SUPPLY CHAIN MANAGEMENT PROBLEMS: A REVIEW

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ABSTRACT
Supply chain management (SCM) deals with flow management of funding, information, and material. It has been attended to in last decade or so more than ever since it can reduce total cost of the entire system while increasing customer satisfaction level. There are numerous issues in SCM, yet, in this paper, just only four, namely, Inventory management, Facility location, Information technology, and Sourcing, are discussed. The objective of Inventory management is to determine appropriate policies and strategies to answer the question of how much and when to order. Information plays a significant role to link each activity in supply chain to work continuously and effectively so as to enhance performance of the system. Facility location aims at investigating appropriate location to set facilities in order to reduce inventory and transportation cost for the whole supply chain. Sourcing, the major concern of this paper, is a strategy for making decisions either making in-house or outsource some activities. One of all activities of sourcing is the process of selection of appropriate suppliers. This paper aims to review the literature regarding the four aspects in supply chain and discusses in some details the topic of sourcing.

KEY WORDS
Supply Chain, Inventory Management, Information Technology, Facility Location, Sourcing, Supplier Selection

1. Introduction

Global competitiveness forces companies to adjust themselves and attempt to apply efficient methods, strategies, techniques in order to lower their costs while increasing customer satisfaction in order to survive. In addition, now businesses seem to be difficult to survive alone, as was the case in the past, so they have to concern competition among supply chains rather than among companies [1]. Consequently, supply chain management that has been attended to in last decade has become an alternative strategy to get benefits such as reduce the entire cost, increase flexibility of system, smooth flow of material, increase customer service level, improve product development, quality and delivery goals, and to eliminate waste [2].

Supply Chain Management is a strategy to manage material flow, information flow, and funding flow so as to increase benefit to total system [3]. It involves with many company activities, such as selection of location for shortest distance of transport of product and raw material; suitable inventory policy for lowest cost; and making decisions on make or buy to reach the customer's need. For example, according to [4], Dell Computer closely monitors its account balance to control and mange cash flow; creates the web page to provide information for all parties; and apply telephone and internet ordering system to get customer's information. As a result, Dell services its customers at high level with a well known status in computer businesses.

From literature review, it was found that four major aspects in supply chain are popular to work with: inventory management, facility location, information technology, and sourcing. These are the main factors that lead companies to incur high cost or provide high level of customer satisfaction if there is an efficient management. Therefore, this paper aims to discuss in some details these crucial aspects in supply chain. For sourcing, this paper mainly focus on supplier selection issue because it is the significant process that still need to be developed.

2. Inventory

Inventory management deals with two questions; when and how much to order to minimize total cost while retain customer satisfaction level. Ideally, companies should not handle inventories, yet because of uncertainties, most companies, except the ones who work on efficient JIT, have to provide inventories to avoid risks. Apparently, the more holding inventories, the lower getting risk but the higher the investment. Therefore, this is a need to optimize to achieve minimum total cost.

Huiskonen et al [5] discussed how to make a policy for make to order or make to stock, to provide service for different customer demand. The result showed that if demand is stable and continuous, companies should make to stock. Lee and Yao [6] investigate appropriate lot size

and replenishment time, in order to minimize the total costs per unit time. It showed through experiments that the proposed algorithm can find the global optimal solution. Bailey and Rabinovich [7] proposed an Analytical model for decision making on two inventory policies: in-stock inventory and drop-shipped inventory, of an Internet book retailer. They indicated that retailer should adopt in-stock inventory policy in case of unexpected demand.

Piplani and Viswanathan [8] studied the impact of the Supplier-Owned Inventory (SOI) strategy on total cost of the system. They concluded that SOI strategy in supply chain result in lower total cost of the entire system. Axsater [9] proposed a technique for determining appropriate reorder point for two stages system: warehouses and retailer. It was found that replenish rate at warehouse should be much lower than at retailers. Gen and Syarif [10] developed a Hybridized Spanning Tree-based genetic algorithm. When comparing with the traditional ones, proposed method is more effective. Haksever and Moussourakis [11] applied MIP to determine when and how to order under multiple resource constraints. The solution of the test model was drawn very fast, in seconds, even for the largest problem.

