



## Editorial

### Sustainable Operations Management: design, modelling and analysis

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In recent years, Sustainable Operations Management (SOM) has started receiving attention from both operations management and management science researchers. SOM includes topics such as green supply chain (eg, Linton *et al.*, 2007; Darnall *et al.*, 2008), green procurement (eg, Seuring and Müller, 2008; Walker *et al.*, 2009) and reverse logistics (RL) (eg, Dowlatshahi, 2005; Srivastava, 2008). SOM has a potentially vital role to play in contributing to solutions for the complex sustainability challenges confronted by many organisations (Kleindorfer *et al.*, 2005; White and Lee, 2009). As a result, a number of operations management researchers and practitioners are dealing with the challenges of integrating the issues of sustainability in protecting the environment and reducing the carbon footprint (eg, Carter and Rogers, 2008; Lee, 2011). Both researchers and practitioners recognise the importance of SOM as a key strategic component in the development of cost-effective and sustainable global supply chains to meet the increasing needs of customers in terms of flexibility, responsiveness and cost while safeguarding natural resources for future generations. Most of the research on SOM has been limited to literature reviews (eg, Linton *et al.*, 2007), conceptual frameworks (eg, Seuring and Müller, 2008), case studies (eg, Pagell and Wu, 2009) and some empirical papers (eg, Zhu *et al.*, 2005). However, SOM requires modelling and analysis for performance measures and metrics of various options available for SOM in both in manufacturing and services. White and Lee (2009) further argue that sustainable development has been largely regarded as a global challenge and the potential of Operational Research (OR) is yet to be properly exploited in this area.

An analysis of the OR discipline in developing economies by White *et al.* (2011) supports the latter argument. Through this research, White *et al.* (2011) highlight that OR can make a significant contribution towards enhanced decision making, yet still OR has not been methodically utilised to address the Millennium Development Goals. The contribution by Kleindorfer *et al.*, (2005) highlights the analysis of papers in the area of ‘Sustainable Operations Management’ in the first 50 issues of ‘Production and Operations Management’. Although Kleindorfer *et al.*, (2005) focus on supply chain

issues, their analysis offers limited insights to the overall development and status of the area. Similarly, Seuring and Müller (2008), in their literature review, specifically focus on the advent and growth of integrated supply chain management. A much broader effort is made by Srivastava (2007), but primarily focusing on a RL perspective. Ormerod and Ulrich (2013), on the other hand, focus on analysing OR and ethics and argue that despite the energetic engagement of OR in organisations in different contexts, there is still a lot to do—especially providing clarity as to how OR practices can be ethically established. Although sustainability offers an all-encompassing framework for much of the former and continuing environmental research in operations, Linton *et al.* (2007) argue that in essence, sustainability in operations and supply chain management moves beyond current conventional practices. Research into how academia, researchers and practitioners can integrate OR within SOM is critical, as such research not only requires many questions be answered but also the establishment of a wide variety of approaches including conducting case studies, model development, statistical testing of propositions and machine learning (Kleindorfer *et al.*, 2005; Matos and Hall, 2007; Linton *et al.*, 2007).

Nevertheless, there are not many articles that deal with modelling and analysis of SOM decision making at strategic, tactical and operational levels that are important for implementation of SOM decisions. The aim of this special issue is to help researchers and decision makers to understand the strategies, tactics and implementation processes involved in SOM decisions and the performance measures and metrics through modelling and analysis of SOM. With the help of these articles appearing in this special issue, one should be able to gain a better understanding of the issues involved in SOM and how to model and evaluate SOM decision-making environments and decisions through appropriate modelling and analysis of both manufacturing and service supply chains. The scope of the special issue is to present researchers and senior managers with conceptual modelling and analysis of various sustainable operations decisions and their performance outcomes in supply chains. This includes optimisation related to closed-loop chains, carbon footprinting of supply chains, life-cycle management, greening supply chains, green and reverse logistics, product and process development towards improving energy savings, efficiency of transport and other related areas. Emphasis is placed on sustainable operations design, modelling and analysis, optimisation, and their performance measurement in a supply chain. The special issue contains articles that cover the following topics:

