Preface

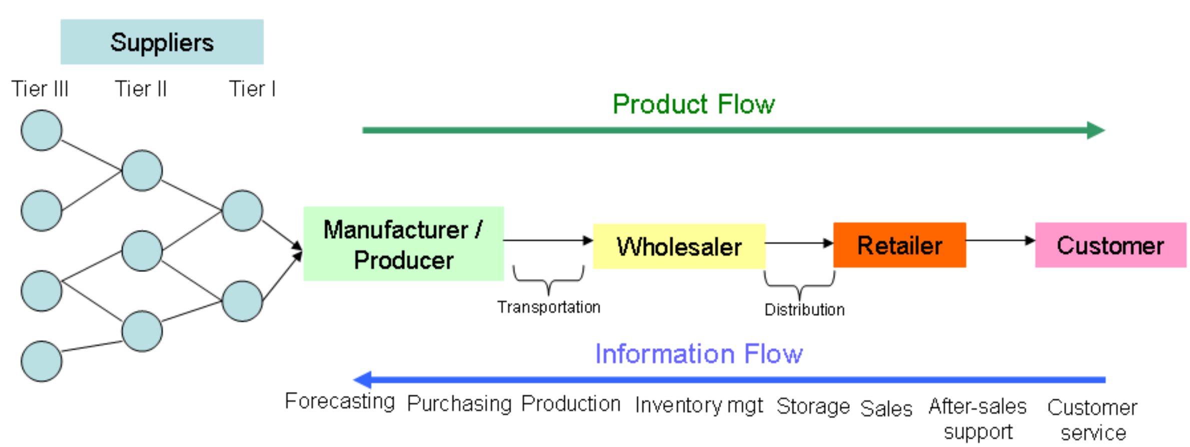
THE ROLE OF QUANTITATIVE METHODS IN SUPPLY CHAIN MANAGEMENT

Introduction

The supply chain of both manufacturing and commercial enterprises comprises a highly distributed environment, in which complex processes evolve in a network of companies (see Figure 1). Such processes include materials procurement and storage, production of intermediate and final products, warehousing, sales, customer service, and distribution. The role of the supply chain in a company's competitiveness is critical, since the supply chain affects directly customer satisfaction, inventory and distribution costs, and responsiveness to the ever changing markets. This role becomes more critical in today's distributed manufacturing environment, in which companies focus on core competencies and outsource supportive tasks, thus creating large supply networks. Within this environment, there are strong interactions of multiple entities, processes, and data. For each process in isolation, it is usually feasible to identify those decisions that are locally optimal, especially in a deterministic setting. However, decision making in supply chain systems should consider intrinsic uncertainties, while coordinating the interests and goals of the multitude of processes involved.

Operational Research-based Management Science (OR/MS) methods as well as Computational Intelligence (i.e. nature inspired techniques), offer effective techniques for modelling, analyzing and

Figure 1. The flow of materials and information in the supply chain



optimising operations in the uncertain environment of the supply chain, especially since these techniques are capable of handling complex interdependencies.

Operations Research and Computational Intelligence

The well-known and widely applied area of operational research (Churchman *et al.,* 1957; Hillier & Liebermann, 2005) offers powerful tools that enable optimal or near-optimal decision making in complex problems. Operational Research (OR) work may be classified into three major focus areas:

1. Probability, optimization, and dynamical systems theory (Luenberger, 1979; Kelly, 1994; Pinter, 2005)
2. Modeling (including construction and mathematical analysis of models, implementation and solution using computers, validation of models with data), (Jensen & Bard, 2003; Williams, 1999).
3. OR Applications in engineering and economics' disciplines that use models to make a practical impact on real-world problems (Thomson, 1982; Pinney & McWilliams, 1987).

Typical problems addressed successfully by OR include, optimal search, critical path analysis or project planning, floor planning, network optimization, allocation problems, production planning and scheduling, supply chain management, efficient messaging and customer response tactics, automation, transportation, distribution, etc.

