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Profit Maximization Based on Customer Satisfaction Level in a Multi-Layer Multi-Product Supply Chain

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Abstract This paper concerns with a mathematical model considering customer satisfaction requirements in a supply chain. The model tradeoffs the supply chain ability to fulfill the customers' requirements and the limited budget in a variety of production phases. The decisions made here help to determine the profit provider price and economic quantity while the effective supplier and priori requirements are found. A numerical example illustrates the applicability of the proposed mathematical model.

Keywords Customer Satisfaction, Profit Maximization, Supply Chain.

1 Introduction

For many years, members of supply chains have been separated by organization and philosophy. Interactions between them have often been adversarial, with each trying to gain at the other's expense. Today, this long-established pattern is rapidly giving way to system integration due to increasing external competitive threat. The advocates argue that all of the subsystems of a supply chain are connected. The outputs from one system are the inputs of the other systems. Thus, integration of the complete scope of the supply chain from the supplier through the manufacturer to the retailer needs to be considered so that fully transparent information is shared freely among members, and collective strategies can be designed to optimize the system's joint objectives. While the importance of achieving integration in the supply chain is generally well recognized, for real-world applications designing a sophisticated integrated system is an arduous task. Few firms are so powerful that they can manage the entire supply chain so as to drive individual members to a superimposed integrated objective [1].

A fundamental change in the global competitive landscape is driving prices to levels that in real terms are as low as they have ever been. A number of causal factors have contributed to this new market environment. First, there are new global competitors who have entered the marketplace supported by low-cost manufacturing bases. The dramatic rise of China as a major producer of quality consumer products is an evidence of this. Secondly, the removal of barriers to trade and the de-regulation of many markets have accelerated this trend enabling

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new players to rapidly gain ground. One result of this has been overcapacity in many industries [2]. Overcapacity implies an excess of supply against demand and hence leads to further downward pressure on price. A further cause of price deflation, it has been suggested in [3], is the Internet which makes price comparison so much easier. The Internet has also enabled auctions and exchanges to be established in the industry wide levels that have also tended to drive down prices.

Changes in competition (globalization, standardization in production and so on) have recently led to many businesses cutting production in order to focus on key competencies. Thus, an even larger portion of value added is subcontracted resulting in significant expansion in the supply chain in many industrial markets. While this trend has brought benefits in that businesses have been able to concentrate on their strengths and focus their main assets in specific areas, this strategic orientation also has increased the need to collaborate and integrate activities between the different companies in the supply chain. Therefore, most companies today try to establish relationships with their partners in the supply chain rather than concentrating on purchasing [4]. This development is further supported by today's business relationships offering one of the most effective remaining opportunities for significant cost reduction and value improvement [5]. However, Frazier et al. [6] observed that these opportunities mainly depend on the closeness of the relationship.

In this sense, suppliers in particular have cultivated business relationships for years by investing in their customers with a view to safeguarding subsequent business dealings from out-suppliers [7]. However, there comes a point where making business relationships closer is only possible when both the supplier and the customer are prepared to invest in this special type of collaboration, as relationships in which the reason for staying in are solely determined by investments made on the part of the supplier are unstable by their very nature. As soon as competitors offer comprehensive benefits in alternative business transactions, there is an economic reason for customers to switch suppliers [8]. This means that further investments will only become financially viable from the supplier's point of view if the customer is also prepared to put himself into a position of some dependence on the supplier. Both transaction partners then may devolve their economic welfare, at least in part, to the conduct of the other partner. Companies must be aware that Supply Chain Pricing will only provide a clear competitive advantage for the period of time when the competitors not yet have adapted to the new perspective. Taking the situation into consideration where a market or branch has completely switched into SCP, the use of our concept will no longer dispose of our stated over all advantage. In this situation, it can surely amount to nothing more than the prevention of competitive disadvantage [9].

2 Statement of the problem

The problem is composed of a three-layer supply chain including the supplier, manufacturing and customer. Due to several products provided by the supply chain, customers express their satisfaction level in a category of requirements to be fulfilled by the manufacturing segment. The manufacturer also has limited resources to satisfy customers' needs. Different phases of manufacturing costs are divided in maintenance, quality assurance, transportation and machine related costs. Suppliers are also effective in the decision making since the raw materials different suppliers provide cause different improvements or drawbacks in the aforementioned phases. Therefore, a mathematical model is developed both to consider customer satisfaction requirements and the manufacturing resource limitation. The model is capable to tradeoff the supply chain ability to fulfill customers' requirements and the limited resources, in a variety of production phases. The output of the mathematical model determines the profit provider price and economic quantity while the effective supplier and priori requirements are found.

