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## Supply Chain Management and Management Science: A Successful Marriage

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**Abstract** – The last century has witnessed extant studies on the applications of Management Science (MS) to a diverse set of Supply Chain Management (SCM) issues. This paper provides an overview of the contribution of MS within SCM. A framework is developed in this paper with a sampling of MS contributions to major SCM dimensions. Future research directions are presented.

**Keywords:** Management Science (MS); Supply Chain Management (SCM); Review paper

## 1. Management Science

Management Science (MS) is a field that develops and applies scientific and analytical methods for addressing managerial concerns. The principles of Scientific Management (Taylor 1911) supported the need and application of quantitative methods to the management discipline. The history of management sciences and operations research goes well into the early 20<sup>th</sup> century. Maybe the greatest progress in MS methods and tools occurred during a time of crisis. During World War II scientists from different disciplines were formed to develop and apply quantitative methods in support of military decision-making problems. These methods were later used in management decision-making, supporting the field's title of Management Science.

Although a field with significant history, the definitions for Management Science do vary. Ansoff and Brandenburg (1967) define Management Science as “a normative study of interdisciplinary systems involving human participants”. The Institute for Operations Research and the Management Sciences (INFORMS) defines Management Science as “an interdisciplinary branch of applied mathematics, engineering and sciences that uses various scientific research-based principles, strategies, and analytical methods including mathematical modeling, statistics and algorithms to improve an organization's ability to enact rational and meaningful management decisions.” Integrating scientific methods and modeling for solving management problems is needed for effective management science. To further this sentiment the following statement is provided: “Management Science itself is not the impressive array of tools that have been built up over the years (optimization, simulation, decision analysis, queuing, and so on) but rather the art of reasoning logically with formal models.” (Powell 2001).

Management Science is synonymous with other terms such as Operations Research (Operational Research), Decision Sciences, and more recently, Business Analytics. Although there might be nuanced differences, these fields greatly overlap. Nonetheless MS is a very broad field of study with relatively ambiguous boundaries.

According to INFORMS, Management Science encompasses three levels of research:

- *Fundamental*: this level comprises three mathematical disciplines: probability, optimization, and dynamic systems theory.
- *Modeling*: this level concerns formulating models, gathering data, and analyzing them mathematically.
- *Application*: this level builds upon the other two levels to handle real-world problems.

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While the fundamental level might be independent of management disciplines, the other two levels have a direct connection with one or more management disciplines and, sometimes, a particular problem. Management Science significantly contributes to marketing, financial management, operations management, human resource management, transportation, logistics, and supply chain management. In this paper, the focus would be on the contribution of Management Science within supply chain management (SCM).

## **2. Supply Chain Management**

Supply chain management is not new, the practice may go back millennia. Yet, it is only recently that organizations have recognized it as a competitive weapon (Christopher 2011). SCM as a management and scientific field has existed for more than a century, even though the term supply chain management is more recent. Oliver and Webber (1982) were one of the first to use the term to refer to the integration of various business functions. Throughout these past few decades researchers have defined SCM differently. Some example definitions include:

“Supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole”. (Mentzer et al. 2001).

“Supply Chain Management is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders.” (Lambert and Cooper 2000).

“Supply-chain management is the strategic, tactical, and operational decision making that optimizes supply-chain performance.” (Fox et al. 2000).

“The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole”(Christopher 2011).

A common theme in these and others definitions of SCM includes:

- Existence of at least two actors (a supplier and a customer);
- Existence of some elements of exchange (e.g. material, information);
- Coordination between the actors and business functions (e.g. marketing, production, finance);
- The coordination aims to reach one or more objectives (e.g. minimizing cost, increasing customer satisfaction).

There are different frameworks for Supply Chain Management (Cooper et al. 1997, Croom et al. 2000, Tan 2001, Chen and Paulraj 2004), one of the most widely used is the one proposed by Croom et al. (2000), where they reviewed the literature and considered different perspectives to classify the topics related to SCM. As it has been also mentioned by them, the list is not complete, so one may find other topics to be included in this table. However, it is comprehensive.