Computational Intelligence (CI) is a term corresponding to a new generation of algorithmic methodologies in artificial intelligence, which combines elements of learning, adaptation, evolution and approximate (fuzzy) reasoning to create programs that -in a way- can be considered intelligent. Various editions can be found in modern literature around the fundamentals of CI, such as (Nilsson, 1998; Chen, 2000; Zimmermann *et al.,* 2001; Engelbrecht, 2002). CI has emerged as a rapid growing field in the past few years. Its variety of intelligent techniques emulate human intelligence and processes found in natural systems such as adaptation and learning, planning under large uncertainty, coping with large amounts of data, etc.

Computational intelligence methodologies can be generally classified into three major areas:

1. Standard widely acknowledged and applied intelligent techniques, such as neural networks (Haykin, 1994; Chen & Wang, 2006), fuzzy systems (Zadeh, 1965; Dubois & Prade, 1980), genetic algorithms and genetic programming (Holland, 1975; Koza, 1992) and other machine learning algorithms (Michalski, *et a.,l* 1983; Mitchell, 1997). These methods manage to successfully perform association, generalization, function approximation, rule induction, etc. in difficult multivariate domains of application.
2. Hybrid and Adaptive Intelligence (Negoita *et al.,* 2005; Abbod *et al.,* 2002), i.e. efficient combinations of the above mentioned intelligent techniques, with other intelligent or conventional methodologies for handling complex problems. Usually one of the methods combined within a hybrid or adaptive scheme, is used either to filter or to fine tune special operations of another methodology. Most popular hybrid methodologies are neuro-fuzzy systems, evolving-fuzzy systems, neuro-genetic approaches and genetic-fuzzy ones.
3. Nature Inspired Intelligence (NII) such as swarm intelligence, ant colony optimization, bee-algorithms, artificial immune systems etc., (Kannan *et al.,* 2004; Dorigo, 2005). Usually these

methodologies represent simultaneous exploration and exploitation of the search space in a smart manner (i.e. local and global search), analogously to the way natural systems or societies perform similar tasks (e.g. swarm flying or swimming, food search and identification, etc.)

Recent collections of research papers or textbooks demonstrate the potential of CI methods to address applications in transportation (Teodorovic, 2008), production planning (Voß and Woodruff, 2006), and supply chain management (Chaib-draa & Müller, 2006).

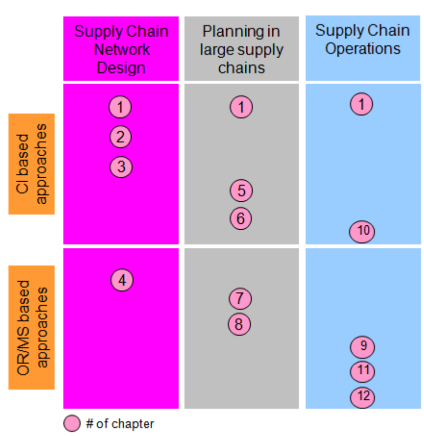
Scope and Contents of this Volume

This edited volume presents intelligent OR/MS and CI approaches for addressing the significant activities along the entire spectrum of the supply chain i.e. from forecasting, planning for production and distribution to actual implementation, including production and inventory control, warehouse management, management of transportation, and distribution. Emphasis is given to those methods and techniques that provide effective solutions to complex supply chain problems. The edited volume also includes integrated case studies that describe the solution to actual problems of high complexity. All concepts, ideas, methods and techniques, as well as integrated applications, presented in this volume aim in illustrating the significant value of CI and OR in resolving complex supply chain issues and providing breakthrough results.

Figure 2 classifies the contents of the current volume with respect to both the area of supply chain management addressed, as well as the type of method used. The volume contents are grouped in three sections:

- Section 1 focuses on the synthesis, or design, of supply chains.
- Section 2 focuses on planning, including forecasting and inventory management, in large supply chains.
- Section 3 focuses on supply chain operations, including warehouse management, production scheduling, as well as transportation and distribution.

Figure 2.Chapter classification



Prior to these three sections, Chapter 1 presents a survey of the available literature, regarding the use of nature-inspired (NI) methodologies to address supply chain management problems. The chapter presents initially the main characteristics and issues in a supply chain. In addition, some NI algorithms as well as their underlying natural principles are analyzed followed by findings from the literature review. The chapter concludes with a future research agenda in the area of NI in Supply Chain Management.