- Implications of SOM in the 21st century organisational competitiveness;

- Modelling of performance measures and metrics in SOM;
- Modelling and assessment of life-cycle perspectives of SOM;
- Modelling of cost/benefit and risk considerations/realisations in SOM;
- Macro-economic or industry-wide modelling and assessment of sustainable policies and actions;
- Justification for SOM through conceptual modelling and analysis through the use of OR techniques;
- Selecting SOM alternatives through appropriate Operations Research modelling and analysis;
- Models for studying the impact of sustainable operations initiatives and policies;
- Optimal supply chain configuration from a strategic, tactical or operational perspective;
- Performance measures and models for SOM decisions;
- Partnership development for SOM through modelling and optimisation.

The 11 papers appearing in this special issue deal with the above issues of modelling and analysis of SOM. A brief summary of each article is presented below.

SOM can be defined as the operations strategies, tactics and techniques, and operational policies to support both the economic and the environmental objectives and goals. The subject of sustainability has gained much attention from both researchers and practitioners over the past 6–8 years. Most of the articles deal with sustainability from an environmental perspective, but not many of them integrate both economic and environmental implications. Moreover, there is a limited focus on modelling and analysis of SOM integrating the interests of both economic and environmental interests. To address this, Gunasekaran, Irani, Papadopoulos in their paper entitled *Modelling and Analysis of Sustainable Operations Management: Certain Investigations for Research and Applications* review the papers on modelling and analysis of SOM. Therefore, an attempt has been made in this paper to review the extant literature on SOM. The objective is to understand the definition of SOM and present the current status of research in modelling and analysis, as well as future research directions in the field. Considering the recent focus on the subject, they review the literature beginning in 2000 in order to make the study current and more relevant for both researchers and practitioners.

The paper entitled *Infrastructure Topology Optimisation under Competition through Cross-Entropy* by Le Cadre deals with infrastructure topology optimisation competition through cross-entropy. In this paper, a two-level, non-cooperative game between providers acting on stations so as to capture as many consumers as possible is presented. Its deployment being costly, the provider has to optimise both the number of settled stations as well as their locations. In the first level, each provider optimises independently an infrastructure topology, while in the second level they price dynamically the access to their network of stations. The consumers' choices depend on the perception (in terms of price, congestion and distances to the nearest stations)

that they have of the service proposed by each provider. Each provider market share is then obtained as the solution of a fixed point equation since the congestion level is supposed to depend on the market share of the provider, which increases with the number of consumers choosing the same provider. The paper proves that the two-stage game admits a unique equilibrium in price at any time instant. An algorithm based on the cross-entropy method is proposed to optimise the providers' infrastructure topology and it is tested on numerical examples providing economic interpretations.

The selection of sugarcane varieties is an important problem facing companies in Brazil that exploit sugarcane harvest for energy production. In the light of current concerns regarding the reduction of environmental damage and the efficiency of the production system, research into this problem is called for. Florentino and Pato in their paper entitled *A Bi-Objective Genetic Approach for the Selection of Sugarcane Varieties to Comply with Environmental and Economic Requirements* present a bi-objective, genetic approach for the selection of sugarcane varieties to comply with environmental and economic requirements. They begin by outlining the sugarcane variety selection in accordance with technical constraints with the purpose of minimising collection and transport costs and maximising energy obtained from residues of the sugarcane harvest. They then present a previously developed modelisation for the problem within bi-objective binary linear programming and study its hard computational complexity. Fundamentally, this paper is devoted to the application of a bi-objective, genetic heuristic approach to the question addressed. A computational experiment performed using a test set including real and semi-randomly generated instances is then reported. The results prove to be very good in terms of solution quality as well as computing time. For these reasons, this will be an appropriate tool to help sugarcane company managers to plan their production activities.