Although all of those methods provide efficient solutions, some of them still consume excessive computing time. Thus, there are some opportunities to develop further efficient approaches or heuristics that can reduce computing time. In addition, the methods can be developed including other factors such as considering multilevel of stochastic demand [12], stochastic lead time, and focus on service objective [13].

3. Facility Location

Facilities include as many places such as warehouses, plants, retail outlets, distribution center, and etc. The main activity is to determine how many of and where each facility should be located in order to minimize total cost of the whole supply chain.

However, due to the impact of several factors such as customer's location and demand, capacities of producers, number of transporters, etc, facility location problem tend to be large scale networks leading to a NP-complete (non-deterministic polynomial) problem [14]. So, developing heuristics to cope were the main objective for many articles. Rolland et al [14] proposed a new heuristic, *TSpMP*, based on the generic *tabu search* principles to solve problem. The result indicates that *TSpMP* can provide efficient solution in term of time and quality. Chuang [15] applied Quality Function Deployment (QFD) in framework of distribution's location model to assist decision makers to deal with location issue. Syam [16] compared *Simulation Annealing* and *Lagrangian relaxation* for solving the location problem. As one outcome, it concluded that *Lagrangian* methodology outperforms, for medium and large size problem, the *annealing procedure*. Zhou [17] proposes a mathematical model and an efficient solution procedure based on *Genetic Algorithm* for the bi-criteria allocation problem involving multiple warehouses with different capacities. The result found that, because of different size and capacities of warehouses, customers may place their orders at other far away warehouse if there is insufficient capacities of warehouses near them. This can increase the total shipping cost. Jeon and Kim [18] present an improved *hybrid algorithm* of *Simulated annealing* and *Tabu* search for the loss minimization in a large-scale distribution system.

There are still some gaps on this topic of research in integration of location models with other aspects, in particular transportation and inventory problems.

4. Information Technology

Information has a numerous roles in supply chain. It plays as connector to link other supply chain or different organizations work together. Companies can share information, such as customer's demand, supplier's capacity, and in particular inventory, to enhance their performance. As a result of powerful information sharing, companies can gain higher profit and operate more efficiently [19]. For example, due to information technology, Dell Computers can lower inventory level of its manufacturers; this results in returning stock area to be production space of such manufactures [20]. Zhang et al [21] represent benefits of strategy of sharing shipment information of one stage to immediate next stage in supply chain under periodic review inventory policy. Information can be applied in several decision making issues of supply chain like facility, inventory, transportation, sourcing, and pricing and revenue management [4].

There are several information technologies, such as EDI, RFID, E-commerce, ERP, and etc that can be applied for information sharing in supply chain. Number of articles dealing with ERP increase continuously [22]. For example, Aimin et al [23] and Rutner et al [24]studied role, benefit and impact of survey role and impact of ERP on logistic system. Berchet and Habchi [25] focus on developing ERP system using a five-stage model, and integration of the planning process in an ERP system to be a tool for planning process for Alcatel.

There are two main decisions, what and how to share, that firms have to deal with when they focus on information sharing. For the first concern, as several types of information can be shared, companies have to realize advantages and disadvantage of such information and select the one that can create benefit to firms. For instance, customers' demand is one type of information that may be shared to let involving organizations to do production planning and determine quantities of inventory that should be kept in supply chain. Due to different properties and processes of different information technologies, companies have to apply the same standards for communication of those methods to let information flow smoothly and efficiently. Some Standards have been developed for information sharing and exchange such as ISO 10303 STEP, MANDATE, and PSL [26]; as well as, ASC X12 Electronic Data Interchange (EDI) [27]. However lack of standards for complete and seamless communication is still a major obstacle in SC.

