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DEVELOPMENT & IMPLEMENTATION OF SUPPLY CHAIN MANAGEMENT FOCUSING ON PROCUREMENT PROCESSES & SUPPLIERS

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ABSTRACT: *Supply chain optimization is a modern subject, approached by many specialists in their papers [2,6,7,9 and others]. It is the application of processes and tools to ensure the optimal operation of a manufacturing and distribution supply chain. This often involves the application of mathematical modeling techniques using computer software. One of the papers related to supply chain optimization was published in 2007, by Ghodsypour and O´Brien, in an International Journal of Production Economics [8]. The paper focused in optimizing the whole supply chain and make it more effective and efficient by not just focusing on the buyer´s cost but by examining costs from both the buyer and the seller. In this paper we formulated and introduced a discounted cost saving strategy to ensure that both actors (buyer and seller) benefit. Secondly, we included an out of stock and excess inventory costs and then formulated and implemented an optimized solution. The model has been solved by applying mixed-integer nonlinear programming using LINGO software. This paper compares the results with the original work using the same example and provides a win-win situation for both the actor to make the problem feasible even for decentralized situation.*
KEYWORDS: *Supply Chain Optimization, Inventory Costs, Integer Non Linear Programming, LINGO, decentralized supply chain*

INTRODUCTION

Supply chain management is the process by which suppliers, partners, and customers plan, implement and manage the flow of information, service, and products in a way that improves business operations in terms of speed, agility, real-time control, or customer response (Manthouet al., 2004). With intensive internationalization and globalization of markets, multiple dimensions of operational capabilities between suppliers, trading partners, and customers have to be developed for firms to succeed. A key operational capability necessary to meet this challenge is operational information systems that are embedded in a firm's core business processes and its inter-organizational business transactions (Nurmilaakso, 2008).

Production in the early years was simple, with single flow of products moving from raw material suppliers, to manufacturers and then to markets. Nowadays, shorter product lifecycle and increasing demand among all have led to a complicated supply chain. Due to cost pressure and competitive advantages, companies are adopting globalization and outsourcing strategies. This also requires an extended supply chain network, hence increases the nodes in the system. In addition, many companies have introduced lean production concepts, which intend to remove "wastes" from a supply chain, for instance, by reducing the number of suppliers. This helps in smoothing the operations but it would also create problems if unexpected events happen in a supply chain. The rising use of internet helps supply network in sharing information visibility (Christopher and Lee, 2004; Lee, 2002, 2004; Narayanan and Raman, 2004).

The production of highly diversified products with short life cycles such as computer parts, fashion clothes and some food items among many others as well as the remarkably high levels of competition pushes the different companies towards the integration of different production and inventory related decisions. Consequently, companies are realizing the necessity of having elevated levels of mutual understanding and better collaboration with their customers and suppliers alike. To remain competitive, firms can no longer operate as individual and autonomous entities but rather as an integral part of the supply chain. The area of supply chain management (SCM) has gained a lot of interest from researchers as well as practitioners in the industry.

In particular, the integrated single-vendor single-buyer problem, also called the joint economic lot sizing problem (JELP), has received a lot of attention in recent years as it represents the building block *for the wider supply chain. Essentially, the retailer (buyer) observes a deterministic demand and orders lots from the manufacturer (vendor). The vendor satisfies this downstream demand through manufacturing the requested product in lots, where each produced lot is shipped to the buyer in batches. The problem is to find the number of shipments and size of each batch such that the joint manufacturer and retailer cost is minimized. For a vertically integrated supply chain owned partially or jointly by the same company, such coordinated production– shipment policy provides valuable insights and optimal decisions that lead to global optimization. On the other hand, when individual entities are owned separately, such policy may not benefit all parties equally as some may encounter an increase in their costs and hence become less eager to depart from their locally optimized policies. In such situations, sharing those benefits resulting from the coordinated approach becomes a major issue. By using effective incentive systems such as accounting methods, transfer pricing schemes, quantity discount, etc., the objective of each partner can be aligned to that of the supply chain as a whole (Ganeshan, 1999; Li & O'Brien, 1999; Agrawal et al., 2004).*

LITERATURE REVIEW

A supply chain is made up by multiple actors, multiple flows of items, information and finances. Each network node has its own customers' and suppliers' management strategies, demand arrival process and demand forecast methods, inventory control policies and items mixture. An interesting approach in studying the effects of inventory control policies on supply chain performance is proposed by Tagaras and Vlachos (2001). They consider a periodic review inventory control policy working with two replenishment modes (regular and emergency). Graves and Willems (2005) propose a more centric approach on the entire supply chain. They deal with supply chain configurations in terms of suppliers, parts, processes and transportation modes to be selected at each stage trying to minimize the total supply chain cost. Note that different supply chains are characterized by different critical parameters so a decision making tool should provide to managers high flexibility in terms of scenarios definition, critical parameters and performance measures selection. For most companies, providing the customers with a better service at a reduced cost is one of the ultimate strategic goals.

