Green Manufacturing Supply Chain Design and Operations Decision-Support

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Complete List of Authors:	Bhattacharya, Arijit; University of Dubai, College of Business Administration Dey, Prasanta; Aston Business School, Ho, William; The University of Melbourne, Department of Management and Marketing
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Arijit Bhattacharya[1], Prasanta Kumar Dey[2] and William Ho[3]

[1]College of Business Administration, University of Dubai, Deira, Dubai, UAE.
Telephone: +971-4-207 2607
Fax: +971-4-224 2670
E-mail: arijit.bhattacharya2005@gmail.com
abhattacharya@ud.ac.ae

[2]Operations & Information Management Group, Aston Business School, Aston University, Aston Triangle, Birmingham, B4 7ET, UK.
Telephone: +44-(0)-121-204 4011
E-mail: p.k.dey@aston.ac.uk

[3]Department of Management & Marketing, University of Melbourne, Melbourne, Australia.
Telephone: +61-3-903 57560
E-mail: william.ho@unimelb.edu.au

Abstract: This special issue of International Journal of Production Research provides a platform for sharing the knowledge-base, recent research outputs and a review of recent developments highlighting the critical aspects of green manufacturing supply chain design and operations decision support. The special issue includes fifteen contributions presenting new and significant research in the relevant area. Contributions mainly present either a novel green / sustainable manufacturing supply chain design and operations decision-support approach applied to a problem, or a state-of-the-art method on green / sustainable factors in supply chain design and operations. The article delineates an overview of the contributions and their significance, and an introspection on the "green" factors involved.

1. Introduction

Appropriate design and operations of supply and logistics chains integrating economic, environmental and societal aspects can co-create values amongst all the enterprises of a complex supply chain network. Most of the recent publications combining the design, operational, economic and environmental aspects of the supply chains feature complex operational issues. Literature reports a good number of research on the economic, social and environmental aspects (known as triple bottom line or TBL) of the supply / demand chains. A number of decision-support tools are also available to analyse the behaviour of the chains. Appropriate integration of the decision-support tools at the appropriate design and operations

stages of the supply/demand chains can create provisions to achieve long term environmental sustainability.

The very purpose of implementing the 'green' factors in manufacturing supply chain design and operations decision-support is to improve the environmental efficiency, reduce carbon footprint, recycle the used / waste products and by-products, and compliance with the territorial legislations and international treaties while the goal of supply chain is to improve the supply and distribution efficiencies, save time and money as well and satisfy the needs of the customers by providing desired quality products and services. Therefore, there is a scope to trade off among the conflicting goals of "green" and supply chain by way of involving multiple enterprises in the supply chain network through efficient use of resources (i.e. value co-creation), collaboration/partnership (to create less emissions of greenhouse gases) and mediating roles of the enterprises. Thus there is a requirement to trade-off among the environmental impacts of supply chains, costs and greenhouse gas emissions.

The influence of the green factors in supply chain is increasing day by day. CO_2 is the principal greenhouse gas in the carbon market as declared by the United Nations Framework Convention on Climate Change (2015). The CO_2 equivalent (CO_2e) gases emitted across a supply chain for a product is known as its carbon footprint (Reclay Holding 2015). Significant reduction of carbon footprint is one of the main aims in order to improve environmental efficiency of the supply chain network. Considering a number of relevant literature we define "green" supply chain management (Srivastava 2007; Seuring and Müller 2008; Eltayeb et al. 2011; Hassini et al. 2012; Wong et al. 2012; Seuring 2013; Validi et al. 2014a; Validi et al. 2014b; Validi et al. 2015; Fahimnia et al. 2015; Govindan 2015; Eskandarpour et al. 2015):

> "*Green supply chain management is an environmental and operational combined performance related outcome in a multi-enterprise supply chain by way of implementing appropriate value co-creation and collaboration / partnership through efficient management of flow of material, information, capital and other necessary resources along the nodes and links of the supply chain network while integrating goals from TBL, which are derived from both the internal and external stakeholders and their requirements*."

Some comprehensive reviews of the green and sustainable supply chain management studies are available in (Seuring and Müller 2008; McKinnon et al. 2010; Sarkis et al. 2011; Dekker et al. 2012; Benjaafar et al. 2013; Seuring 2013; Fahimnia et al. 2015). Most of these reviews focus on the growth of the field of study, identification of the research gaps, and some specific areas of interest (Fahimnia et al. 2015) e.g. green logistics, reverse logistics, closed-loop supply chain, and sustainable supply chain network design etc. However scant information is available on the application of decision-support approaches on green manufacturing supply chain design and operations.

