LOW CARBON GLOBAL SUPPLY CHAIN:

A STUDY OF INDIAN TEXTILE SECTOR

KRISHNENDU SHAW

DEPARTMENT OF MANAGEMENT STUDIES

INDIAN INSTITUTE OF TECHNOLOGY DELHI

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By

KRISHNENDU SHAW

Department of Management Studies

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CERTIFICATE

This is to certify that the thesis entitled "**Low Carbon Global Supply Chain: A Study of Indian Textile Sector**" being submitted by **Krishnendu Shaw** 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 him. He has worked under our 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.

(**Prof. Surendra S. Yadav**)

Department of Management Studies

Indian Institute of Technology Delhi

New Delhi-110016

INDIA

(**Prof. Ravi Shankar**)

Department of Management Studies

Indian Institute of Technology Delhi

New Delhi-110016

INDIA

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(Krishnendu Shaw)

ABSTRACT

Carbon emission reduction is very essential to mitigate world's biggest threat, global warming. Several initiatives are being taken at different levels to reduce carbon emission in the environment. These initiatives are - (a) negotiation among various countries (Example: Kyoto protocol) at global-level, (b) policies at country-level (India, China, USA, UK, etc.), and (c) policies at firm-level. This research falls into the third category, and focuses on sustainability and carbon reduction issues for global supply chains.

An extensive literature review has been conducted to identify the research gaps. To explore the current environmental practices and to test hypotheses, a questionnaire-based survey has been conducted among Indian textile and apparel firms, which are specifically associated with international trade, or have a global supply chain. Different statistical analyses (Factor Analysis, Reliability, and Regression) have been conducted in this study. By analyzing the results of statistical tests, it has been realized that Indian textile and apparel firms still lack sufficient knowledge for quantifying and optimizing carbon footprint for their global supply chain. The contemporary literature on green supply chain has mostly focused on empirical studies, and somewhat overlooked mathematical modeling to handle carbon footprint reduction for global supply chain. This research has emphasized on three types of mathematical models, which are supplier selection, lot-sizing and supply chain network optimization, which have broadly been referred to as helpful tools for minimizing carbon footprint of a supply chain.

In the third phase of the research, an attempt has been made to develop a supplier selection model incorporating the carbon footprint issue. This research proposed a single-period, multi-product supplier selection model considering various issues like cost (ordering, purchasing, transportation, handing, custom clearance), taxes (purchasing tax

& import duty), quality rejection, lead time, capacities of suppliers and containers, demand, carbon footprint of purchased material, carbon footprint of transportation, and sourcing carbon-cap. Benders Decomposition Algorithm was applied to get a feasible solution of the model. To illustrate the applicability of the proposed model, a case study was conducted over India-based apparel manufacturing company, and further, sensitivity analysis was performed on the model.

As supplier selection model only focuses on single-period system, therefore, it is very difficult to appraise the scenario of multi-period system. This study further proposes a multi-period lot-sizing model addressing the carbon-footprint issue. The model was built taking into consideration various issues such as multi-product, multi-period, multi-supplier, ordering cost, transportation cost, inventory holding cost, purchasing tax, import duty, handing cost, carbon footprint of product, carbon footprint of transportation, carbon-cap, carbon-offset, demand, container and supplier capacities, etc. Two different models such as fixed carbon-cap and carbon-offset were developed. Sensitivity analysis was carried out on the model by varying the footprint of sourced material, carbon price and ordering size.

Supplier selection and lot-sizing models often help in optimizing carbon footprint from supplier to manufacturer; however, these models are unable to optimize the whole supply chain network, which includes other entities also. Subsequently, a multi-objective supply chain network model was developed taking into consideration multi-echelon (suppliers, manufacturers and customers), multi-periods, single-product, different types of trucks, raw material carbon footprint, transportation carbon footprint, production footprint, trade-credit etc. Goal programming was applied to this problem to handle multiple conflicting goals, like emission reduction, cost and trade credit, etc. as these often prevail in supply chain decision making. A case study over garment supply chain was conducted to assess

the applicability of the model. Sensitivity analysis was conducted on this model by varying the deviational variables of the objective goals.

In the last phase, an effort was made to develop a global supply chain network optimization model extending the scope of previous models. This model tries to capture a whole supply chain, and its allied emissions. This model considers multiple-products, multiple-suppliers, multiple-manufacturing facilities, multiple-warehouses, multiple-transportation containers, inventory, various taxes, carbon footprint of raw material, transportation and manufacturing, carbon-cap, carbon-cap with trade and final product carbon footprint. A real life case study was carried out over garment manufacturing firm to see the applicability of the proposed model. Sensitivity analysis was also carried out for this model.

Key words: Low carbon supply chain, Carbon footprint, Sustainability, Green supply chain, **S**upplier selection, Lot-sizing, Supply chain network optimization, Global supply chain.

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