A STUDY OF SINGLE AND MULTIPLE PRODUCT SUPPLY CHAINS DESIGN TO DEVELOP BUSINESS

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ABSTRACT

A supply chain can be defined as a network of autonomous or semiautonomous business entities collectively responsible for procurement, manufacturing and distribution activities associated with one or more families of related products. Different entities in a supply chain operate subject to different sets of constraints and objectives. However, these entities are highly interdependent when it comes to improving performance of the supply chain in terms of objectives such as on- time delivery, quality assurance, and cost minimization. As a result, performance of any entity in a supply chain depends on the performance of others, and their willingness and ability to coordinate activities within the supply chain. Supply chain reengineering efforts have the potential to impact performance in a big way. Often they are undertaken with only a probabilistic view of the future, and it is essential to perform a detailed risk analysis before adopting a new process. In addition, many times these reengineering efforts are made under politically and emotionally charged circumstances.A typical supply chain faces uncertainty in terms of supply, demand, and process. Our framework reduces the effort involved in modelling various alternatives and measuring their performance through simulation under different assumptions about uncertainties. This eases the ability of decision makers to quantitatively assess the risk and benefits associated with various supply chain reengineering alternatives. In this study, we describe our framework in its current state and provide examples to demonstrate how issues relevant to supply chain management can be analysed using it.

KEYWORDS: *Single and Multiple Product, Supply Chains Design, Develop, Business, performance, activities.*

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INTRODUCTION: Companies operate in business environments that are increasingly volatile, which is one of the reasons why managing demand and supply uncertainties has become a key objective for operations (Simchi-Levi 2010). Demand uncertainty relates to product characteristics: for example, the demand of a new product is less predictable than that of an improved version of an existing product, and an innovative high-technology consumer product is less predictable than a functional product such as basic food or energy. Supply uncertainty, on the other hand, is linked to the supply process: when the manufacturing process and technology are mature, the supply process is typically stable, but if technology is novel and the supply base is limited in size and experience, the supply process evolves in more uncertain ways. In addition to these operational factors, various low-probability high-impact events, such as natural catastrophes can cause unexpected drops in demand or shortages in supply (Kleindorfer and Saad 2005).

Important decisions that are critical for managing demand and supply include designing the supply chain or network, determining the long term production capacity, and making sourcing decisions for critical materials and services. The impact of uncertainties on these decision problems varies from negligible to critical: planning daily operations when workforce and other resources are fixed is a largely deterministic problem, but the problem of designing a supply network for a new consumer product involves significant uncertainty. Even though the importance of uncertainties is recognized by most decision makers, they are not very well dealt with in practice. Sheffi (2005) lists various cases where demand and supply mismatches have had serious consequences: for example, in 1998, Marks & Spencer gambled on gray being the fashion colors of the coming sales season for clothes and lost £150 million in sales failures and clearingexcess stock; in 2000, IBM launched new Think Pad models and seriously under-forecasted their demand, which lead to severe shortages, customer dissatisfaction and substantial amount of lost sales; and in 2003, Wyeth prepared 4 million flu vaccine doses but was able to sell less than 400 000 of them. Yet, there are success stories, too, such as the video rental giant Blockbusters, which increased its US market share from 24% to 40% between 1997 and 2002 largely due to the introduction of a new revenue sharing contract for demand risk management; and Hewlett-Packard, who

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introduced a new procurement risk management strategy that generated over $400 million in cumulative cost savings between 2001 and 2007 (Nagali et al. 2008).

Demand uncertainty is a critical driver for modern supply chain planning practices and in industries such as fashion retail, demand forecast accuracy has a major impact on company's financial performance. In general, the higher upstream in the supply chain a company is, the more forecast- driven (as opposed to demand-driven) the operations, and thus, the higher the impact of demand uncertainty. This is illustrated by the bullwhip effect, which describes the amplification of order quantities and inventories when moving upstream in a supply chain. This fluctuation is partly caused by the poor visibility of the end customer demand, which results in ―information distortion‖ in demand forecasting. In practice, however, systemic approaches to demand uncertainty are rare: a typical demand planning process is based on a point forecast over the planning horizon (Kilger and Wagner 2008). At best, forecast deviation is estimated from historical performance and buffers such as safety stocks are adjusted based on the estimated deviation.