5. Sourcing

For the last decade, sourcing had not been of interest in many developing countries, resulting from lack of knowledge, understanding about this issue, as well, no infrastructure to support [28]. Now, because of advance development of efficient technology and telecommunication, sourcing is of considerable interest to several companies around the world.

Sourcing is a strategy in deciding either to make or buy (in-house or outsourcing) according to buyer/manufacturer's demand. When companies get new order of new products with new design, new structure, or other changes, they have to deal with those decisions. If they decide to make in-house, they must have adequate expertise and knowledge to do this; otherwise, deciding to buy from outside tend to be better. In addition, Abdel-Malek et al [29] suggested that companies should outsource some activities and focus on their core competencies in order to increase competitiveness, capacity and inventory aggregation, lower cost and higher quality. Nevertheless, outsourcing can provide some risks like loss of competitive and competent knowledge, and conflicting objectives [30]. Therefore, it is necessary to consider formalities in decision making regarding outsourcing. The main issue of outsourcing, supplier selection, is discussed below.

5.1 Supplier selection

Supplier selection is a significant role of the purchasing department because it can affect cost of purchasing and relation with suppliers [31]. For example, according to Weber and Current [32], some automobile producers invest more than 50% of total revenues for purchasing components and parts form outside providers. Ghodsypour and O'Brien [33] describe that if the companies can select appropriate vendor, they can lower purchasing cost. On the other hand, selecting inappropriate suppliers can lead companies to backlogs and shortages in quality of products [34].

For supplier selection, there are three alternatives. First, sole sourcing happens when there is only one supplier available and the company has to select it to handle the demand. The company may face some risk form this case like inventory shortage if such supplier deliver orders late or provide low quality products at high price [35]. To avoid those problems, some companies are encouraged to make relationship or partnership with their sole supplier. Second, single sourcing refers to selection of only one from several available suppliers. Whereas, the last choice, multi-sourcing mean companies can select many suppliers from a number of available ones. This can lead companies to get lower price product with high quality through competition. As a result suppliers have to improve their quality to meet the requirements of buyers. Therefore, which suppliers should be selected is a crucial job for companies with several methods available to them.

5.2 A procedure of supplier selection

There are two important activities involved with vendor selection process: define criteria and find out method to select suppliers.

5.2.1 Defining criteria

Dickson [cited in 36], that has been referred often, summarized form a survey of 273 purchasing agents and managers that there were 23 criteria that can be considered in supplier selection decision. Weber et al [37] found from review of 74 articles, since 1966, that net price, delivery, and quality were the first three criteria used in most articles. Haq and Kannan [34] also confirmed that most of their literature surveyed focus on the three criteria. From our reviewed of literature [38-44], we found that the three criteria are still being applied in supplier selection decision. However, none were concerned with transportation cost in detail, although it is has significant impact on supplier selection cost.

5.2.2 Methods

From reviewed literature, it was found that methods applied in supplier selection problem depend upon Single Sourcing or Multiple Sourcing decision.

5.2.2.1 Single sourcing

Single sourcing happens when all available suppliers can reach buyer's requirements, but buyer would like to select only one appropriate supplier. There are several methods to take such decision. Two of the more frequently use are Linear Weighting method and Analytical Hierarchy Process (AHP). The first method is pretty simple to work with while AHP is more accurate than the other scoring methods [45] as it can deal with both qualitative and quantitative factors in complex and unstructured decision making [34].