Most of the work related to JELP has been conducted in the context of a two layer supply chain consisting of a single vendor and a single buyer. Goyal (1977) suggested a lot-for-lot policy with the assumption of infinite production rate for the manufacturer. Later, Banerjee (1986) maintained the lot-for-lot policy for the more realistic case of a finite production rate. The lot-for-lot assumption was relaxed by Goyal (1988) where he assumed that the vendor ships the lot in a number of equal size shipments. Goyal (1995) developed a policy where the shipment sizes increase by a factor increasing geometrically. Hill (1997) generalized the latter model through considering the geometric growth factor as a decision variable. The optimal solution to the problem in its general form (i.e., without any assumptions regarding the shipment policy) was obtained by Hill (1999). Goyal and Nebebe (2000) considered a policy where the first shipment is small and the following ship- ments are larger and of equal size. For a comprehensive review of the JELP, the reader is referred to Ben-Daya et al. (2008). More recently, this problem has been extended to the case of a three layer supply chain. Khouja (2003) was the first to consider a three stage supply chain with one or more firms at each stage.

Recently, some researchers have developed joint decision making in multiple-supplier single-buyer supply chains. Kim et al. (2005) developed a production-delivery policy in a supply chain consisting of a single manufacturer with multiple plants in parallel and a single warehouse, and a single retailer. They built a model to determine an optimal production cycle length (or interchangeably production lot size) for the manufacturer, a delivery policy (i.e. frequency and quantity) to the retailer and a production allocation scheme for multiple plants so as to minimize the average total cost incurred by both the manufacturer and the retailer. Yung et al. (2006) presented heuristics solutions to a joint decision problem for a single product and for multiple products in a production distribution network system with multiple suppliers and multiple destinations.

Park et al. (2006) developed a mathematical model in which the retailer places orders based on the EOQ policy and allocates them to the multiple manufacturers. In their model production, allocation ratios and shipment frequencies at the manufacturers as well as purchasing cycle length at the retailer are formulated to minimize the average total cost that includes average total cost at the manufacturers and retailer. Van Der Veen and Venugopal (2005) introduced a revenue-sharing model in the video rental supply chain consisting of two independent firms, namely a movie studio and a video rental shop. They *discussed three scenarios, namely solitaire or decentralized scenario, partnership and revenue sharing. Their paper showed that the decentralized situation could not optimize the chain, but revenue-sharing contracts could lead to whole optimization of the supply chain with a win–win situation. This paper is the extension of the work by Ghodsypour and O´Brien (2007), the same model has been used with multiple-supplier single-buyer coordination model, which optimizes the total supply chain but in order to create a win-win situation for both the actors (buyer and seller) a discounted cost saving strategy has been formulated, and in the second part an out of stock and excess inventory costs has been introduced.*

METHOD

The objective function is to minimize the total annual cost of a supply chain that includes supplier and buyer annual costs, the following model has been used which was implemented by Ghodyspour and O´Brien (2007);

$$Min\ (ASCT) = Min\ [\ D \sum_{i\ 1}^{m} X_i\ (C_i+Z_i) + \sqrt{2rD\sum_{i\ 1}^{m} R}\ \ x \sum_{i\ 1}^{m} x_i^{2}\ (C_i + D\ \frac{Z_i}{P_i}\ )$$

s.t.

$$\sum_{i\ 1}^{m} X_i = 1$$

$X_i \leq \frac{P_i}{D}$, $\quad i \in S$

$X_i \geq$, $\quad i \in S$

$X_i = 0$, $\quad i \neq S$

$X_i \geq 0$, $\quad i = 1,2,3, \ldots, m.$

D buyer´s annual demand rate
Di quantity purchased per year from the ith supplier
Q order quantity per period
Qi order quantity per period from the ith supplier
Ai fixed/order cost for the ith supplier
Xi percent of Q assigned to the ith supplier
Si ith supplier´s setup cost
pi annual production rate of the ith supplier
zi variable cost for each product of the ith supplier
Ci purchasing price of each product from the ith supplier
m number of suppliers
r annual inventory holding cost rate
T time of a buyer´s period
Ti time of consuming an ordered quantity of the ith supplier

D, Ai, Si, pi, zi, ci, qi, and r are known.

