Efficiency Issues in Supply Chain Management

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Abstract

This paper discusses the efficiency issues in purchasing, manufacturing, and transporting over various stages of a supply chain such as supplier selection, production, and distribution. To address the efficiency questions, we group the supply chain into six independent areas. Four of these, vendor management, scheduling, inventory management, and transportation, are related to the product flow, whereas network design and information sharing are non-flow related.

Keywords: Efficiency, Supply Chain Management

Introduction

For the last two decades, the business organisations are facing unprecedented challenges to improve efficiency or productivity. The Black Monday of October, 1987 came as a warning to the business world to find better ways to do business and the advent of personal computer added to the competition among the organisations to affect re-engineering. Even business ethics took its toll and we saw the collapse of Enron and world dot com through their cooked up books. The recent stock market crash since the middle of 2008 added fuel to fire that caused bank failures and shortage of liquidity and investments. Several factors came in to the fore: cure the flagging profitability, improve the bottom line, improve the short-term share holder's profit, and the fear of merger. Governments, industries and businesses have embraced downsizing and outsourcing as primary cure. Downsizing has appeared in different paradigms such as restructuring, reengineering, re-hosting, life-sizing etc. The ideas of productivity, efficiency, effectiveness, performance, quality, best practices and flexible organisations and systems became the common paradigm of doing business. Even the then Prime Minister of a socialist country such as India, Atal Bihari Vajpayee, was coining the word "*utpadakta*" meaning productivity during the turn of the century. In this section we will explain various terms mentioned above, that add to the success of a business.

The concept of efficiency, effectiveness, quality, productivity and overall organisational performance in some form or the other has occupied researchers in economics as early as 1957 (Ferrell), in management science (Charnes *et al*., 1978), productions operations (Eilon, 1987, Sumanth, 1988), organizational behaviour (Proctor *et al*., 1994) and in accounting (Sherman, 1988) etc.). Efficiency is the totality of the outputs that can be obtained from an economic unit. Effectiveness is however, a nebulous concept. Bhatt *et al*. (2004), while defining the overall productivity measure of performance of Canadian orchestras in 12 cities, did discuss what the meaning of effectiveness might entail. One component of effectiveness is the amount of the earned revenue generated and the number of audience brought in. If these results are measured against inputs provided, this measure would be used as efficiency. This, of course, is using 'efficiency' in a particular way. It does not measure other potential aspects of efficiency- the number of musician hours used to rehearse and perform music, the generation of largest possible audience with the fewest possible performances or creation of the most media exposure for the smallest possible advertisement buy. Then, there is a question and the role of quality. If the quality of the product or performance is not up to the satisfaction, it will result in fewer audiences down the road or a line up for the return of the tickets or products. Maarten (2008) comes up with a general system theory explanation that

effectiveness = actual outputs/ desired outputs.

Efficiency = actual outputs/ actual inputs

and then productivity is a combination of effectiveness and efficiency. In an overall production/manufacturing system productivity gets defined as

efficiency + effectiveness + quality.

Deming (1986) defined

quality = worker's efforts/ total cost

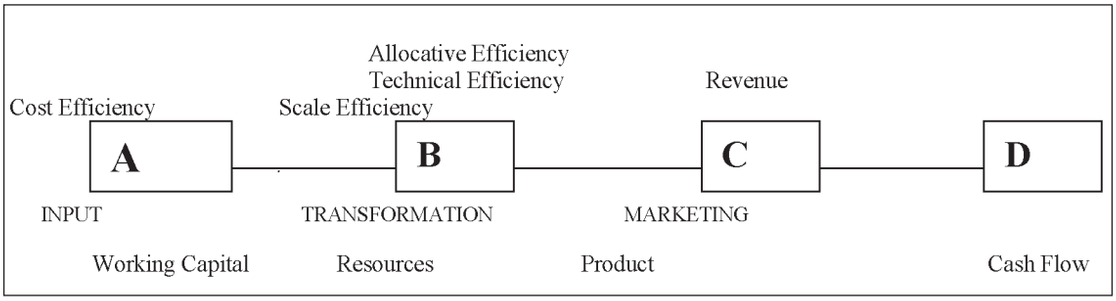
and argued that increasing quality will reduce cost. Businesses would ensure quality through return policies and poor quality would offset the savings garnered in the input costs. He emphasized the change in the culture of organisations to accept the dynamic and continuous nature of quality and efficiency improvement that it is a continuous work in progress. A new dimension that is going to be added to this concept is that of carbon trading. The concern for global warming is already taking hold in the "cap and trade" policy under consideration with the U.S. administration. The call for buying local products to save the fuel and carbon emissions is becoming a reality.