Supply uncertainty is as critical as demand uncertainty for supply chain strategy (Lee 2002). It has received increasing attention lately, and two separate trends can be identified: i) intense competition, pressure to cut costs, and rapid pace of technological development have led to operational supply uncertainties caused by, for example, constrained capacity, or quality problems; and ii) various high-impact disruptions such as natural catastrophes and financial term oils have induced disruptive supply risks that have had serious consequences. Compared to demand, the impacts of supply uncertainties on supply chain decisions are not yet as well understood.The proposed study is design to explore the impacts of supply uncertainties on different types of supply chain design decisions, such as facility location, customer demand assignment, and inventory decisions, and propose supply chain design models to help decision makers design lean but more reliable supply chain networks by taking supply uncertainty issues into consideration at the supply chain design phase.

Two common types of supply uncertainties, the random yield of supply and the random disruption of supply, are considered. For simplification, we only study single product problems in this dissertation. For most

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industries, it is very difficult to accurately forecast the demand for new products. In an emerging industry, manufacturers devote substantial efforts to studying the applications and benefits of new technologies.However, when a technology is new, firms have little information on the commercial uptake of new products and, therefore, have poor forecasts of the product demand. Demand forecasts for new products can also be inaccurate in existing industries. Customers' tastes and preferences are hard to predict and will change over time. Therefore, the historical demand patterns for an existing product might not always be a good reference for the next generation of products.

REVIEW OF LITERATURE: The SCM as understood so far is the process of procuring, moving, storing and retrieving of material as well as managing people and information efficiently and economically. Generally planning, procurement, manufacturing, marketing and the distribution in any organization along with the supply chain operate independently. These organizations have their own objectives and more often than not these objectives conflict with each other. It is also evident that marketing objective of high consumer service and attainment of maximum sales output, always conflicts with manufacturing and distribution goals. Invariably manufacturing operations are designed to maximize output and lower the costs with little consideration for the impact on inventory levels and distribution capabilities. Purchasing contracts often get negotiated with scarce or minimal information beyond traditional buying patterns. The net effect of these aspects is generation of voids as regards to an integrated plan in any organization.

The formulation of SCM system design arises under two conditions. Firstly when a new system is being set up or secondly when the existing system is to be changed and redesigned to accommodate certain imperative changes. These changes may occur due to changes in requirement of consumers, demands, product, costs or policy changes as numerated below :-

(a) Consumer service requirements may change due to varying market competition, service policy, changes in consumer demand or the pattern of consumer demand.

(b) Change in demand can be a result of shift in population or shift in consumer attitude resulting in changes to demands by location, time, product etc.

(c) Technological changes also affect the consumer demand pattern, change in product characteristics such as weight, volume and shape effect packaging, handling, storage and transportation options.

(d) Changes due to implementation of new taxes or policies, Labour agreements, development in IT systems, changes in storage and transportation costs can also force a company to change its pricing policy.

Most of the ―responsiveness‖ literature for supply chains tends to be qualitative and conceptual, and has not been subjected to the kind of quantitative analysis that this study intends to address. There are, however, several related works that offer relevant in sights. Lee, Padmanabhan, and Whang (1997) further demonstrated that the―bullwhip‖ effect is a consequence of the information delay due to the structure of supply chains, and the severity of this effect is positively related to lead times. Responsiveness in the wider supply chain context has been discussed by Fisher (1997), who argues that the product characteristics (innovative or functional) and life cycles need to be linked to the layout and functions (conversion and market mediation) of the supply chain. He also pointed out the need of reducing the lead time, which enables quick response to unpredictable demand to minimize stock-outs, markdowns and obsolete inventory. Matson and McFarlane (1999) discussed concepts and issues associated with responsiveness in productionand illustrated the audit tools they proposed from a case study in the steel industry. Recently, several conceptual models on supply chain responsiveness have been proposed. Christopher and Towill (2001) integrate lead time and agility to highlight the differences in their approach, and combined them to propose an integrated hybrid strategy for designing cost-effective responsive supply chains with seamless connection between manufacturing and logistics. In a later work, Yusuf, Gunasekaran, Adeleye, and Sivayoganathan (2004) have reviewed emerging patterns for creating responsive supply chains based on survey research driven by a conceptual model. Holweg (2005) proposed in his study that product, process and volume are three key factors that determine the responsiveness of a supply chain system, and provided guidelines on how to align the supply chain strategy to these three factors in order to balance responsiveness to customer demand and supply chain efficiency. An examination of supply chain

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systems in process industries from a responsiveness view point was carried out by Shaw, Burgess, Mattos, and Stec (2005). These authors also proposed a conceptual management strategy to improve responsiveness.

