

MODELLING OF OPERATIONAL ISSUES IN HUMANITARIAN SUPPLY CHAINS

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MODELLING OF OPERATIONAL ISSUES IN HUMANITARIAN SUPPLY CHAINS

by

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CERTIFICATE

The thesis entitled ‘Modelling of operational issues in humanitarian supply chains’, being submitted by Mr. Ashish Kumar Kaushal to the Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy (Ph. D.) is a record of bonafide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for submission of this thesis, which has attained the standard required for Ph. D. degree of this institute. The results presented in this thesis have not been submitted in part or in full to any other university or institute for award of any degree or diploma.

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गुरुर्ब्रह्मा गुरुर्विष्णुः गुरुर्देवो महेश्वरः । गुरुः साक्षात् परं ब्रह्म तस्मै श्री गुरवे नमः ॥

भावार्थः

गुरु ब्रह्मा है, गुरु विष्णु है, गुरु हि शंकर है; गुरु हि साक्षात् परब्रह्म है; उन सद्गुरु को प्रणाम ।

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दृष्टान्तो नैव दृष्टस्त्रिभुवनजठरे सद्गुरोर्ज्ञानदातुः स्पर्शश्चेत्तत्र कलप्यः स नयति यदहो स्वहृतामश्मसारम् । न स्पर्शत्वं तथापि श्रितचरगुणयुगे सद्गुरुः स्वीयशिष्ये स्वीयं साम्यं विधत्ते भवति निरुपमस्तेवालौकिकोऽपि ॥

भावार्थः

तीनों लोक, स्वर्ग, पृथ्वी, पाताल में ज्ञान देनेवाले गुरु के लिए कोई उपमा नहीं दिखाई देती । गुरु को पारसमणि के जैसा मानते हैं, तो वह ठीक नहीं है, कारण पारसमणि केवल लोहे को सोना बनाता है, पर स्वयं जैसा नहीं बनाता ! सद्गुरु तो अपने चरणों का आश्रय लेनेवाले शिष्य को अपने जैसा बना देता है; इस लिए गुरुदेव के लिए कोई उपमा नहि है, गुरु तो अलौकिक है ।

Ashish Kumar Kaushal

ABSTRACT

Design of humanitarian logistics network is a major strategic task due to its significant influence on the performance and responsiveness of a relief supply chain. When a disaster occurs, critical resources are very scarce. Therefore, these resources must be used very efficiently by the relief teams to cover maximum area and deliver in a manner to minimize losses. The thesis presents four models to manage the humanitarian supply chain. Both pre-disaster issues and post-disaster relief distribution issues are modeled in this thesis. In this first study, a three-echelon humanitarian logistics network design involving a few regional distribution centers, local distribution centers and un-related distribution locations is formulated. The research is motivated by failure in designing and managing a relief network during flash floods that occurred at Uttarakhand, India in 2013. About 8400 lives were lost and 21000 people were rendered homeless and an economic loss of 1100000 ('000 US\$) was reported. A mathematical model is developed to integrate location, allocation and distribution issues with considerations such as coverage radius, capacity constraints and reliability of distribution centers (DCs). The objective of the model is to minimize the total cost, the total distribution time and shortage cost of unfulfilled demands. A multi-objective Imperialist Competitive Algorithm (MICA) is proposed to solve the large instances of this problem.

In the second study, a joint unreliable facility location-allocation and inventory problem for healthcare logistics is considered. The problem is driven by real circumstances faced by humanitarian relief organizations for locating healthcare facilities and allocating medicinal resources. The location problem aims at determining the number and the position of required humanitarian aid distribution centers (HADCs). The allocation problem deals with the allocation of relief demand and inventory levels at different relief warehouses. The model considers that each victim has a demand which is uncertain. To achieve the targeted service level, a minimum safety stock should be maintained. The problem is formulated as a mixed integer nonlinear programming model. In the model, the first objective deals with the minimization of total expected total cost when facilities are prone to failure with considerations like demand, lead-time, and service-level. The second objective minimizes the non-covered demand within the affected area. Since the joint location-allocation and inventory problem is known to be NP-hard, a hybrid evolutionary Firefly-Genetic Algorithm (FGA) is used to solve the model. The algorithm provides promising solutions

for medium and large-scale instances. Computational analysis revealed that the proposed approach is suitable for large-scale practical applications.

In the third study, a multi-objective stochastic programming model for developing a disaster response plan, which integrates pre-and post-disaster decisions is developed. The objectives of the model are the maximization of the overall expected demand coverage, minimization of the sum expected cost, and minimization of the difference in the satisfaction rates between nodes. A multi-swarm particle swarm optimization with dynamic learning strategy (PSO-DLS) is proposed to improve the performance of standard PSO. The computational results attained by the proposed PSO-DLS algorithm were compared with those obtained using a multiobjective modified time-variant of PSO (TVMOPSO), the Non-dominated Sorting Genetic Algorithm (NSGA-II), Strength Pareto Evolutionary Algorithm (SPEA). Experimental results of the test cases demonstrate the applicability and efficacy of the proposed model.