Any business, industry or government undertakings are expected to be accountable to their stock/ stake holders for the funds they provide. This generally guides their internal culture to produce highest quality of goods and services at the lowest possible cost. The aim is to follow the best practices in their operations and dealings. The concept of "best practices" also deals with efficiency and productivity but the concept is socio/technical. Cormican and O'Sullivan (2004) define a best practice model as a socio/technical systems approach to all aspects of organisation. This includes people, process and the technology related issues. It is the sum total of the efficiencies obtained through optimizing the performance levels strategy, culture, planning, structure and communication and collaboration. The idea is to asses where we are and where we aught to be. Productivity being a well defined technical concept but to associate the performance of the organisation as a whole we will use efficiency to define the best practices of an organisation as an over arching term.

The history of achieving better in a recorded formal setting such as production or manufacturing or planning dates back to the times of Taylor, and Gilbreth (time and motion study) in the early twentieth century . But the pioneer of it all was William Edward Deming. His concept of efficiency, productivity and organisational performance is in the root of all these discussions of best practices. His 14 points of management (Deming, 1986) became a must for every CEO of US business in the nineties. He helped Japanese business after the Second World War to improve quality in production as well as in management. His efforts resulted in developing the just-in-time manufacturing process at Toyota Motors in 1975. Deming was a statistician and taught statistical quality control. He mentioned once that he considered Prof. Prashanta Mahalanobis one of his gurus. Mahalanobis was the creator of the second five year plan of India implemented from 1957-1962. The author is honoured to have been associated with him during his tenure at Indian Statistical Institute, Calcutta.

In a general production process, the overall efficiency or productivity is defined as an aggregate of cost efficiency, that converts capital cost into input resources; allocative (optimal mix of inputs), technical (optimal amount of inputs) and scale (optimal volume and minimum fixed cost) efficiencies of the transformation process that convert resources to products, and revenue efficiency that converts outputs to cash flow as in Fig.1 (Sherman, 1988). Revenue efficiency, which is the marketing and sales segment, depends on quality. An improvement in quality will therefore increase productivity. A study by General Electric on its dishwasher revealed that a 45% improvement in quality increased the labour productivity by 42% (Sumanth, 1988).

Fig. 1: A Production Process



In a complex system dealing with multiple outputs and multiple inputs, Sumanth (1998), on similar lines, has classified productivity in four categories:

(a) Partial productivity, which is a ratio of outputs to only one class of inputs, say labour.

(b) Total factor productivity with only capital and labour inputs.

(c) Total productivity in which all inputs are considered and

(d) Comprehensive total productivity that also includes undefined qualitative factors such as quality, relevance etc

Productivity (or efficiency in reference to organisation as a whole) is often defined as a performance index (PI), which is a ratio of an output to an input. Ratio analysis typically involves a number of PIs to gauge the overall performance of an organisation. Generally PI is meaningful only when there is a single output and a single input. Brinkerhoff (1990) gives several such productivity ratios to consider for an organisation. Governments and business report their performance citing such indices as ROI (Return on investment), ROS (return on sales), PE (Price –earning) ratio etc. National Health Service of UK reports on 400 PIs that are published annually (Thanassoulis *et al*., 1996). Thus productivity of an organisation as a whole is hard to define as it involves several outputs and multiple inputs, some of them non-commensurable. This is why, when a productivity improvement program is designed for a production process, the process is viewed in several stages. Rastogi (1988) identifies productivity improvement in three stages:

(a) Improvement in operation and technology of the production process by using various methods such as motion study, ergonomics, work study, value analysis, learning curves, Quality control, CAD/CAM, flexible manufacturing system (FMS) etc.