## **3. The contribution of Management Science in Supply Chain Management**

Here, our goal is not to systematically review the literature, as for the contribution of MS in different components of SCM separate review papers can be written, and indeed there are several excellent review papers. In Table 1, we give some examples of the contribution of MS in SCM, using the SCM components introduced by Croom et al. (2000). These various contributions are meant to provide the reader with exemplary works, and are not exhaustive.

## **4. Recent Exemplary MS Works by SCM Topic**

### **4.1. Strategic Management**

#### *Strategic supply chain design*

Strategic supply chain design has been widely addressed. Recent papers include Ishfaq and Raja (2015) who applied decision trees and logistic regression to rural telemedicine network design, Mathiyazhagan et al. (2015)

Table 1. Main component bodies of Supply Chain Management

Topic	Supply Chain Function
<b>Strategic Management</b>	Strategic supply chain design
	Sourcing
	Make or buy
	Supply network design
	Strategic alliances
	Strategic supplier segmentation
	Capability development
	Strategic purchasing
<b>Logistics</b>	Information integration
	Cross docking
	Capacity planning
	Distribution channel management
	Reverse logistics
<b>Marketing</b>	Customer service management
	Efficient replenishment
	After sales service
<b>Relationship Development</b>	Suppliers
	Vendor Managed Inventory (VMI)
	Partnership sourcing
	Partnership assessment
	JIT, MRP, lean and agile
<b>Organizational Behavior</b>	Human resources management
	Organizational structure
	Supplier selection
<b>Risk management</b>	Simulation modeling
	Business scorecard
	Risk matrices
	Can be considered in all SC functions
<b>Sustainability</b>	

who used the analytic hierarchy process (AHP) to implement green supply chain management, and Huang et al. (2009) who used game theory and a genetic algorithm to model coordination of greenhouse gas emissions.

#### *Sourcing*

Sourcing is a critically important function. Modeling support considering multiple criteria are widely suggested, including data envelopment analysis (DEA) by Talluri and Narasimhan (2004), PROMETHEE by Araz and Ozkarahan (2007), as well as AHP support to quality function deployment (QFD) by Xie et al. (2011). The tradeoffs between global and local sourcing were addressed by Boute and Van Mieghem (2014). Strategic issues in supplier selection were addressed by Sarkis (2003) using analytical network process (ANP), Rezaei and Davoodi (2011) using multi-objective optimization (MOOP), Amid et al. (2006) using fuzzy MOOP, and Sevkli (2010) using fuzzy ELECTRE.

#### *Make-or-buy decisions*

Make-or-buy decisions have been modeled through use of AHP by (van de Water and van Peet 2006). Chang et al. (2013) used dynamic and integer programming to aid make-to-order manufacturing scheduling.

### *Supply network design*

Supply network design has been modeled numerous times and in numerous ways. (Shu et al. 2015) provide a complex nonlinear integer programming model of multi-echelon inventory management jointly optimizing warehouse location, warehouse-retailer assignments, inventory replenishment schedules, and safety stock level decisions. The model was proposed to be solved by a cutting-plane mathematical programming model. Garg et al. (2015) proposed a multi-criteria optimization model to manage environmental issues in supply chain network design. Nickel et al. (2012) gave a stochastic mixed-integer linear programming model, Wang et al. (2011) a MOOP model, and Ghorbani et al. (2014) a fuzzy goal programming model.

### *Strategic alliances*

Strategic alliances have proven to be difficult to successfully implement (Vanpoucke and Vereecke 2010). The difficulty of analysis arises due to the dynamic nature of supply chain relationships. Modeling strategic alliances has been addressed by (Song and Panayides 2002) using game theory, and by Famuyiwa et al. (2008) using fuzzy goal programming. Jain et al. (2009) reviewed modeling applications of dynamic supply chains to include agent technology, petri nets, fuzzy logic, and data mining.

### *Strategic supplier segmentation*

Strategic supplier segmentation has shown to be a crucial supply chain management activity for companies work with a large number of suppliers. Suppliers are segmented to a manageable number of groups and different strategies are formulated to manage different segments rather than individual suppliers. Supplier segmentation has been modeled by fuzzy AHP (Rezaei and Ortt 2013a), fuzzy logic (Rezaei and Ortt 2013b), best worst method (Rezaei et al. 2015), PROMETHEE and MAUT and AHP (Segura and Maroto 2017), and also using multi-objective programming (Neumüller et al. 2016).