1) Linear weighting
The Linear weighting is a simple and easy method in which all suppliers are rated on several unstructured criteria and the highest total score supplier will take orders from the buyer. The total score for each vendor can be calculated as equation below:

$$T_i = \sum_{j=1}^{m} w_{ij} \qquad (i = 1 \ldots n)$$

Choose supplier k when $T_k = \max T_i$

Where
n = number of criteria, different from each company and situation
m = number of suppliers
w_{ij} = weight of supplier i with criterion j (given from decision makers)

2) Analytical Hierarchy Process (AHP)
AHP models the decision problem as a hierarchy of Goal, Major criteria and subcriteria for each criterion by as far as it clarifies the issues of constraints. It also adds the alternatives (suppliers) as leaves of the tree. It mixes both quantitative and qualitative criteria. Then it applies pairwise comparison for each set of children nodes with respect to their parents. For pariwise comparison, it will be done in matrix form, shown as Table 1, by decision makers to show how important (w_{ij}) by using Saaty's 1-9 scale for each node in the first column is as compared to the others in the first row [46].

Procedure 1: the local weight (LW) for each child of node (x) can be calculated as below.

Table 1: Sample Matrix for Pairwise Comparison for Children of A Node (x)

Parent	**child$_1$**	**child$_2$**	**…**	**child$_m$**
child$_1$	1			
child$_2$	w_{ij}	1		
M			1	
child$_m$				1

Process determines the relative weights:

Let $S_j = \sum_{all\ i} w_{ij} \quad ; \forall j$

$$LW_i = \frac{\sum_{j=1}^{m} \left(\frac{w_{ij}}{S_j} \right)}{m} ; \ i = 1,\ldots,m$$

w_{ij} = weight of pairwise comparison
m = number of children nodes respect to their parent

These values are stored as a relative measure at the node. We will call these value GW(node), the GW (Goal) = 1.

Procedure 2: the process of calculating the total weight for each alternative with respect to the Goal is demonstrated as follow:

$P_j(A_i)$ is defined as the j^{th} path connecting the Goal to Alternative A_i; i = 1,…,m.
$NP(A_i)$ = Total number of path for A_i

For i = 1,…,m [alternatives]
  $W_i = 0$
  For j = 1,…,$NP(A_i)$ [number of paths]
    Find a path $P_j(A_i)$ from the Goal node to A_i
    $\bar{W}_j^i = \prod_{x \in P_j(A_i)} GW(x)$
    $W_i = W_i + \bar{W}_j^i$
  End for j
End for i

$$W_i = \sum_{i=1}^{m} W_{A_i}$$

$$W_i^{\%} = \frac{W_i}{\sum_{i=1}^{n} W_i} \text{, normalised}$$

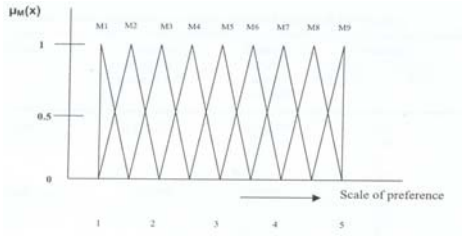
$W_i^{\%}$ shows the ranking of alternatives i [i = 1,….,m]. Thus, the A_i that has the highest $W_i^{\%}$ will be selected as solution.

Barbarosoglu and Yazgac [47] designed AHP model to select vendor for Turkish industry. They commended that managers who are responsible to supplier selection decision have to be well-informed about AHP implementation.

3) Fuzzy-AHP
Even though AHP can deal with multicirteria problems, pairwise comparison based on the scale of 1 to 9 of Saaty's might be tough for decision makers to show how much one criterion is more important than the others. So AHP may be applied with other methods to avoid or reduce that problem. One of which is Fuzzy logic that is very useful to work with vague or imperfect information like "*good quality*" or "*bad quality*" that is tough to be

measured accurately [43]. Fuzzy will convert linguistic scale to triangular membership function for pairwise comparison scale, substituted for the original crisp scales in AHP. The decision makers would have more choices to deal with in case they are not sure about their judgment.

Haq and Kannan [34] proposed fuzzy-AHP model that applies membership function of preference scale shown as Figure 1. The results showed that proposed method took less time of supplier selection process compared to ordinary AHP.