As mentioned before, Section 1 focuses on the synthesis, or design, of supply chains in order to address market opportunities on both an opportunistic or long-term basis.

Chapter 2 recognizes the significant contribution that e-marketplaces may offer to supply chain integration, and especially in areas such as enhanced information sharing among partners, reduction of administrative costs, streamlining of transactions, and improvement of transparency. Building upon these strengths, the research addresses the case of coalitions of small and medium-size suppliers, which are formed to respond effectively to significant customer requests, and to share the related risk. Specifically, the work focuses on key steps of coalition management, including the selection of the partners, synthesis of customer proposals, and profit sharing among partners. To address the latter, the authors combine game theory (Sharpley value), simulation experiments and a multi-agent architecture, for coalition management and profit sharing among partners in neutral e-marketplaces.. They have also developed a simulation environment based on multi agent architecture to test their approach and to support the competitiveness of SMEs. The test results show that in this environment, suppliers that form coalitions gain more benefits than the customers.

Chapter 3 also addresses aspects of collaboration among independent supply chains in the context of co-opetition, in which firms cooperate and compete at the same time. The researchers investigate sharing of production capacity in inter-firm networks. Specifically they focus on the issue of capacity investments under two models: In the first model there is no sharing of information in the inter-firm network, while in the second there is a periodic information exchange among firms concerning production capacity. The proposed models have been simulated and tested using a Multi Agent Architecture. The simulation results indicate that under the Information Sharing model the capacity investments can be drastically reduced, maintaining a high level of profit (at the same level as in the no information sharing model).

Chapter 4 addresses the design of supply chain networks comprising multiproduct production facilities with shared production resources, warehouses, distribution centers, and customer zones. Furthermore, demand uncertainty is considered through a number of likely scenarios. The problem is formulated as a mixed-integer linear programming problem, which aims to assist senior operations management in decision making about production allocation, production capacity per site, purchase of raw materials and network configuration. The proposed model is solved to global optimality using standard branch-and-bound techniques. The results of a significant case study indicate the value of a model that considers the complex interactions of such networks. Furthermore, the computational cost was found to be relatively low, thus making the overall model attractive for the solution of large-scale problems.

Section 2 focuses on planning, including forecasting and inventory management, in large supply chains.

Chapter 5 explores the potential of computational intelligence approaches as forecasting mechanisms for end product sales to the customer. It proposes a multivariate forecasting methodology that uses advanced training methods (Optimized Levenberg-Marquardt with Adaptive Momentum) in Artificial Neural Networks (ANNs), while exploring the potential of the powerful Support Vector Machines theory in this area. The proposed approach has been evaluated using public data from the Netflix movie rental online DVD store in order to predict the demand for movie rentals during the critical, for sales, Christmas holiday season. All ANNs tested performed quite well, while the winner exhibited reasonable prediction capability. These results illustrate the value of advanced multivariate models in capturing the complex interactions that influence SC demand in uncertain environments.

Chapter 6 addresses the problem of developing ordering policies that minimise the overall supply chain cost, while mitigating the bullwhip effect, in which demand variance at the customer end is amplified along the chain upstream. The researchers extend work in Evolutionary Algorithms and simulation to develop effective ordering policies. The extension comprises of capitalising on the Quantum Inspired Genetic Algorithm (QIGA) and on Grammatical Evolution (GE). Both the standard supply chain of the Beer Game, and arborescent supply chains have been investigated under stochastic demand distributions and lead times, and capacitated inventory. The results indicate that GE, with an appropriate grammar, can outperform other EA approaches over a range of supply network topologies and constraints. This does not appear to hold, in general, for QIGA in its current implementation. Thus, GE may effectively support a decision support system for ordering.

Chapter 7 overviews recent trends for risk management in extended supply chains. Risk and disruptions of operations are becoming significant issues as supply chains become globalised. Within this context, the chapter focuses on the area of quantifying the impact of supply chain disruptions on optimal determination of inventory control policies in a stochastic environment with unreliable sourcing. Specifically, single period (newsvendor-type) problems are examined, analyzing typical methodologies for systems with multiple unreliable suppliers due to production or distribution disruptions. Several promising directions for future research are also discussed, including extensions to multiple types of products, to more than two suppliers, as well as the explicit inclusion of service level concerns.