3 Mathematical formulation

The indices, parameters and decision variables of the proposed problem are listed below.

Indices:

i	number of products	i=1, …, I,
j	number of suppliers	j=1, …, J,
k	number of customer requirement	k=1, …, K.

Parameters:

C_{ik}	cost of fulfilling requirement kth for product ith
CM_{ijk}	total maintenance cost in hand to fulfill requirement kth provided by supplier jth for product ith
CQ_{ijk}	total quality assurance cost in hand to fulfill requirement kth provided by supplier jth for product ith
CA_{ijk}	total machines cost in hand to fulfill requirement kth provided by supplier jth for product ith
CT_{ijk}	total transportation cost in hand to fulfill requirement kth provided by supplier jth for product ith
W_k	the satisfaction level of customers for a product fulfilled requirement kth (a value in [0, 1])
D_{ik}	dement for product ith fulfilled the requirement kth
T_{ik}	throughput to produce product ith fulfilled the requirement kth

Decision variables:

X_{ijk}	1, if requirement kth is chosen from supplier jth to be fulfilled in product ith; 0, otherwise.
Y_{ijk}	1, if supplier jth is chosen for requirement kth to be fulfilled in product ith; 0, otherwise.
P_{ijk}	allocated price for requirement kth provided by supplier jth to be fulfilled in product ith.
N_{ijk}	number of production for product ith having requirement kth provided by supplier jth.

The mathematical model is therefore,

$$Max\ Z = \sum_i \sum_j \sum_k (P_{ijk} \times N_{ijk} \times W_k) - \sum_i \sum_j \sum_k (X_{ijk} \times C_{ik}) \quad (1)$$

s.t.

$$\sum_j \sum_k X_{ijk} \times C_{ik} \times W_k \le \sum_j \sum_k CM_{ijk} \qquad \forall i, \quad (2)$$

$$\sum_j \sum_k X_{ijk} \times Y_{ijk} \times C_{ik} \times W_k \le \sum_j \sum_k CQ_{ijk} \qquad \forall i, \quad (3)$$

$$\sum_j \sum_k X_{ijk} \times Y_{ijk} \times C_{ik} \times W_k \le \sum_j \sum_k CT_{ijk} \qquad \forall i, \quad (4)$$

$$\sum_j \sum_k X_{ijk} \times C_{ik} \times W_k \le \sum_j \sum_k CA_{ijk} \qquad \forall i, \quad (5)$$

$$\sum_j \sum_k N_{ijk} \ge \sum_k D_{ik} \qquad \forall i, \quad (6)$$

$$\sum_j \sum_k X_{ijk} \times N_{ijk} \le \sum_k T_{ik} \qquad \forall i, \quad (7)$$

$$\sum_j X_{ijk} \times Y_{ijk} = 1 \qquad \forall i,k, \quad (8)$$

$$X_{ijk}, Y_{ijk} \in \{0,1\}, \quad \forall i,j,k, \quad (9)$$

$$N_{ijk}, P_{ijk} \ge 0, \quad \forall i,j,k. \quad (10)$$

Equation (1) is the objective function maximizing the total profit of the supply chain. Equations (2) to (5) confine the supply chain expenditures to an upper limit as maintenance, quality, transportation, and machines, respectively. Equation (6) certifies that the number of production should be more than or equal to the demand received. Equation (7) denotes that the number of production is confined by the throughput. Equation (8) certifies that at least one supplier will be chosen to fulfill the customers' requirements. Relations (9) and (10) are the sign and kind of the decision variables.

4 Numerical example

Here, a numerical example is illustrated to verify the applicability of the proposed model. Two products and three suppliers are considered. The requirements and their corresponding satisfaction levels are given in Table 1. Note that the 13 requirements measured by the customers are: quality of material, employee training, material inspection, final inspection, quality of supplier material, availability of machines, in-factory transportation, packing quality, wages, production capacity, maintenance, external transportation, process capability. The satisfaction levels for the requirement of the customers are reported in Table 1. Cost of fulfilling the requirements for the products are shown in Table 2.