NUMERICAL EXAMPLE

Suppose a purchase manager would like to buy one product from three suppliers with information as given in Table1. Demand rate (D) = 1000000 and r = 0.25.

Table 1. Supplier´s Information for situation 1

	Price (C_i)	Fixed Cost (A_i)	Production rate (Pi)	Setup Cost (S_i)	Production variable cost (Z_i)
Sup. 1	112	7450	510000	9800	93
Sup. 2	118	6120	670000	9400	89
Sup. 3	114	6590	450000	8600	90

Table 2. Values of variables calculated by LINGO (by Ghodyspour & O´Brien)

Cases	X_1	X_2	X_3	Q	Buyer´s Annual cost (BAC)	Supplier´s Annual cost (SSAC)	Annual supply chain total cost (ASCT)
1	0.51	0.04	0.45	52248	113868109	92597737	206465846
2	0.51	0.49	0	43778	115564425	91912656	207477081
5	0	0.55	0.45	41972	116811210	90302159	207113369

For situation 1, we used hidden and trial method, and regulate the values of Price (C_i) and Product variable cost (Z_i). And found that an optimum situation is achieved when increasing the values of Z_i by 2 and decreasing C_i by 3.

Table 3. Values of variables calculated by LINGO for situation 1

	Z1,Z2,Z3= 93,89,90	Z1,Z2,Z3= 95,91,92	Z1,Z2,Z3= 97,93,94	Z1,Z2,Z3= 99,95,96	Z1,Z2,Z3= 101,97,98
	C1,C2,C3= 112,118,114	C1,C2,C3= 109,115,111	C1,C2,C3= 106,112,108	C1,C2,C3= 103,109,105	C1,C2,C3= 100,106,102
BAC	113868100	110859000	107849900	104840800	101831700
SSAC	92597740	94610310	96622880	98635450	100648000
ASCT	206465840	205469310	204472780	203476250	202479700
BAC-SSAC	21270360	16248690	11227020	6205350	1183700

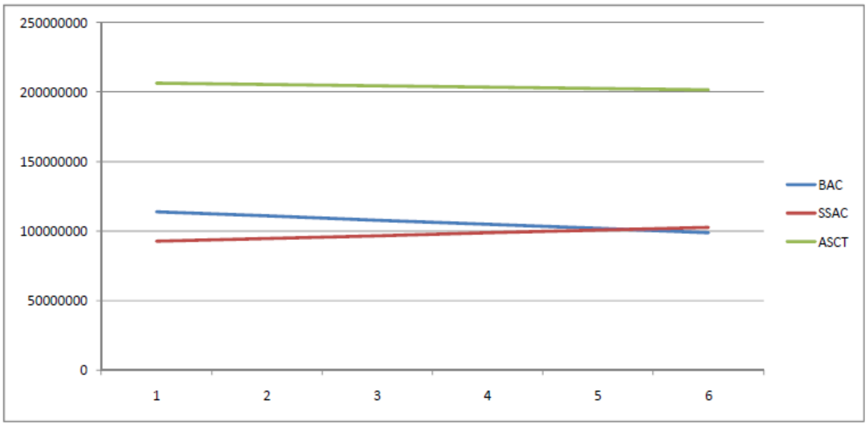

Figure 1. Comparison of values for BAC & SSAC

For a centralized model, the company, which owns both the buyer and vendor, it is possible for the company to accept the situation but in case of decentralized model the buyer and the suppliers are components of different companies and in order to optimize the whole supply chain, one of the above case should be accepted. The graph shows a point where the value of BAC is equal to SSAC but point to be noted that C_i can't be more than Z_i so there should be mutual understanding between the supplier and buyer.

The second part of the paper is to include the out of stock and excess inventory costs, so that the solution of the problem could be more practical. The out of stock costs include the benefit of the number of products that has to be selled and excess inventory costs include annual inventory holding costs which has to carry for the next year. As it's shown in Table 2 that the supply chain total cost for case 2 as compare to case 1 has been reduced which is contrary to the results for Ghodyspour & O'Brien.