Chapter 8 deals with modelling and solution approaches for both the problem of prepositioning emergency supplies prior to a disaster, as well as the problem of their distribution after the disaster onset. Initially, some key aspects that are critical to the design and operations of effective relief distribution networks are discussed followed by a review of different algorithmic approaches reported in the literature of pre-disaster prepositioning of emergency supplies. A non-exhaustive survey of solution approaches for the post-disaster distribution of supplies is also presented. Chapter 8 reviews also a series of exact and heuristic methods that can be applied to tackle the aforementioned problems. In addition, the advantages and limitations of each of these two classes of approaches are discussed. The chapter concludes with a methodological framework for addressing the design and operation of relief distribution networks and some interesting research avenues.

Section 3 focuses on supply chain operations, including warehouse management, production scheduling, as well as transportation and distribution.

Chapter 9 deals with the development of an analytical parametric model for the order picking process in a modular warehouse. The research attempts to address three distinct, yet relevant, areas: (i) to produce a generic and analytical framework to model the order picking process, (ii) to define practical performance measures for the order picking process, and (iii) to provide the tools for a warehouse manager to set goals, measure performance and identify areas of improvement in his area of responsibility. In addition to these, the Chapter sets the foundations to further expand on other warehouse processes, such as loading/unloading, products receipt, etc., that pass the boundaries of order picking. The analysis is corroborated by a case study, accompanied by ABC analysis of the warehouse operation and a presentation of a fair frame to measure workers' performance.

Chapter 10 addresses the coordination of internal production supply chains in serial manufacturing lines. The model line examined comprises a set of unreliable machines linked with buffers, and the objective is to resolve the trade-off between minimizing holding costs and maintaining a high service rate. The work analyzes the performance of six important pull production control policies using discrete event simulation and setting the control parameters of each policy through a hybrid Genetic Algorithm (GA). Two types of penalty functions have been explored for constraint handling: A "death penalty" function and an exponential penalty function, which is synthesized using the results of the GA with the "death penalty" function. The latter exhibits superior results. Furthermore, the sensitivity analysis of significant system parameters offers considerable insight to the underlying mechanics of the JIT control policies examined.

Chapter 11 addresses a problem related to the courier environment in which a fleet of vehicles serves a set of customers using a hybrid service policy that includes (a) mandatory and (b) flexible requests (calls). The authors propose a new method to perform assignment of service requests (calls) with some flexibility taking into account expected routes in a multi-period horizon. The problem is solved on a rolling horizon basis in order to address the dynamics of arriving calls. The method is tested through several theoretical examples, as well as in an extensive industrial case, and appears to be superior to current methods used in practice.

Chapter 12 presents two travel time prediction methods that are embedded in a real-time fleet management system applied in fleets that execute urban freight deliveries. The author discusses the prediction results generated by the two methods that use historical and real-time data, respectively. The first method follows the *k-nn* model, which relies on the non-parametric regression method, whereas the second one relies on an interpolation scheme, which is employed during the transmission of real-time traffic data in fixed intervals. The study focuses on exploring the interaction of factors that affect prediction accuracy by modelling both prediction methods. The data employed are provided by real-life scenarios of a freight carrier and the experiments follow a 2-level full factorial design approach.

Standard operational research is now a mature and widely recognized field of applied mathematics and high-level computation. The ever-growing realm of applications and the computing power explosion of the last two decades are driving related research in new exciting directions, continuing to play an important role in modern management engineering. A pioneering position of those real world OR applications holds for supply chain management, a fast growing topic combining computing algorithms either based on discrete mathematics and heuristics, or related to computational intelligence based on evolution, learning and adaptation. To this end, we hope that the present Volume contributes towards the advancement of high quality research in CI solutions for real world OR problems.

As a final note to this introduction , the authors would like to express their sincere appreciation to all authors, contributors and external reviewers of the papers submitted for this edition.

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