This special issue of International Journal of Production Research provides a platform for sharing the knowledge-base, recent research outputs and a review of recent developments highlighting the critical aspects of green manufacturing supply chain design and operations decision support. The special issue includes fifteen contributions presenting new and significant research in the relevant area. Contributions mainly present either a novel green / sustainable manufacturing supply chain design and operations decision-support approach applied to a problem, or a state-of-the-art method on green / sustainable factors in supply chain design and operations. An overview of the contributions and their significance is delineated below.

2. Articles on Green Supply Chain Design and Operations Decision-Support

The article titled "Sustainable pricing and production policies for two competing firms with carbon emissions tax" by Chen and Hao (2015) provides two competing firms' decision models with carbon emissions tax policy. The article makes an important contribution to both the firms and the policy-makers. The outcome of the research helps the firms with different efficiencies in order to decide optimal retail pricing and production with carbon emissions tax policy under competing environment.

The article "Remanufacturing decisions and implications under material cost uncertainty" by Shi and Min (2015) investigates how economically rational decisions on remanufacturing are made from a real-world perspective. The article assumes that the material cost for the product follows a Geometric Brownian Motion process. Based on this assumption the research derives the optimal condition for implementing a remanufacturing system. Considering the outcome of the implemented model on photocopier production system the article suggests an environmental policy-maker to subsidise the firm for the remanufactured products instead of providing a reimbursement for the establishment of the remanufacturing system.

Yu and Ramanathan (2015) in their article entitled "An empirical examination of stakeholder pressures, green operations practices and environmental performance" explore two key attributes constituting green operations practices viz. internal green management and green product/process design. The article examines the links of adopting green operations practices with stakeholder pressures and environmental performance. The article reports data collected from 167 manufacturing firms in the UK which has been analysed using structural equation modelling. The research reports that internal green management fully mediates the relationship between stakeholder pressures and green product/process design and the relationship between stakeholder pressures and environmental performance.

A comprehensive taxonomy of green supply chain management practices is reported in the article "Developing green supply chain management taxonomy-based decision support system" by Kumar et al. (2015). A two-stage cluster analysis is used for the development of the green supply chain management taxonomy. The article develops a structural equation modelling-driven decision-support system following the taxonomy. The study may assist

managers in making decisions by exploring the relationship among the external factors, internal factors, and green supply chain operational practices.

In the article "Greening the food supply chain: an optimisation model for sustainable design of refrigerated automated warehouses" Meneghetti and Monti (2015) present a constraint programming optimisation model for the sustainable design of refrigerated automated storage and retrieval systems (R-AS/RS). The model analyses the impact of supply chain decision variables, viz. the facility location, the storage temperature and the incoming product temperature, on costs, energy use and carbon dioxide emissions. In this article energy requirements for refrigeration and AS/RS machines are modelled. The research reports that the R-AS/RS design optimisation plays a crucial role in fostering sustainable food supply chains.

The article entitled "Policy insights from a green supply chain optimisation model" by Fahimnia et al. (2015) presents a trade-off supply chain model that is used to investigate the economic and environmental impacts of carbon pricing on manufacturing and distribution planning decisions of an actual supply chain. The article further examines the relationship between carbon price and fuel price and demonstrates how carbon should be priced to cater for possible variations in fuel price. The research findings assist in identifying the critical activities along the supply chain on which to focus in order to minimise the cost implications of a carbon-pricing regulation.

Govindan et al. (2015) in their article entitled "Evaluation of green manufacturing practices using a hybrid MCDM model combining DANP with PROMETHEE" propose a methodological framework to evaluate green manufacturing practices (GMP). The framework is a hybrid model combining DEMATEL based on ANP (DANP) Preference Ranking Organisation METHod for Enrichment Evaluations (PROMETHEE). The framework is validated with the data of a rubber tyres and tubes manufacturing industry. The outcome of this case successfully identifies the best GM practice for this case industry, which is 3R (reducing, reusing and recycling).

The article "A supply chain design approach considering environmentally sensitive customers: the case of a German manufacturing SME" by Altmann (2015) focuses on the impact of customers' requirements regarding the environmental performance of a product on strategic supply chain design decisions of the manufacturer of the product. The article presents a multi-echelon, multi-product supply chain design model that considers both economic and environmental impacts of value-adding activities in the supply chain. A mixed-integer linear programming supply chain design model with a demand function influenced by sustainability requirements is presented in the article. The model is applied to the case of German manufacturing SME. The contribution of the article is the consideration of the linkage between customers' demand behaviour and supply chain design decisions.

