial flows. The benefits of integration of these technologies in OSCM have been studied by many researchers in the past. However, the integration of Big Data in OSCM from the viewpoint of 3V i.e., volume, velocity and variety concept is still an unexplored territory.

Various processes involved in OSCM generate hugely voluminous data having the essential 3V characteristics of Big Data. This Big Data has huge potential to unravel the hidden business insights that can help an organization outperform its competitors. Due to the substantial benefits of Big Data in OSCM, this field of study has been continuously growing from just an emerging area, not a long back to a full-fledged research area at present, drawing attention of practicing professionals from industry as well as academicians worldwide in equal measures. Many theoretical frameworks on Big Data for OSCM have been proposed. However, the complexities

associated with the 3V concept of Big Data have generally not been addressed in these frameworks. This research proposes Big Data frameworks in three key domains of OSCM namely, procurement, joint procurement and carrier selection, and facility layout problem.

This research further identifies and analyzes the interactions among various enablers which are critical to the success of Big Data initiatives in OSCM. For this purpose, fourteen enablers of Big Data in OSCM have been selected from literature and consequent deliberations with experts from industry. Three different multi criteria decision making techniques (MCDM) namely, interpretive structural modeling (ISM), fuzzy total interpretive structural modeling (Fuzzy-TISM), and decision making trial and evaluation laboratory (DEMATEL) have been used to identify driving enablers. Further, common enablers from each technique, their hierarchies and inter-relationships have been established.

The research then attempts to model the supplier selection and lot-sizing problem using Big Data, with a view of overall reduction in the procurement cost as well as carbon emissions. The parameters used in the mathematical model are chosen so as to represent 3V dimensions of Big Data. Carbon emissions caused due to ordering, holding the inventory, production and handling and transportation have been considered. The proposed mathematical model is a mixed-integer-non-linear-program (MINLP). Further, for the purpose of evaluating the carbon emissions, three different carbon regulating policies namely, carbon cap-and-trade, strict cap on carbon emissions and carbon tax on emissions, have been considered and insights are drawn. The validation of the proposed MINLP has been done using a randomly generated dataset mapped on the 3V parameters of Big Data, i.e. volume, velocity, and variety.

The research further explores the integration of Big Data in the domain of dynamic cellular facility layout problem (DCFLP). The 3Vs of Big Data are mapped to FLP, which has been

formulated as MINLP. Principal component analysis (PCA) is used to reduce the number of factors affecting layout design. A simulated annealing (SA) based metaheuristic has been used to solve the model and for generating different dynamic layout pools. Three different MCDM techniques namely, interpretive ranking process (IRP), weighted-IRP and The Techniques for Order of Preference by Similarity to Ideal Solution (TOPSIS) are utilized to rank the layouts. Finally, an aggregated ranking is derived using an integer linear programming based method to select the best layout.

Lastly, thesis is concluded by highlighting the major contributions of this research work, and suggesting some directions for the future research.

Keywords: Big Data, Operations and Supply Chain Management (OSCM), facility layout problem (FLP), procurement problem, supplier selection, order allocation, cellular facility layout, MCDM

सार

बिग डेटा पिछले एक दशक में लगातार प्रमुखता हासिल कर रहा है। यह बड़े पैमाने पर बैंकिंग क्षेत्रों, खुदरा उद्योगों और सरकारी एजेंसियों में ग्राहकों के खर्च व्यवहार, सुरक्षा और धोखाधड़ी का पता लगाने, भावनाओं का पता लगाने, इत्यादि के विश्लेषण करने के लिए उपयोग किया गया है। हालांकि, ऑपरेशंस एंड सप्लाइ चैन मैनेजमेंट (ओएससीएम) में बिग डेटा एप्लीकेशन अपेक्षाकृत नया है। हालांकि, अधिकांश संगठन अपनी आपूर्ति श्रृंखलाओं में बिग डेटा अनुप्रयोगों से भारी लाभ की उम्मीद करते हैं, लेकिन वास्तविक उपयोग बहुत कम है और काफी बड़ी संख्या में फर्म इसके व्यावसायिक मूल्य का अनावरण करने में विफल रहती हैं। बिग डेटा में बड़ी मात्रा में डेटा कैचरिंग और उसका सटीक विश्लेषण शामिल है। सूचना प्रौद्योगिकी इसमें अहम भूमिका निभाती है। ओएससीएम में विभिन्न सूचना प्रौद्योगिकी सक्षम इंफ्रास्ट्रक्चर (उदाहरण के लिए एंटरप्राइज़ रिसोर्स प्लानिंग (ERP), रेडियो फ्रीक्वेंसी आइडेंटिफिकेशन (RFID), इंटरनेट ऑफ थिंग्स (IoT), क्लाउड कंप्यूटिंग और इलेक्ट्रॉनिक डेटा इंटरचेंज (EDI) का उपयोग एक फर्म को प्रभावी ढंग से अपनी जानकारी, सामग्री और वित्तीय प्रवाह पर नियंत्रण में रखने में सक्षम बनाता है। ओएससीएम में इन प्रौद्योगिकियों के एकीकरण के लाभों का अध्ययन अतीत में कई शोधकर्ताओं द्वारा किया गया है। हालांकि, 3वीं अर्थात् वॉल्यूम, वेलोसिटी, और वैरायटी की अवधारणा से ओएससीएम में बिग डेटा का एकीकरण अभी भी एक अस्पष्टीकृत क्षेत्र है।