In the fourth study, integrated model for location-inventory-routing decisions during pre-and post-disaster phase is developed. Uncertainties in the stock of basic relief facilities and relief demand are also considered. In this work, an enhanced Fireworks Algorithm (FA) is developed which uses differential evolution (DE) operators such as crossover, mutation, and selection. Various comparative analyses are undertaken to examine, (1) location and routing model vs. the integrated model, (2) location and inventory model vs. the integrated model, (3) effect of transshipment on the disaster response plan. Numerical analysis of the model shows that multiple supply sources can ensure efficient selection of location and reduce the deprivation costs. The results also indicate that prepositioning relief items at critical locations increases the distribution efficiency and partial prepositioning and post-disaster purchasing can reduce the shortage of emergency supplies.

The research provides insight relevant to academia and humanitarian supply chain practitioners in taking decisions in prepositioning as a preparedness measure. The research also identifies the environment in which prepositioning can be used as a means to mitigate the impacts of a disaster and also develops integrated models for carrying out relief activities in the prepositioning stage and post-disaster phase.

सार

राहत आपूर्ति श्रृंखला के प्रदर्शन और प्रतिक्रिया पर इसके महत्वपूर्ण प्रभाव के कारण मानवतावादी रसद नेटवर्क का डिजाइन एक प्रमुख सामरिक कार्य है। जब आपदा होती है, तो महत्वपूर्ण संसाधन बहुत दुर्लभ होते हैं। इसलिए, इन संसाधनों को राहत क्षेत्र द्वारा अधिकतम क्षेत्र को कवर करने और घाटे को कम करने के तरीके को वितरित करने के लिए बहुत कुशलतापूर्वक उपयोग किया जाना चाहिए। थीसिस मानवतावादी आपूर्ति श्रृंखला का प्रबंधन करने के लिए चार मॉडल प्रस्तुत करता है। पूर्व-आपदा मुद्दों और बाद में आपदा राहत वितरण मुद्दों दोनों इस थीसिस में मॉडलिंग किए गए हैं। इस पहले अध्ययन में, कुछ क्षेत्रीय वितरण केंद्रों, स्थानीय वितरण केंद्रों और गैर-संबंधित वितरण स्थानों से जुड़े तीन-एखल मानवतावादी रसद नेटवर्क डिजाइन तैयार किए गए हैं। शोध 2013 में उत्तराखंड, भारत में होने वाली फ्लैश बाढ़ के दौरान एक राहत नेटवर्क के डिजाइन और प्रबंधन में विफलता से प्रेरित है। लगभग 8400 लोग खो गए थे और 21000 लोगों को बेघर किया गया था और 1100000 (1000 यूएस \$) की आर्थिक हानि की सूचना मिली थी। कवरेज त्रिज्या, क्षमता बाधाओं और वितरण केंद्रों (डीसी) की विश्वसनीयता जैसे विचारों के साथ स्थान, आवंटन और वितरण मुद्दों को एकीकृत करने के लिए एक गणितीय मॉडल विकसित किया गया है। मॉडल का उद्देश्य कुल लागत, कुल वितरण समय और अपूर्ण मांगों की कमी की लागत को कम करना है। इस समस्या के बड़े उदाहरणों को हल करने के लिए एक बहुउद्देश्यीय इंपीरियलिस्ट प्रतिस्पर्धी एल्गोरिदम (एमआईसीए) का प्रस्ताव है।

दूसरे अध्ययन में, एक संयुक्त अविश्वसनीय सुविधा स्थान-आवंटन और स्वास्थ्य देखभाल रसद के लिए सूची समस्या माना जाता है। समस्या स्वास्थ्य देखभाल सुविधाओं का पता लगाने और औषधीय संसाधनों को आवंटित करने के लिए मानवतावादी राहत संगठनों द्वारा सामना की जाने वाली असली परिस्थितियों से प्रेरित होती है। स्थान की समस्या का उद्देश्य आवश्यक मानवतावादी सहायता वितरण केंद्रों (एचएडीसी) की संख्या और स्थिति निर्धारित करना है। आवंटन समस्या विभिन्न राहत गोदामों में राहत मांग और सूची स्तर के आवंटन से संबंधित है। मॉडल मानता है कि प्रत्येक पीड़ित की मांग होती है जो अनिश्चित है। लक्षित सेवा स्तर को प्राप्त करने के लिए, न्यूनतम सुरक्षा स्टॉक बनाए रखा जाना चाहिए। समस्या मिश्रित पूर्णांक गैर रेखीय प्रोग्रामिंग मॉडल के रूप में तैयार की जाती है। मॉडल में, पहला उद्देश्य कुल अनुमानित कुल लागत को कम करने के साथ सौदा करता है जब मांग मांग, लीड-टाइम और सेवा-स्तर जैसे विचारों के साथ विफलता की संभावना होती है। दूसरा उद्देश्य प्रभावित क्षेत्र में गैर-कवर की मांग को कम करता है। चूंकि संयुक्त स्थान-आवंटन और सूची समस्या एनपी-हार्ड होने के लिए जानी जाती है, इसलिए मॉडल को हल करने के लिए एक हाइब्रिड विकासवादी फायरली-जेनेटिक एल्गोरिदम (एफजीए) का उपयोग किया जाता है। एल्गोरिदम मध्यम और बड़े पैमाने पर