The optimisation towards supply chain structures that consider both economic and environmental performance is an important research topic. However, when designing supply chains, enterprises are commonly faced with the competing factors of reduced cost, improved customer service and increased environmental factors as a multi-trade-off problem. Ozceylan and Paksoy in their paper entitled *Environmentally Conscious Optimisation of Supply Chain Networks* deal with optimisation of supply chain networks considering the environmental issues and their impact on supply chain performance. This paper proposes an environmentally conscious optimisation model of a supply chain network with a broader and more comprehensive objective function that considers not just the transportation costs, but also the costs of the amount of greenhouse gas emissions, fuel consumption, transportation times, noise and road surface quality. The paper sheds light on the trade-offs between various parameters such as vehicle speed, fuel, time, emissions, noise and their total cost and offers managers insights on economies of environmentally conscious supply chain optimisation. An integer non-linear programming

model is developed to support decision makers find the optimal solution in given situations. The proposed model is then validated through the solution of an example, where its applicability to supply chain problems is demonstrated.

With a growing awareness of carbon footprints and their impact on environmental degradation, many firms hope to streamline their RL operations involving end-of-use products. However, managing end-of-use products can be extremely challenging due to inherent complexity involved in the collection, sorting, transshipment and processing of these products. Despite numerous challenges, the efficient handling of these products can be a source of competitive advantage. In this regard, the plastics recycling industry in Southern India is no exception. This industry often copes with the problem of picking up recyclable plastic bottles using private collecting agents, transferring those bottles to the Initial Collection Points (ICPs), and then trans-shipping and consolidating them at Centralised Return Centres (CRCs) for final shipment to processing centres where these bottles are treated for recycling. This problem can be further complicated by the dilemma of finding the most suitable locations for ICPs and CRCs and the optimal routing of vehicles serving ICPs and CRCs. The paper entitled *Combined Location and Routing Problems for Designing the Quality-Dependent and Multi-Product Reverse Logistics Network* by Min, Sheriff and Nachiappan presents combined location and routing problems for designing a quality-dependent and multi-product RL network. To aid the industry in dealing with such RL problems, they develop a mathematical model and then evaluate the performance of that model with the actual data obtained from a case study of an Indian company.

Generally, supply chain cluster (SCC) evolution follows the innovation and its selection strategies. To reduce further the innovation risk: SCC must seek feasible innovation strategies to match ecological niche matching degree; within a competing cluster, it should avoid the hazardous nature of pure competition that affects the innovation output, and within a cooperation innovation cluster, it should look carefully for the cooperation innovation mechanism. Ji and Gunasekaran in their paper entitled *Evolution of Innovation and its Strategies: From Ecological Niche Models of Supply Chain Clusters* present the evolution of innovation and its strategies from ecological niche models of SSCs. They examine the impact of the growth of SCCs from a perspective of ecological niche, the innovation strategy and the expansion of ecological niche, and its matching degree on the influence of the growth in SCC. They present the ecological niche expansion model, growth model and growth evolution model of SCCs. The findings of this research suggest that:

- there is a five-stage evolution in which the characteristics are different in different innovation strategies;
- the ecological niche width of an SCC is connected by each member's ecological niche, the expansion process is constituted by the members' ecological niche expansion;

- at each stage, SCC should identify the ecological niche matching degree between members and innovation modes when the SCC expands the niche width to a certain limit.

Finally, a case study demonstrates the application potential of the model and its implications.

Over the last decade, a number of research studies have advocated the use of Information Technology (IT) in different aspects of logistics and distribution operations. Lam, Choy, Gunasekaran, Chow, Tsim, Tse and Lu in their paper entitled *Impact of Information Technology on the Performance of the Logistics Industry: The Case of Hong Kong and Pearl Delta Region* study the impact of IT on the performance of the logistics industry with the cases of Hong Kong (HK) and the Pearl River Delta (PRD) region. They examine the current state of the use of IT and its impact on logistics service performance through a survey of 250 logistics companies in HK and the PRD region. A hypotheses model is also proposed in which the theories of the Market-Based View and the Resource-Based View are applied to link up the implications of IT capabilities with logistics performance. The model was tested using Structural Equation Modelling. The findings suggest that:

- IT implementation directly enhances the service quality of logistics companies;
- the impact of IT implementation improves service quality thereby creating competitiveness.