The article "A hybrid MCDM approach for improving the performance of green suppliers in the TFT-LCD industry" by Tsui et al. (2015) explores a problem-solving process for green

supplier evaluation. A hybrid multiple criteria decision-making with preference ranking organisation method is proposed to evaluate and assist polarizer suppliers for improving the performance of green suppliers in the TFT-LCD industry to achieve the aspiration level. The results show the ranking as well as the suppliers' strengths/weaknesses and provide an insight to enhance the suppliers' competitiveness.

Lake et al. (2015) in their paper titled "An application of hybrid life cycle assessment as a decision support framework for green supply chains" provides both theoretical insights and a practical application to inform the process of adopting a decision support framework based on a life cycle assessment (LCA) methodology to inform carbon emissions mitigation strategies within supply chains. The study argues that by integrating the environmental assessment based on the LCA approach into a decision-making process, businesses can be able to formulate and evaluate effective strategies for green supply chains. The proposed decision support framework integrates multi-regional input–output (MRIO) with LCA method.

The paper "Inter-organisational green packaging design: a case study of influencing factors and constraints in the automotive supply chain" by White et al. (2015) presents a case study of a UK-based automotive component manufacturing SME that explores the complexity of inter-organisational packaging design. The research identifies the important criteria that influence packaging design including customer requirements, legislation, operational and environmental concerns. The modelling framework employs multiple criteria decision analysis (MCDA) methods including fuzzy analytical hierarchical process (AHP) and a fuzzy extension of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The model enables to trade-off between the competing needs of operational and environmental objectives.

Gallear et al. (2015) in their article entitled "The mediating effect of environmental and ethical behaviour on supply chain partnership decisions and management appreciation of supplier partnership risks" examine the effect of firms' investment in environmental and ethical behaviour (EEB) as part of corporate social responsibility in mediating the relationship between supply chain partnership (SCP) and management appreciation of the risk of partnering. The outcome of this research confirms the mediation effect, highlighting the value to supply chain strategy and design of investing in EEB on three fronts: building internal awareness, monitoring and sharing best practice.

In the article titled "A hybrid framework for the modelling and optimization of decision problems in sustainable supply chain management" by Sitek and Wikarek (2015) a robust and effective hybrid optimisation approach is proposed. The hybrid approach proposed in this article combines mathematical programming and constraint programming. The proposed approach helps to make decisions relating to timely execution of orders, environmental costs of order execution, fleet size needs, capacity of distribution centres, recycling etc. The results are used to design 'green' supply chain.

The article "A review of decision-support tools and performance measurement and sustainable supply chain management" by Taticchi et al. (2015) provides a systematic literature review related to decision-support tools and performance measurement for sustainable supply chain management. A total of 384 papers published from 2000 to 2013 have been analysed using bibliometric techniques. The outcome of this review indicates that the green supply chain research field is growing and there is a need for integrated performance frameworks with new generation decision-support tools incorporating triple bottom line (TBL) approach for managing sustainable supply chains.

Brandenburg (2015) in his article titled "Low carbon supply chain configuration for a new product – a goal programming approach" a goal programming model is suggested to optimise the supply chain configuration for a new consumer product under consideration of economic and environmental criteria. The model is applied to a case example of a fast moving consumer goods manufacturer. The proposed model trade-offs between the ecologic factor of carbon emission, and financial value creation and customer service level. The article suggests that a focused economic optimisation strongly amplifies negative environmental impacts of demand uncertainties.

3. Conclusion

The three Guest Editors take this opportunity to gratefully acknowledge all the contributing authors, practising professionals from industry and academia and the reviewers. The Guest Editors convey their heartfelt thanks to all the reviewers for providing their valuable time in reviewing the manuscripts and providing constructive comments, which made this special issue possible. The Guest Editors would like to thank Professor Alexandre Dolgui (the Editor-in-Chief of the International Journal of Production Research) for extending immense cooperation and providing us constructive advice from time to time. The Guest Editors also like to acknowledge Tamara Bowler – Peer Review Coordinator of Taylor & Francis, and the editorial office colleagues who have all endeavoured to bring this Special Issue possible. It is hoped that this special issue would contribute significantly to the field of green manufacturing supply chain design and operations decision-support.

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Author/s:
Bhattacharya, A; Dey, PK; Ho, W

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