ओएससीएम में शामिल विभिन्न प्रक्रियाएं बड़ी मात्रा में बिग डेटा की आवश्यक 3 वीं विशेषताओं के साथ अत्यधिक मात्रा में डेटा उत्पन्न करती हैं। इस बिग डेटा में छिपी हुई व्यापार अंतर्दृष्टि को उजागर करने की बड़ी क्षमता है जो एक संगठन को अपने प्रतिद्वंद्वियों को बेहतर बनाने में मदद कर सकता है। ओएससीएम में बिग डेटा के पर्याप्त लाभों के कारण, अध्ययन का यह क्षेत्र केवल कुछ सालों पूर्व एक उभरते हुए क्षेत्र से वर्तमान में एक पूर्ण अनुसंधान क्षेत्र के रूप में लगातार बढ़ रहा है, और उद्योग से पेशेवरों के साथ-साथ

शिक्षाविदों का भी ध्यान समान रूप से आकर्षित कर रहा है। ओएससीएम के लिए बिग डेटा पर कई सैद्धांतिक रूपरेखाएं प्रस्तावित की गई हैं। हालाँकि, बिग डेटा की 3वीं अवधारणा से जुड़ी जटिलताओं को आम तौर पर इन रूपरेखाओं में संबोधित नहीं किया गया है। यह शोध ओएससीएम के तीन प्रमुख डोमेन अर्थात् खरीद, संयुक्त खरीद और वाहक चयन और सुविधा लेआउट समस्या में बिग डेटा फ्रेमवर्क का प्रस्ताव करता है।

यह शोध आगे चलकर विभिन्न बिग डेटा एनाल्लर्स के बीच संबंध की पहचान और विश्लेषण करता है जो ओएससीएम में बिग डेटा पहल की सफलता के लिए महत्वपूर्ण हैं। इस प्रयोजन के लिए, ओएससीएम में बिग डेटा के चौदह एनाल्लर्स को साहित्य और उद्योग के विशेषज्ञों के साथ विचार-विमर्श से चुना गया है। तीन अलग-अलग मल्टी मानदंड निर्णय लेने की तकनीक (एमसीडीएम) अर्थात्, व्याख्यात्मक संरचनात्मक मॉडलिंग (आईएसएम), फजी कुल व्याख्यात्मक संरचनात्मक मॉडलिंग (फ़ज़ी-टीआईएसएम), और डीमाटेल (DEMATEL) का उपयोग ड्राइविंग एनाल्लर्स की पहचान करने के लिए किया गया है। इसके अलावा, प्रत्येक तकनीक, उनके पदानुक्रमों और अंतर-संबंधों से आम प्रवर्तक स्थापित किए गए हैं।