(b) Improvement in organisation of production process using suitable operation research techniques such as production scheduling, material management, zero base budgeting network analysis, PERT-CPM etc to improve allocative efficiency and effectiveness.

(c) Human productivity improvement methods such as job design, job enrichment, rotation, flextime, incentives, improving work conditions, and worker's participation to improve quality and labour productivity.

Supply Chain Management

Bhatt *et al.* (2006) trace the history of supply chain management (SCM) and its establishment as a subject in academia. The new SCM turned out to be the merger of purchasing and logistics and some more. Purchasing tended toward an upstream, supplier-facing concept whereas logistics tend to be outbound, a customer facing concept. Later, procurement, manufacturing operations and sales/marketing functions were added in the mix. Lambert *et al*. (1998) rendered the most acceptable definition of SCM so far. According to them, SCM 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." These key business processes are: (1) customer relationship management, (2) customer service management, (3) demand management, (4) order fulfillment, (5) manufacturing flow management, (6) supplier relationship management, (7) product development and commercialisation, and (8) return management. For our purpose, in this paper, we shall define SCM as a process of using information with the objective of optimizing the flow of products within a supply chain. A supply chain is thus a flow of goods and services through:

Suppliers → Manufactures → Distributors → Retailers → Customers

In order to discuss the efficiency improvement in activities in various parts a supply chain, we shall divide the paper into six independent areas. The first four: vendor (supplier) management, scheduling, inventory management, and transportation are related to the flow of product and data within the supply chain. Although, the product flow does not necessarily follow this order-for example, inventories can be places almost anywhere in the flow, this arrangement will be helpful in dealing with the problem taxonomy in here. Finally, the last two areas are non-flow related, which are: network design and information sharing.

Supplier management

One of the most important components for an effective supply chain strategy is to have appropriate suppliers. With SCM, suppliers are no longer an entity that can be easily replaced. SCM requires partnership and vendor relation development rather than simple contractual relationships. In that sense, OR (operations research) models have been used to support these new requirements. Bhatt and Borgesa (2005) discuss the operation research

models in SCM. We shall briefly discuss strategic issues and new developments. For this, the problem taxonomy in this area can be divided in to three categories: supplier selection, supplier performance evaluation, and supplier contract negotiation.

Supplier Selection

The objective of the vendor selection problem is to choose from a potential list of vendor candidates the ones that best suit the company's interest. At the same time, the problem also should determine how many suppliers the company needs, and how much business has to be allocated to each supplier. Normally, the supplier selection problem involves attaining multiple objectives at the same time; therefore, the OR models used to address this problem tend to have multi-criteria objectives. The most representative solution methods that fit this condition are Multi-objective Programming (MOP) (Weber and Current, 1993), Data Envelopment Analysis (DEA) (Weber *et al*., 2000), and Analytical Hierarchical Process (AHP) (Nydick and Hill, 1992). Recently, Appadoo, Bhatt and Bector (2007), and Appadoo *et al*. (2008) used the fuzzy TOPSIS method for the multi-criteria supplier selection problem for a single decision and a group decision making situation. For each product, the suppliers were evaluated for the criteria such as: profile, technology, quality, delivery and flexibility.