Because of regulatory pressures from government and non-government bodies and public awareness of the need to protect the environment, incorporating sustainability concerns in product design has become a key strategic consideration in new product development (NPD). However, selecting an appropriate sustainable design solution is a challenging task. As well as the fact that such a decision involves conflicting objectives, there is also the issue that environmental impact considerations can occur at all stages of a product's life cycle. Modelling and assessing NPD and operations management from a Life-Cycle Assessment (LCA) perspective is becoming increasingly popular and highly important. However, on its own it is somewhat limited. The paper entitled *A Comprehensive Decision Support Model for the Evaluation of Eco-Designs* by White, Wang and Chan presents a comprehensive decision support model for the evaluation of eco-designs. They present a dynamic approach that integrates LCA, fuzzy logic and Analytical Network Process (ANP) to support the selection of environmentally sustainable product designs. A numerical example is provided as an operational guideline on how to apply it to the LCA of eco-designs. The results show that the proposed fuzzy ANP approach is a viable methodology and can be used as an effective tool for the evaluation of environmentally sustainable product designs.

Ever since the announcement that UK Higher Education (HE) fees were to increase up to £9000, many universities have expressed concern about how to attract the best students while

offering choice and promoting student mobility through broader access. This, in turn, has led to questioning how such complexity might be modelled using sophisticated OR techniques. Because Higher Education Institutions (HEIs) are now beginning to compete 'against' rather than 'with' each other, potential students are paying increased attention to where and what they will study, as well as graduate opportunities after their degree. Hence, the quality of education services becomes increasingly vital for HEIs in order to attract potential students. Dwivedi, Irani and Williams in their paper entitled *Analysing Factors Affecting the Choice of Emergent Human Resource Capital* develop a framework of those factors affecting international (non-EU) students' choice of institution. A survey approach is utilised to determine the importance of a number of factors (identified from the literature) based on data collected from students of two different types of institutions (a university and a feeder institution). Through a better understanding of factors such as social influence, financial and career opportunities, universities should be well placed to construct models underpinned by OR principles that will promote scenario modelling within HE.

RL involves several activities that according to the decisions regarding how to implement and use them, can have an important cost implications for an organisation that seriously affects its performance. The paper entitled *Improving Organisational Performance through Reverse Logistics* by Ramirez and Garcia-Morales discusses improving organisational performance through RL. They analyse how the different activities of RL could affect costs, and thus the performance of the organisation. The study is based on a survey of the most important companies in the Spanish market using a structural model. Our analysis highlights that:

- RL has different costs depending on the type of activity, therefore it is important to select the most appropriate combination and implementation of these RL activities;
- RL activities affect RL costs, so they decisively determine organisational performance.

A number implications and contributions stem from the discussion and conclusions of the study.

Sharif, Alshawi, Kamal, Eldabi and Mazhar in their paper entitled *Exploring the Role of Supplier Relationship Management for Sustainable Operations: An OR Perspective* explore the role of Supplier Relationship Management (SRM) for sustainable operations from an OR perspective. This paper provides a systems-based approach to the exploration of the relationship and integration between SRM factors as part of a SOM agenda. The authors have chosen electronic Procurement (e-Procurement) as a suitable context in this light. Through a review of extant literature, a Systems Archetype (SA) model is developed (based upon the 'accidental adversaries' archetype) and findings from a quantitative pilot study exploring key factors pertinent to e-Procurement SRM were gathered, and evaluated against SOM factors. The objective of this research is to describe and visualise the causal inter-

relationships involved in SRM-SOM through the application of a SA (as an OR tool). The authors believe that this research also provides a unique approach to developing and harnessing the useful and unique properties of Systems Thinking (ST), by attempting to reduce and organise the (generally *ad hoc* and wide-ranging) sequence of subjective perspectives commonly experienced in causal mapping experiments. The paper builds upon the extant literature, and provides a further basis for continuing research in the areas of ST, SAs and the application of OR to plan sustainable operations.

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