Another group of relevant papers to be considered are on supply chain design and operation. A general review of this area and a specific review for supply chains in process industries are presented by Shah (2005). Some recent works include the following. Tsiakis, Shah, and Pantelides (2001) presented a supply chain design model for the steady-state continuous processes. Their supply chain model was developed based on determining the connection between multiple markets and multiple plants with fixed locations. Jackson and Grossmann (2003) presented a temporal decomposition scheme based on Lagrangean decomposition for a nonlinear programming problem model for multi-site production planning and distribution, where nonlinear terms arise from the relationship between production and physical properties or blending ratios. Schulz, Diaz, and Bandoni (2005) described tomtit-period MINLP models for short-term planning of petrochemical complexes. Linearization techniques were applied to reformulate the non-convex bilinear constraints as MILP models.

Recently, Sousa, Shah, and Papa Georgiou (2006) presented a two stage procedure for supply chain design with responsiveness testing. In the first stage, they design the supply chain network and optimize the production and distribution planning over a long time horizon. In the second stage, responsiveness of the first stage decisions are assessed using the service level to the customers (i.e. delay in the order fulfilment). However, all these models consider supply chain networks with only dedicated processes. Multiproduct batch plants or flexible processes were not taken into account, and hence no scheduling models were included.

There are works on supply chain optimization with consideration of flexible processes in the production network, but most of them are restricted to planning and scheduling for a given facility in a fixed location without extension to the multi-site supply chain network design problems. A bi-level decomposition algorithm was proposed, which reduced the computational time significantly. Kallrath (2002) described a tool for simultaneous strategic and operational planning in a multi-site

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production network, where key decisions include operating modes of equipment in each time period, production and supply of products, minor changes to the infrastructure and raw material purchases and contracts. A multi-period model is formulated where equipment may undergo one change of operation mode per period. The standard material balance equations are adjusted to account for the fact that transportation times are much shorter than the period durations. Chen, Wang, and Lee (2003) presented a multiproduct, multi-stage and multi-period production and distribution planning model. They also proposed a two-phase fuzzy decision- making method to obtain a compromise solution among all participants of the multi-enterprise supply chain.

To account for product demand fluctuation and to obtain a better understanding of how uncertainty affects the supply chain performance, a number of approaches have been proposed in the chemical engineering literature for the quantitative treatment of uncertainty in the design, planning and scheduling problems. A classification of different areas of uncertainty for batch chemical plant design is suggested by Subramanian, Pekny, and Reklaitis (1994), where uncertainty in price, demand, equipment reliability and manufacturing are taken into account. The authors used the popular scenario based approach, which attempts to capture uncertainty by representing it in terms of a number of discrete realizations of the stochastic quantities, constituting distinct scenarios.

Each complete realization of all uncertain parameters gives rise to a scenario and all the possible future outcomes are forecasted and taken into account through the use of scenarios. The objective is to find an expected solution which performs well under all scenarios. The scenario-based approach provides a straightforward way to implicitly account for uncertainty. Its main drawback is that it typically relies on either a priori forecasting of all possible outcomes, or the explicit/implicit discretization's of a continuous multivariate probability distribution by methods of Gaussian quadrature integration or Monte Carlo sampling, which can result in an exponential number of scenarios.

Another popular method to address the uncertainty is using probabilistic approaches, which consider the uncertainty aspect of the supply chain by treating one or more parameters as random variables with known probability distribution. By introducing a

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certain number of nonlinear terms from continuous distribution, this approach can lead to a reasonable size of the deterministic equivalent representation of the probabilistic model, circumventing the need for explicit/implicit discretization or sampling.

SUPPLY CHAIN PROCESS: The Production Planning and Inventory Control Process encompass the manufacturing and storage sub-processes, and their interfaces. More specifically, production planning describes the design and management of the entire manufacturing process (including raw material scheduling and acquisition, manufacturing process design and scheduling, and material handling design and control). Inventory control describes the design and management of the storage policies and procedures for raw materials, work-in-process inventories, and usually, final products. The Distribution and Logistics Process determines how products are retrieved and transported from the warehouse to retailers. These products may be transported to retailers directly, or may first be moved to distribution facilities, which, in turn, transport products to retailers. This process includes the management of inventory retrieval, transportation, and final product delivery. These processes interact with one another to produce an integrated supply chain. The design and management of these processes determine the extent to which the supply chain works as a unit to meet required performance objectives.