### *Capability development*

Capability development, which is critical for competitive advantage building within supply chains has been addressed. Singh Srari and Gregory (2008) developed a configuration definition and mapping approach and compared configuration mapping tools. Bhaskaran and Krishnan (2009) provided a formulation of the impact of joint product development. Security issues, an important capability, within supply chains was modeled by Li (2014) using AHP. Sequential capability development has also been recently introduced with a mix use of structural equation modeling and ANP (Dangol et al. 2015).

### *Strategic purchasing*

Strategic purchasing is growing in importance with the need to quickly respond to changes in demand. Yeung (2008) found that strategic supply management improves on-time shipments, reduces operating costs, improves customer satisfaction and improves business performance. Nair et al. (2015) examined strategic and operational criteria appropriate for supplier selection and monitoring, applying a path model to assess survey data, finding positive impact for specific criteria. Cachon and Swinney (2011) applied a game theoretic model to quick response production capabilities in the fast-moving fashion industry.

## **4.2. Logistics**

### *Integration of materials and information*

Integration of materials and information is critical to successful supply chain logistics. Hozak and Hill (2009) found that technology such as RFID along with internal planning and control have a positive impact on supply chain performance. Lu et al. (2013) modeled a web-based information platform in the semiconductor industry which mitigated the bullwhip effect. (Zhang et al. 2015) provided an integration model of supply chain partner integration in managing material, information, knowledge, and financial flows.

### *Cross-docking*

Cross-docking was analytically modeled by (Waller et al. 2006), while Larbi et al. (2011) used heuristic algorithms. Shi et al. (2013) applied discrete-event simulation along with robust optimization and bootstrapping

to JIT in the automotive industry including cross docking. Abouee-Mehrizi et al. (2013) used mixed integer linear programming to determine the number and location of cross-docks to assign retailers to suppliers. Shi et al. (2014) used a multi-response optimization model with response surface methodology to an auto parts supply chain design. Mohtashami (2015) applied a genetic algorithm to a cross-docking model to reduce warehouse space requirements, inventory management costs, and turnaround times.

#### *Capacity planning*

Capacity planning is to manage the production and supply capacity of individual companies and the supply chain as a whole. It was addressed through stochastic integer programming by Hood et al. (2003). Jayaraman (2006) used a mathematical programming model for aggregate production planning and control in long-range planning of a closed-loop supply chain. Chao et al. (2009) applied stochastic modeling for a telecom industry capacity expansion problem. Jodlbauer and Reitner (2012) used integer programming to obtain a capacity feasible production plan considering alternative routings, safety stock, lot splitting, and lot summarization. Wang et al. (2013) used a fuzzy goal programming model for a high tech manufacturing capacity requirements planning model. Çetinkaya et al. (2009) developed a mixed-integer optimization model for inventory and transportation decisions in Frito-Lay's outbound supply chain.

#### *Distribution channel management*

Distribution channel management is managing activities which involve delivering products and services to the customers through distribution partners. It was modeled by (Seifert et al. 2006) to integrate virtual stores with direct and indirect distribution channels. Huang et al. (2009) developed a dynamic system model for supply chain distribution considering risk management. Paksoy et al. (2012) used fuzzy AHP and fuzzy TOPSIS. Davis et al. (2014) modeled allocation of inventory risk in a two-stage supply chain considering channel efficiency and profit distribution.

#### *Reverse logistics*

Reverse logistics is defined as “planning, implementing, and controlling the efficient and effective flow and storage of goods, services and related information between the point of consumption and the point of origin for economical or environmental purposes” (Rezaei 2015a). Salema et al. (2007) proposed a generic optimization model for reverse distribution network, minimizing the total cost of the network while considering capacity limits, multi-product management and uncertainty on product demands and returns. Niknejad and Petrovic (2014) formulated a mixed integer programming problem for reverse logistics and solved it using a two-phase fuzzy mixed integer optimization algorithm. For reviewing quantitative models for reverse logistics we refer to review papers (Fleischmann et al. 1997, Rezaei 2015a, Bazan et al. 2016, Govindan et al. 2015b).