उदाहरणों के लिए आशाजनक समाधान प्रदान करता है। कम्प्यूटेशनल विश्लेषण से पता चला कि प्रस्तावित दृष्टिकोण बड़े पैमाने पर व्यावहारिक अनुप्रयोगों के लिए उपयुक्त है।

तीसरे अध्ययन में, एक आपदा प्रतिक्रिया योजना विकसित करने के लिए एक बहुउद्देशीय स्टोकास्टिक प्रोग्रामिंग मॉडल, जो पूर्व और बाद में आपदा निर्णयों को एकीकृत करता है, विकसित किया गया है। मॉडल के उद्देश्य कुल अपेक्षित मांग कवरेज का अधिकतमकरण, अपेक्षित लागत को कम करने, और नोड्स के बीच संतुष्टि दरों में अंतर को कम करने के लिए अधिकतम हैं। मानक पीएसओ के प्रदर्शन में सुधार करने के लिए गतिशील सीखने की रणनीति (पीएसओ-डीएलएस) के साथ एक बहु-झुंड कण झुकाव अनुकूलन का प्रस्ताव है। प्रस्तावित पीएसओ-डीएलएस एल्गोरिदम द्वारा प्राप्त किए गए कम्प्यूटेशनल परिणामों की तुलना पीएसओ (टीवीएमओपीएसओ), गैर-वर्चस्व वाले सॉर्टिंग जेनेटिक एल्गोरिदम (एनएसजीए-2), स्ट्रेथ पारेतो इवोल्यूशनरी एल्गोरिदम (एसपीईए) के बहुउद्देशीय संशोधित समय-संस्करण का उपयोग करके प्राप्त की गई थी। परीक्षण मामलों के प्रायोगिक परिणाम प्रस्तावित मॉडल की प्रयोज्यता और प्रभावकारिता का प्रदर्शन करते हैं।

चौथे अध्ययन में, प्री-एंड-पोस्ट-आपदा चरण के दौरान स्थान-सूची-रूटिंग निर्णयों के लिए एकीकृत मॉडल विकसित किया गया है। बुनियादी राहत सुविधाओं और राहत मांग के स्टॉक में अनिश्चितताओं पर भी विचार किया जाता है। इस काम में, एक उन्नत आतिशबाजी एल्गोरिदम (एफए) विकसित किया गया है जो पारस्परिक, उत्परिवर्तन, और चयन जैसे भिन्न विकास (डीई) ऑपरेटरों का उपयोग करता है। जांच के लिए विभिन्न तुलनात्मक विश्लेषण किए जाते हैं, (1) एकीकृत मॉडल बनाम स्थान और रूटिंग मॉडल बनाम, (2) स्थान और सूची मॉडल बनाम एकीकृत मॉडल, (3) आपदा प्रतिक्रिया योजना पर ट्रांसपोर्ट के प्रभाव। मॉडल के संख्यात्मक विश्लेषण से पता चलता है कि कई आपूर्ति स्रोत स्थान के कुशल चयन को सुनिश्चित कर सकते हैं और वंचित लागत को कम कर सकते हैं। नतीजे यह भी इंगित करते हैं कि महत्वपूर्ण स्थानों पर राहत वस्तुओं को पूर्ववत करने से वितरण दक्षता बढ़ जाती है और आंशिक पूर्वोत्तर और पोस्ट-आपदा खरीद आपातकालीन आपूर्ति की कमी को कम कर सकती है।

शोध तैयारी माप के रूप में पूर्वनिर्धारित करने में निर्णय लेने में अकादमिक और मानवीय आपूर्ति श्रृंखला चिकित्सकों के लिए अंतर्दृष्टि अंतर्दृष्टि प्रदान करता है। शोध पर्यावरण को भी पहचानता है जिसमें आपदा के प्रभाव को कम करने के साधनों के रूप में प्रीपोजिशनिंग का उपयोग किया जा सकता है और पूर्वोत्तर चरण और आपदा चरण में राहत गतिविधियों को करने के लिए एकीकृत मॉडल भी विकसित किया जा सकता है।

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