Supplier Performance Evaluation

Once the suppliers have been selected, it is required to monitor their performance continuously. DEA uses fractional programming (Charnes *et al*.,1978; Bhatt,1989) to compare relatively efficient suppliers based on multiple inputs and outputs (Weber, 1996)

Supplier Contract Negotiation

As stated before, with SCM, the importance of establishing a long-term relationship with suppliers is critical. In that sense, contract negotiation is the first step in establishing a successful relationship with suppliers. Charles Fishman (2006) in his book- The Wal-mart Effect, cites an example (described in section Packaging and Warehouse Management) as to how they negotiate with the suppliers to keep up to their slogan- We Sell for Less. Since the introduction of food section, it is: Save Money, Live Better. The concept of Reverse Marketing further alludes to negotiating with suppliers to match the supplies with the replenishment policies of the company (Leenders and Blenkhorn, 1988)

Scheduling

Scheduling is also known as production planning and control. The scheduling process involves all activities required to determine the amount of products to be produced in a certain planning horizon (T) to accomplish a certain demand (D). After determining the demand, the next step is to prepare the aggregate plan. The aggregate plan is a preliminary schedule of an organisation's overall operations that will satisfy the demand forecast at a minimum cost (Leung and Chan, 2009). After obtaining the Aggregate Plan, the next step is to develop the master production plan. In comparison with the Aggregate Plan, the master production plan includes capacity restrictions, and is more short term in nature. Finally, the master production plan is translated into loading and sequencing decisions, which mainly deal with deciding which jobs are going to be assigned to which specific work centers, and in which order this assignment is to be carried out. But, before we even embark upon production planning, there are two necessary steps to consider: one, product screening and two, brand selection. By designing an appropriate production plan that meets the demand, minimizes the costs of inventories and the costs of hiring and firing, the manufactures save money and adds to overall efficiency.

Product Screening

Research in new product development has identified product idea (design) screening to be critical in the development process in order to get a high quality product. Smimou, Bhatt and Dahl (2005) proposed a fuzzy analytical approach to a problem of selecting the best design idea from among five chosen. They were compared against three criteria: originality, appeal and effectiveness. In multi-criteria decision making, where the criteria are not quantifiable and judgment choices are to be made, fuzzy models are being used increasingly.

Brand (product) selection

A manufacturer or a retailer or even a consumer often seeks to purchase the best part or component or a product from suppliers. Among various brands available, the question boils down to selecting the one that fits their criteria best. In marketing literature, it is known as the problem of

brand selection. This topic also falls under "purchasing" which is a vital part of SCM. Not only the businesses, the national governments do a lot of purchasing that makes a large part of government budget. The Public Works and Government Services Canada (PWGSC), of Government of Canada manages 60,000 transactions annually and purchases $12 billion in goods and services such as flu vaccine, security systems and military aircrafts (www.tpsgc-pwgsc.gc.ca). For brand (product selection, the most well know solution method is called scoring model of Fishbein. Bhatt, Bhatnagar and Appadoo (2009) used a TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method to show over an example of selecting keynote computers that, it betters the Fishbein selection..

Enterprise Resource Planning (ERP)

As the organisations are embracing computer technology, ERP is gaining a high priory in business operations. ERP is an organisation- technology interface (Wang *et al*., 2008). The success of ERP adoption depends on external factors: vendor support, consultant competence, and internal factors within the organisation such as ERP team competence, ERP leadership, top management support and finally, the user support. If ERP lacks these factors, the studies found that almost 70% of ERP implementations have been found unsuccessful. Bhatt, Orellana and Jayaraman (2009) implemented ERP for a Winnipeg manufacturing firm to consolidate separate production, accounting and purchase systems for four separate production lines. It saved company a huge amount of money as well as it made it easier to monitor inventory levels, issue production orders, and track the financial health of the organisation.

Inventory Management

In every segment of a supply chain, there are inventories in the form of raw material, components, and end product at manufacturing plants, warehouses, in transportation and with retailers. These inventories are said to make up 20 to 60 percent of the asset of a firm. Therefore, using proper inventory policies in a supply chain can give a decisive

edge to a firm over its competitors. Inventories carry huge costs such as variable cost,carrying cast, setup/order cost, shortage cost, and transportation cost etc. Managing inventories can be divided into two different areas: packaging and warehouse management, and multi-echelon inventory policies.