फिर शोध में आपूर्तिकर्ता के चयन और आदेश की मात्रा की समस्या को बिग डेटा का उपयोग करते हुए मॉडल करने का प्रयास किया गया है। खरीद लागत के साथ-साथ कार्बन उत्सर्जन में समग्र कमी के दृष्टिकोण के साथ। गणितीय मॉडल में उपयोग किए जाने वाले मापदंडों को इस प्रकार चुना गया है कि बिग डेटा के 3वीं आयामों का प्रतिनिधित्व किया जा सके। ऑर्डर देने, इनवेंटरी रखने, उत्पादन और हैंडलिंग और परिवहन के कारण कार्बन उत्सर्जन पर विचार किया गया है। प्रस्तावित गणितीय मॉडल एक मिश्रित-पूर्णांक-गैर-रैखिक-कार्यक्रम (MINLP) है। इसके अलावा, कार्बन उत्सर्जन के मूल्यांकन के उद्देश्य से, तीन अलग-अलग कार्बन विनियमन नीतियों जैसे कि कार्बन कैप-एंड-ट्रेड, कार्बन उत्सर्जन पर सख्त कैप और उत्सर्जन पर कार्बन टैक्स, पर विचार किया गया है और अंतर्दृष्टि तैयार की गई हैं। प्रस्तावित MINLP का सत्यापन बिग

डेटा के 3वीं मापदंडों, यानी वॉल्यूम, वेलोसिटी, और वैरायटी पर मैप किए गए यादृच्छिक ढंग से उत्पन्न डेटासेट का उपयोग करके किया गया है।

अनुसंधान आगे गतिशील सेलुलर सुविधा लेआउट समस्या (डी सी एफ अल पी) के क्षेत्र में बिग डेटा के एकीकरण की पड़ताल करता है। बिग डेटा के 3वीं को एफ अल पी में मैप किया गया है, जिसे ऍम आई एन अल पी (MINLP) के रूप में तैयार किया गया है। प्रमुख घटक विश्लेषण (पीसीए) का उपयोग लेआउट डिजाइन को प्रभावित करने वाले कारकों की संख्या को कम करने के लिए किया जाता है। मॉडल को हल करने के लिए और विभिन्न गतिशील लेआउट पूल बनाने के लिए एक सिमुलेटेड एनीलिंग (SA) आधारित मेटाहेयूरिस्टिक का उपयोग किया गया है। तीन अलग-अलग एमसीडीएम तकनीकों अर्थात्, व्याख्यात्मक रैंकिंग प्रक्रिया (आई आर पी), भारित-आई आर पी और तकनीक के लिए ऑर्डर ऑफ वरीयता द्वारा समान समाधान से आदर्श समाधान (टोप्सिस) का उपयोग लेआउट को रैंक करने के लिए किया जाता है। अंत में, एक सर्वश्रेष्ठ रैंकिंग का चयन करने के लिए एक पूर्णांक रैखिक प्रोग्रामिंग आधारित पद्धति का उपयोग करके एक एकत्रित रैंकिंग प्राप्त की जाती है।

अंत में, थीसिस इस शोध कार्य के प्रमुख योगदानों को उजागर करके, और भविष्य के अनुसंधान के लिए कुछ दिशाओं का सुझाव देकर संपन्न की जाती है।

कीवर्ड: बिग डेटा, ऑपरेशंस एंड सप्लाय चैन मैनेजमेंट (ओएससीएम), सुविधा लेआउट समस्या (एफ अल पी), खरीद समस्या, आपूर्तिकर्ता चयन, ऑर्डर आवंटन, सेलुलर सुविधा लेआउट, एमसीडीएम

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LIST OF ABBREVIATIONS

OSCM	Operations And Supply Chain Management
ERP	Enterprise Resource Planning
RFID	Radio Frequency Identification
EOBR	Electronic On-Board Recorder
GDP	Gross Domestic Product
GPS	Global Positioning System
EDI	Electronic Data Interchange
EOQ	Economic Order Quantity
WIP	Work-in-progress
IoT	Internet Of Things
MCDM	Multi Criteria Decision Making Techniques
ISM	Interpretive Structural Modeling
SSIM	Structural Self Interaction Matric
TISM	Total Interpretive Structural Modeling
DEMATEL	Decision Making Trial And Evaluation Laboratory
IRP	Interpretive ranking process
TOPSIS	The Techniques for Order of Preference by Similarity to Ideal Solution
AHP	Analytical Hierarchy Process
ILP	integer linear program
MHD	material handling distance
MINLP	Mixed-Integer-Non-Linear-Program
FLP	Facility Layout Problem
DCFLP	Dynamic Cellular Facility Layout Problem
EEC	Electric Energy Consumption
PCA	Principal Component Analysis
SA	Simulated Annealing
ACO	Ant Colony Optimization
GA	Genetic Algorithm