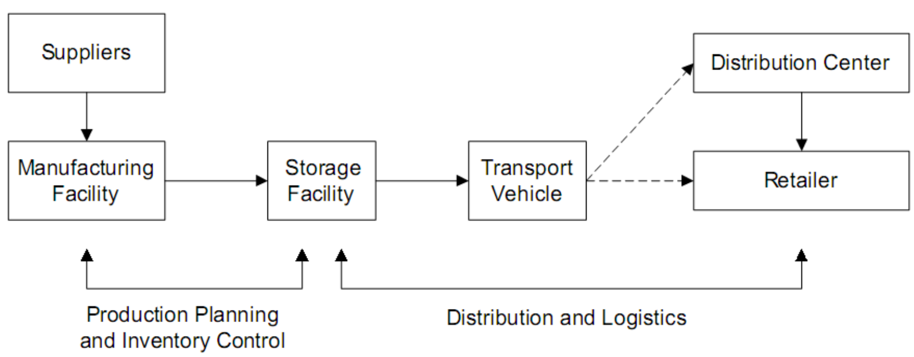

Figure 1- The Supply Chain Process

DECISION VARIABLES IN SUPPLY CHAIN MODELING: In supply chain modeling, the performance measures are expressed as functions of one or more decision variables. These decision variables

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are then chosen in such a way as to optimize one or more performance measures.

• **Production/Distribution Scheduling:** Scheduling the manufacturing and/or distribution.

• **Inventory Levels:** Determining the amount and location of every raw material, subassembly, and final assembly storage.

• **Number of Stages (Echelons):** Determining the number of stages (or echelons) that will comprise the supply chain. This involves either increasing or decreasing the chain is level of vertical integration by combining (or eliminating) stages or separating (or adding) stages, respectively.

• **Distribution Center (DC) -** Customer Assignment: Determining which DC(s) will serve which customer(s).

• **Plant -** Product Assignment: Determining which plant(s) will manufacture which product(s).

• **Buyer -** Supplier Relationships: Determining and developing critical aspects of the buyer-supplier relationship.

• **Product Differentiation Step Specification:** Determining the step within the process of product manufacturing at which the product should be differentiated (or specialized).

• **Number of Product Types Held in Inventory:** Determining the number of different product types that will be held in finished goods inventory.

SUPPLY CHAIN MODELING ISSUES:

In supply chain modeling, there are a number of issues that are receiving increasing attention, as evidenced by their prevalent consideration in the work reviewed here. These issues are: (1) product postponement, (2) global versus single- nation supply chain modeling, and (3) demand distortion and variance amplification.

Product Postponement: Product postponement is the practice of delaying one or more operations to a later point in the supply chain, thus delaying the point of product differentiation. There are numerous potential benefits to be realized from postponement, one of the most compelling of which is the reduction in the value and amount of held inventory, resulting in lower holding costs. There are two primary considerations in developing a postponement strategy for a particular end- item: (1) determining how many steps to

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postpone and (2) determining which steps to postpone.

Global vs. Single-Nation Supply Chain Modeling: Global Supply Chains (GSC) are supply chains that operate (i.e., contain facilities) in multiple nations. When modeling GSCs, there are additional considerations affecting SC performance that are not present in supply chains operating in a single nation. Export regulations, duty rates, and exchange rates are a few of the additional necessary considerations when modeling GSCs.

Demand Distortion and Variance Amplification: Demand distortion is the phenomenon in which orders to the supplier have larger variance than sales to the buyer and variance amplification occurs when the distortion of the demand propagates upstream in amplified. These phenomena (also known collectively as the bullwhip effect or whiplash effect) are common in supply chain systems. The consequences of the bullwhip effect on the supply chain may be severe, the most serious of which is excess inventory costs. As a result, a number of strategies have been developed to counteractthe effects of demand distortion and variance amplification.

CONCLUSION:A supply chain is defined as a set of relationships among suppliers, manufacturers, distributors, and retailers that facilitates the transformation of raw materials into final products. Although the supply chain is comprised of a number of business components, the chain itself is viewed as a single entity. Traditionally, practitioners and researchers have limited their analyses and scope to individual stages within the larger chain, but have recently identified a need for a more integrated approach to manufacturing system design. Consequently, the supply chain framework has emerged as an important component of this new, integrated approach. Supply chain reengineering efforts have the potential to impact performance in a big way. Often they are undertaken with only a probabilistic view of the future, and it is essential to perform a detailed risk analysis before adopting a new process. In addition, many times these reengineering efforts are made under politically and emotionally charged circumstances. A typical supply chain faces uncertainty in terms of supply, demand, and process. Our framework reduces the effort involved in modelling various alternatives and measuring their performance through simulation under different assumptions about uncertainties. This eases the ability of decision makers to quantitatively assess the risk and benefits associated with various supply chain reengineering alternatives. Recently, however, there has been increasing attention placed on the performance, design, and analysis of the supply chain as a whole. This attention is largely a result of the rising costs of manufacturing, the shrinking resources of manufacturing bases, shortened product life cycles, the leveling of the playing field within manufacturing, and the globalization of market economies.

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