### **4.3. Marketing**

#### *Customer service management*

Customer service management is considered as one of the most important aspects of supply chain management as it manages the point where is the ultimate goal of a supply chain, customer. Satisfied customers for a supply chain prove success. It was modeled by Cheung et al. (2003) using case-based reasoning and adaptive time-series. Ren and Zhou (2008) used a queuing model to coordinate staffing in a call center involved with outsourcing considering service quality maintenance.

#### *Efficient replenishment*

Efficient replenishment is about using the organization's resources and skills in the most proper way to replenish the required materials. It was dealt with by Lin et al. (2009) using an heuristic algorithm to obtain more efficient replenishment by determining better production cycle and product life cycle.

#### *After sales service*

After sales service can be considered as part of customer relationship management which concerns all the activities which happen after a product or service is sold or offered. It was addressed by Deshpande et al. (2003)

through an inventory model for analysis of part attributes and performance of after-sales service. Kurata and Nam (2010) applied analytical modeling and game theory to this issue.

#### **4.4. Relationship Development**

##### *Supplier development*

Supplier development is a strategic activity to improve suppliers' capabilities and willingness to cooperate. It was modeled by Bai and Sarkis (2010) using rough set theory, while Fu et al. (2012) used grey-based DEMATEL. Supplier development co-investment, by both supplier and buyer, has also been recently studied from a game theoretic perspective (Bai and Sarkis 2016).

##### *VMI*

VMI, vendor managed inventory, is a major means of tying suppliers to retailers. Within this context Ryu et al. (2013) used a fractal-based approach to inventory management for coordination of inventory policies across supply chains. Aftan et al. (2015) introduced an operations model for retail replenishment collaboration. Borade and Sweeney (2015) presented a decision support system based on a genetic algorithm for a VMI supply chain. Jiang et al. (2015) used nonlinear mixed integer Nash bargaining model for a joint inventory supply chain. Investigation of this topic can also occur in different stages of supply chain management, for example in logistics and delivery modeling of optimal routes for VMI setting has been completed (Park et al. 2016). Çetinkaya and Lee (2000) used analytical modeling to consider VMI in stock replenishment and shipment scheduling.

##### *Partnership sourcing*

Partnership sourcing was addressed by Jain et al. (2009) who applied agent technology, petri nets, fuzzy logic and data mining to support dynamic supply chain supplier-buyer relationships. Bai and Sarkis (2012) used neighborhood rough set theory for identification and selection of performance measures for desired sourcing outcomes. Rezaei (2015b) used assignment models to aid linking suppliers and buyers.

##### *Partnership assessment*

Partnership assessment is important since it focuses on the relationship performance between a buyer and supplier. This relational view was modeled by Piltan and Sowlati (2016) used ANP to evaluate partnership. Chen and Wu (2010) used a systematic procedure to evaluate an automobile manufacturer–distributor partnership. They used Interpretive Structure Modeling (ISM) and ANP for partnership evaluation.

##### *JIT, MRP, lean and agile*

JIT, MRP, lean and agile are important technologies and approaches supporting efficient assembly operations, impacting logistics operations. (Hsu et al. 2006) developed an optimization model for stocking quantity identification in an assemble-to-order domain. Kojima et al. (2008) provided modeling to evaluate performance of supply chains in the JIT environment using discrete-time Markov processes. Tsai (2011) developed a production and shipment model incorporating learning effects in an inventory situation involving deteriorating items.

#### **4.5. Organizational Behavior**

##### *Human resources management*

Human resources management modeling was given by Schultz et al. (2010), using an optimal and a heuristic rearrangement of workers to increase throughput. Größler and Zock (2010) used system dynamics modeling for a German logistics provider's recruiting and training process. Swenseth and Olson (2014) applied a simulation model for analysis of a human resources supply chain.

##### *Organizational structure*

Organizational structure was considered in a nonlinear constrained optimization problem evaluating performance of a serial manufacturing and supply system by Liu et al. (2004). Lamsal et al. (2016) considered the organizational structure of an agricultural system for harvesting logistics in the United States.