Packaging and Warehouse Management

Warehouse space is a scarce resource in many organisations; therefore it is important to find the optimal arrangement to place products in a warehouse – this objective is formally known as Warehouse Management. One of the earliest problems studied in this area was the packaging problem. The problem objective is to determine the size and number of packaging boxes that will minimise the total system cost. Packaging occupies valuable warehouse and shelf space. With the new emphasis of environmental concerns, there has been a constant emphasis on biodegradability and waste management (Davis and Song, 2006)). There has been a surge in polymer, polythene, plastic and polyester based packaging during eighties and nineties. The jute industries of West Bengal and East Bengal went in to a slump.

Charles Fishman in his book- The Wal-Mart Effect (2006) cites an example of cooperation among the retailers and suppliers that can change the mode of doing business and enhance the savings not only for businesses and customers but for environment as well. In the nineties, nearly every brand and style of deodorant-roll- on and solid, powder-fresh or unscented, came in a cardboard box. The product already came in a sturdy and solid can or plastic container. The box took up shelf space. It wasted cardboard. Shipping the weight of cardboard wasted fuel. The box itself cost money to design, to produce. The box turned out to cost a nickel (five cents). Half of it went to the suppliers and the remaining to the customers. With 200 million adults in US, it caused a savings of $10 million of which $5 million, the customers got to keep. This is repeated atleast five times a year. Millions of trees were not cut down, acres of cardboard were not manufactured only to be discarded and one billion of deodorant boxes did not end up in landfills.

Inventory Policies

As stated above, the inventories in a supply chain form a multi-echelon system. Inventories are supplied down the stream of the supply chain from:

Suppliers → Manufactures → Distributors → Retailers → Customers.

However, the inventories are demanded from customers to the upstream. The inventory demands are probabilistic and periodic (say monthly or when the stocks are about to finish and the order is triggered by the safety stock (s,S) or a (s,Q) policy. The proper ordering policies would have two objectives. One is to minimize the total inventory

cost that consists of: (1) purchase or manufacturing cost, (2) inventory holding cost and (3) back-logging cost. The second objective is to minimize or even eliminate the "bullwhip effect"- the amplification of demand variability from a downstream site to an upstream site. Supply chains are normally categorized in to three types: arborescence chains, where each node supplies more than one downstream node, coalescence chains, where each node is supplied by more than one upstream node. The final type is a serial chain, where each node is supplied by only one upstream node and supplies to only one downstream node. These problems are immensely challenging even for simple serial chain. Literature is dense with solution methods ranging from mathematical modeling to simulation. For a good appreciation of this topic, see Aharon *et al*. (2009).

Transportation

Transportation is the process of moving inventory among nodes in the supply chain. A supply chain may have a very complicated network with several nodes; hence, it is critical to optimize the flow of materials in the supply chain using adequate transportation procedures and logistical support. More and more manufacturing, businesses and industries are relying on the 3PL (third party logistics) to move their goods due to the sophisticated nature of logistics and transportation. For example, Dell Computer Company does their business electronically through their website to save the fixed costs. Their monitors are built in Mexico and the hard drives are made in China. All they do in US is assemble and ship. The problem taxonomy in this area can be grouped in to two types. The first type is the routing problem, which is related to finding optimal transportation routes. The second type of problem is the transportation scheduling problem, which deals with determining the optimal order of different transportation systems.

Vehicle Routing Problems

The Vehicle Routing Problem (VRP) is defined as the problem of finding a set of routes for a fleet of vehicles which have to service a number of stops or nodes. The vehicles depart and arrive at a single depot. This is similar to the standard traveling salesman problem, and the Chinese postman problem. In combinatorial analysis, this is an NP-hard problem. Therefore, there are several heuristics. Breedam (2001) compares a descent (local optimizer) heuristics and two meta-heuristics: Simulated annealing and Tabu Search.