Table 4. Values of Variables calculated by LINGO after addition of out of stock and inventory costs

Annual Supply Chain total cost after addition of Out of Stock and Excess Inventory Costs						
	ASCT	AIHC	ACST+AIHC	Out of Stock(OOS)	ACST+OOS	Total
Case 1	206465846	17819550	224285396			224285396
Case2	207477081	5172300	212649381			212649381
Case 3(Excess Inventory)	207113369			2354000000	2561113369	2561113369

SUPPLY-DEMAND MODEL

What price for a commodity results in equal supply and demand? We will solve by graphing.

Suppose the "supply curve" for a commodity is x=5p-150, where p is the per unit price in Euro and x is the number of units of the item that will be supplied to the market price. For example, at a price of 50(p=50) the supply will be x=5(50)-150=100 units, while at p=100 the supply will be x=5(100)-150=350 units.

Further, suppose the "demand curve" for this commodity is x=375-2,5p, where again p is the per unit price and x represents the number of units of the item that will be sold at the price. For instance, at a price of 50, the demand will be x=375-2,5(50)=250, while only x = 375-2,5(100)=125 units will be demanded at a price of 100.

These calculations show that demand exceeds supply at a price of 50 whereas supply exceeds demand at a price of 100. In each case, then, pressure for a change in price is created. A stable occurs at a price for which supply and demand are equal. We therefore ask if there is a per unit price p_0 for which supply equals demand. Such a price, if it exists, is called an equilibrium price.

Now suppose there is an equilibrium price p_0 and that x_0 is the corresponding supply. Then (p_0, x_0) must lie on the supply curve, that is, $x_0=5p_0-150$, or $5p_0-x_0=150$. But since p_0 is an equilibrium price, supply equals demand, and so (p_0, x_0) must also lie on the demand curve, that is, $x_0=375-2{,}5p_0$, or $2{,}5p_0+x_0=375$. We conclude that if p_0 is an equilibrium price and x_0 is the common number of units supplied and demanded at that price, then (p_0, x_0) is a solution to the system of linear equations

$5p-x=150$ *[supply]*

$2{,}5p+x=375$ *[demand]*

The graph of this system in the P_x plane appears in Figure 2.

The two lines have a unique point in common which we estimate to be (70,200). Thus, the system has a unique solution, and the equilibrium price is about 70 Euro per unit.

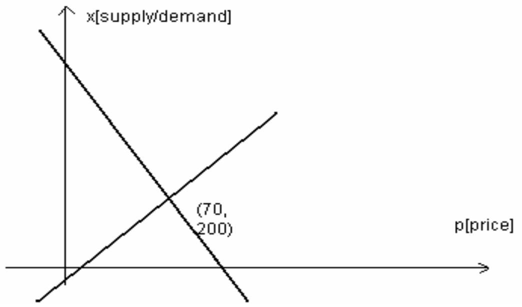

Figure 2. Geometric solution to the system

CONCLUSION & FUTURE WORK

The major aim of the work presented in this paper is to provide a cost-effective approach that would enable manufacturing organizations to gain competitive edge in the global market by coordinating between supplier and buyer to create a win-win situation for a decentralized model. Integrating and coordinating the operations of such organizations for improved awareness and responsiveness to the changes in the manufacturing environment. To make the problem more practical and to achieve this, out of stock & excess inventory costs have been added. Supplier selection is a multiple criteria decision making problem that includes both qualitative and quantitative criteria. These tangible and intangible factors are not equally important. In real cases, many input data are not known precisely for decision making.

Further extensions to this work could be carried out to review the overall effect of differing capacity constraints throughout the supply chain. In addition, further research should be carried out to investigate the varying cost of capacity in these systems, whether it is overtime costs or additional resource costs. Further extensions to this paper should entail a review on the effect of differing demand patterns on the overall supply chain performances. This is in contrast to the fixed demand patterns used in this study.

The research only involves one product, further extension can be made by introducing multiple products, in such case products are substituted or the capacity is limited. A discounted cost can also be introduced based on the ordering quantity from the suppliers. Other numerical softwares can also be used, for example WinQSB which can also solve similar problems (stock theory, production planning, decision problems, Inventory Theory and System, Job Scheduling) and the results can be compared with the one which we obtained after solving with LINGO.

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