#### 4.6. Risk Management

Supply chains face intense turbulence and uncertainty from a variety of sources. Wagner and Bode (2008) surveyed German executives, finding that supply chain performance was negatively impacted by demand side and supply risks, as opposed to less impact from risks from regulation, legal matters, bureaucracy and infrastructure, or even catastrophe. But all of these sources can impact supply chain operations. Huang et al. (2009) used a dynamic system model (based on queuing, with simulation for validation) to assess the impact of disruptive events on supply chains. Olson (2009) outlined the use of three categories of management science modeling to support supply chains (specifically the function of outsourcing evaluation). These models included multi-criteria selection models, simulation models for risk assessment from multiple sources, and balanced scorecard analysis for performance assessment in dealing with risks. Demand uncertainty was modeled by Sodhi and Tang (2009) through linear programming extensions considering demand uncertainty and cash flows. Wu et al. (2014) used maximin models to evaluate supply chain efficiency with respect to risk.

##### *Supplier selection*

Supplier selection modeling was addressed in Wu and Olson (2008a) using stochastic dominance and data envelopment analysis (DEA). These same authors presented simulation models for vendor selection (Wu and Olson 2008b). Wu and Olson (2010) applied DEA in vendor selection models considering value at risk. Olson and Wu (2011) presented outsourcing risk through scenario analysis. Outsourcing risk was considered in Wu et al. (2013) through fuzzy multi-objective programming. Analytical multiple criteria models for supplier selection have been extensively used for green supplier selection (Govindan et al. 2015a).

##### *Simulation*

Simulation has been widely applied to evaluate risk, due to its probabilistic nature. Canbolat et al. (2008) gave a sourcing risk assessment model in the US automotive field, focusing on risk factors obtained from literature review and interviews. Peng et al. (2014) proposed a system dynamics model for disaster relief supply chains.

##### *Balanced scorecards*

Balanced scorecards were proposed by Zimmermann and Seuring (2009) for automobile supply chains. Lee et al. (2015) gave a semantic web-based supplier discovery system matching supplier capabilities with buyer requirements. Brulhart and Moncef (2015) used balanced scorecards to evaluate financial and non-financial performance in a supply chain.

##### *Risk matrices*

Risk matrices were applied by Yang (2010) to evaluate risk factors in the Taiwan shipping industry. Cagliano et al. (2012) developed a risk identification and analysis model for manufacturing supply chains.

Overall a broad review of quantitative models for supply chain risk management has been developed with a network analysis identifying various sub-fields within this topic. Sustainability was an emergent risk management topic (Fahimnia et al. 2015).

#### 4.7. Sustainability

Sustainability is perhaps the youngest topic in this field, which has been considered as an important aspect of almost all functions discussed above. Here we refer to a few examples of considering sustainability dimensions in Supply chain functions. (Rezaei et al. 2016) used BWM for sustainable supplier selection, while (Trapp and Sarkis 2016) used an optimization model for sustainable supplier development.

## 5. Conclusion

Management science support for supply chain management is widespread. Modeling has supported strategic management in many areas, two broad categories being analysis of core competencies and of global strategy. Analytical modeling support has also been applied to many logistics decisions, as well as to marketing decisions. Models have supported relationship development, usually through system design implementing software of various kinds. In the organizational behavior area, models have been proposed to more efficiently manage human resources.

Support to the area of risk management is especially rich, due to the challenge of operating in dynamic environments with unforeseen challenges. This field usually involves probabilistic data. A variety of management science tools have been applied. Supplier selection often involves multiple criteria, calling for tradeoff analysis. Most risk management problems involve probabilistic data, with many stochastic models being applied. Monitoring performance is important, and balanced scorecards offer a means to measure performance on multiple dimensions. Risk matrices perform similar service focusing on risk management.

Reviewing the literature of SCM, Croom et al. (2000) found that the majority of studies in the field are 'descriptive' (67%). These studies facilitate 'prescriptive' studies, which currently have a lower share (33%). It is evident that MS has significantly contributed 'physical' problems in SCM such as inventory management, network and distribution planning, however there are relatively fewer studies in 'soft' problems such as trust and commitment or knowledge transfer. This is partly due to lack of proper MS tools for such problems, and partly due to the traditional dominance of qualitative studies in these parts of SCM. We think that one major future direction would be to devise more appropriate tools for these problems. Given the complex nature of SCM problems, traditional optimization tools might require significant enhancement or may not be applicable, flexible learning, artificial intelligence tools might better capture the complexity of emergent SCM problems. The research and use of MS tools new and old still has a fertile field to plow in the SCM discipline.

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