The voluminous research in this field, though mostly theoretical, does translate in to useful practical implications. For example, the well known UPS (united postal service) designs their routes so that the vehicles avoids taking left turns as much as possible while distribution. It saves the company loads of money in gas by avoiding idling at the intersections and time delays.

The Transportation Scheduling Problem

The transportation scheduling problem states that after the optimal routing has been established, the problem now would be to decide what quantity of which product to transport by how many vehicles over a given period from a node to another downstream so that the total inventory costs and total transportation costs are minimized. (Arunapuram *et al*., 2003).

Network Design

The objective of the facility location problem is to determine the optimal location of plants, warehouses, and distribution centers, etc., which minimizes the total production and distribution costs. Facility location problems are also known as fixed charge problems; because, if a company decides to open a facility, it will need to incur in a fixed cost (the fixed charge). Due to the fixed charge nature of the problem, the solution methods of management science models normally use binary variables (Nickel *et al*., 2003). These problems are also known as facility location and capacity allocation. There are immense incentives and perks given to companies to open their businesses by the local, state or federal governments to create job opportunities for the people of that region. Then, the "client matching" is done if a group of clients (retailers) can be served by a common warehouse to save transportation costs.

Location in network design is a key factor that enhances the efficiency of the SCM, by reducing the long term costs of inventory and transportation. One has only to look at the Wal-Mart's example of location and market place. In 2006 (Fishman), there were 2074 Wal-Mart stores in US. More than half of Americans live within five miles of a Wal-Mart store, less than a 10-minute drive away. Ninety percent of Americans live within 15 miles of a Wal-Mart store. The retail chain has obviously redefined the efficiency by expanding the business while reducing the prices.

Information Sharing

Information sharing is probably the most important concept behind the SCM theory. The whole SCM theory is based on the idea that cooperation yields better results for the players in the supply chain. Many SCM researchers have tried to evaluate the impact of information sharing by using game theory.

A representative example, here, would be of Aviv (2001) who developed a game theory model to analyze a two-member supply chain (a retailer and a supplier). The author used two scenarios in its model: the first scenario, called local forecasting by the author, assumes that each member updates the forecasts of future demands locally without cooperation. The second scenario, called collaborative forecasting by the author, assumes that the players in the supply chain jointly maintain an update a single forecast. The author concludes that both scenarios can bring benefits to the supply chain. The first scenario's benefits mainly depend on the forecasting strength of each individual. On the other hand, the second scenario's benefits are primarily when each player in the supply chain has different forecasting strengths, and those strengths are used together in a single forecast effort.

Supply chain practice focuses on material movement whereas information sharing focuses on information flow about demand upstream. Information sharing has three components to it: information sharing support technology, information content, and information quality. The objective of information sharing about the forecast of demands at different nodes of the supply chain is to improve delivery performance. Delivery performance is measured against: (i) committed date of delivery, for which percent of late deliveries becomes a performance measure (less is better), (ii) order fulfillment rate and (iii) delivery reliability (order fulfillment lead time). A good read on this topic would be Zhou and Benton Jr. (2007) and Yu *et al*. (2009).

Concluding Remarks and Further Research

The efficiency of a supply chain is a sum total of the local efficiencies at different nodes or components of a supply chain. This would further enhance if proper information sharing is conducted in the system. There have been several attempts to actually and formally define an efficiency measure of a supply chain, end to end. Silva *et al*. (2009) do provide a formal measure as:

$$P_{SCM} = \sum w_i \times f_i$$

where, j= 1,…,n, is the number of partners in the supply chain, w_i is the weight that measures the importance of the partner in network, and f_i is the contribution of each of the partners to the evaluated cost of the supply chain in monitory units. This topic is still growing and more research is needed to support the analytic modeling to company specific situations.

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