Table 1 The satisfaction level

k	1	2	3	4	5	6	7	8	9	10	11	12	13
W_k	0.181	0.060	0.060	0.026	0.011	0.040	0.022	0.017	0.028	0.045	0.042	0.142	0.061

Table 2 The cost of fulfilling the requirements

C_{ik}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	30	20	5	4	40	90	2	10	15	70	5	8	35
2	30	30	5	4	50	90	2	15	17	70	4	10	38

The transportation costs, the maintenance costs, the quality assurance costs and the machine costs are reported in Tables 3 to 6, respectively.

Table 3 The transportation costs

CT_{1jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	5	0	0	0	0	0	0	15	0	0	4	0
2	0	5	0	0	0	0	0	0	15	0	0	5	0
3	0	5	0	0	0	0	0	0	15	0	0	3	0
CT_{2jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	8	0	0	0	0	0	0	17	0	0	8	0
2	0	8	0	0	0	0	0	0	17	0	0	6	0
3	0	8	0	0	0	0	0	0	17	0	0	5	0

Table 4 The maintenance costs

CM_{1jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	15	0	0	0	0	0	0	4	0	20	0	0
2	0	15	0	0	0	0	0	0	4	0	20	0	0
3	0	15	0	0	0	0	0	0	4	0	20	0	0
CM_{2jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	3	0	0	0	0	0	0	5	0	35	0	0
2	0	3	0	0	0	0	0	0	5	0	35	0	0
3	0	3	0	0	0	0	0	0	5	0	35	0	0

Table 5 The quality assurance costs

CQ_{1jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	25	20	4	3	35	0	0	10	3	0	0	0	35
2	35	20	2	2	55	0	0	15	3	0	0	0	35
3	20	20	5	5	40	0	0	10	3	0	0	0	35
CQ_{2jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	40	25	1	2	30	0	0	15	3	0	0	0	50
2	25	25	2	4	10	0	0	8	3	0	0	0	50
3	15	25	3	6	15	0	0	5	3	0	0	0	50

Table 6 The machine costs

CA_{1jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	20	0	0	0	70	0	0	15	50	0	0	30
2	0	20	0	0	0	70	0	0	15	50	0	0	30
3	0	20	0	0	0	70	0	0	15	50	0	0	30
CA_{2jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	25	0	0	0	100	0	0	20	60	0	0	45
2	0	25	0	0	0	100	0	0	20	60	0	0	45
3	0	25	0	0	0	100	0	0	20	60	0	0	45

The throughput of the manufacturing system and the demand are given in Table 7 and 8, respectively.

Table 7 The throughput of the system

T_{ik}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	2500	3500	3000	3000	3000	4000	3000	2000	3200	4000	3500	3000	4000
2	4000	5000	4500	4500	4500	5500	4500	3500	4700	6000	5000	4500	5000

Table 8 The demand for the products

D_{ik}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
2	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000

Using the above input data, by the means of LINGO 11 software, the optimization process is fulfilled employing branch and bound approach. The results are reported in Table 9.

Table 9 The outputs

X_{1jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	0	0	0	0	1	0	0	0	1	1	0	0
2	0	0	0	1	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
X_{2jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	0	0	1	0	1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	1	1	0	0
3	1	0	0	0	0	0	0	0	0	0	0	0	0
Y_{1jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	0	0	0	0	1	0	0	0	1	1	0	0
2	0	0	0	1	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
Y_{2jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	0	0	1	0	1	0	0	0	0	0	0	0

2	0	0	0	0	0	0	0	0	0	1	1	0	0
3	1	0	0	0	0	0	0	0	0	0	0	0	0
P_{1jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	3000	0	0	0	0	3000	0	0	0	3000	3000	0	0
2	0	0	0	3000	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
P_{2jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	0	0	3000	0	3000	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	3000	3000	0	0
3	3000	0	0	0	0	0	0	0	0	0	0	0	0
N_{1jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	2500	0	0	2500	0	2500	0	0	0	2500	2500	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
N_{2jk}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	0	0	4000	0	4000	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	4000	4000	0	0
3	4000	0	0	0	0	0	0	0	0	0	0	0	0

The numerical outputs show the number of products that should be produced and their corresponding prices. Also, the allocations of requirements and suppliers are given to fortify the chosen ones and omit or change the application of others.

5 Conclusions

In this paper, a mathematical model was developed to fulfill customers' satisfaction measures into the manufacturing properties in a supply chain. Due to variety of customers' needs several categories were formed each including some requirements. Since manufacturing segment had limited resources to carry out the customers' requirements, a tradeoff between the manufacturing capability and customers' satisfaction performed. The validity of the proposed mathematical model was shown in a numerical example.

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