Membership function Preference	M_1 Equally	M_3 Moderately	M_5 Strongly	M_7 Very Strongly	M_9 Extremely

Figure 1: Membership Function for Pairwise Comparison Scale

5.2.2.2 Multiple sourcing

This decision happens when no supplier can fill all the demand and there are some constraints in decision making like suppliers' capacity, customers' demand, buyers' cost, etc. In addition, each supplier may have different strength and weakness. Therefore, buyers have to make decision on which suppliers should be selected and how much orders should be assigned to each vendor. This situation needs some mathematical models due to its complexity. Then models are developed as Single objective or Multiobjective.

1) Single objective

For this decision, usually being cost criterion, some methods such as Linear Programming, and Mixed Integer Programming can be develop [48].

A typical simple model is as follows:

$$\text{Min Z (cost)} \quad = \sum_{i=1}^{n} P_i Q_i$$

$$\text{S.T.} \quad Q_i \leq C_i, \quad \forall i$$

$$\sum_{i=1}^{n} Q_i \leq D$$

$$Q_i \geq 0, \quad \forall i$$

Other constraints that might be considered including number of defected products, transportation cost, capital of vendors, delivery time.

Where

C_i = Capacity of vendor i

P_i = Price of product from supplier i

Q_i= Quantity of product should be bought from supplier i

D = Total demand

The above model is for only one product so if it is expanded to multiproduct the typical model can be demonstrated as follows:

$$\text{Min Z} \quad = \sum_{i=1}^{n}\sum_{j=1}^{n} P_{ij} Q_{ij}$$

$$\text{S.T.} \quad \sum_{j=1}^{n} Q_{ij} \leq C_i, \quad \forall i$$

$$\sum_{i=1}^{n} Q_{ij} \geq D_j,$$

$$P_{ij}, \quad Q_{ij} \geq 0, \quad \forall i, j$$

Other constraints that might be considered including number of defected products, transportation cost, capital of vendors, delivery time.

Where

Q_{ij} = Quantity of production j, purchased from Supplier i

P_{ij} = Price of Supplier i for product j

C_i = Capacity of Supplier i

D_j = Total demand for product j

1.1) AHP and Linear programming

As mentioned previously, supplier selection problem comprises of multiobjective that are both tangible and intangible. Mathematical models have difficulty taking qualitative factors, so AHP is integrated with mathematical model to let it consider both tangible and intangible factors. For this method, all suppliers will be evaluated with qualitative factors using normal AHP, as mentioned previously; then, weigh of each vendor will be added to objective function and to be solved as the way of optimization techniques do.

Typical simple model shows as follow:

$$\text{Max Z} = \sum_{i=1}^{n}\sum_{j=1}^{n} w_i P_{ij} Q_{ij}$$

$$\text{S.T.} \quad \sum_{i=1}^{n}\sum_{j=1}^{n} Q_{ij} \leq D$$

$$\sum_{j=1}^{n} Q_{ij} \leq C_i, \quad \forall i$$

$$Q_{ij} \geq 0, \quad \forall i, j$$

Other constraints that might be considered including number of defected products, transportation cost, capital of vendors, delivery time.

Where

w_i = Weight of supplier i from AHP procedure

Q_{ij} = Quantity of product j, purchased from supplier i

P_{ij} = Price of Supplier i for product j

D = Total demand

C_i = Capacity of supplier i

Ghodsypour and O'Brien [45] integrated, for the first time, analytic hierarchy process with Linear Programming to select the optimal suppliers by getting the score of vendors from AHP to be coefficients of an objective function in linear model. They found that this method provides several benefits such as: 1) both types of criteria, tangible and intangible, can be considered in one model, 2) "what if" scenarios can be applied, and 3) both weight of criteria and supplier ranking can be done in one approach.

2) Multiobjective

Supplier selection problem is usually multiobjective by its nature as it comprises of several objectives such as minimize purchasing cost, maximize quality, and maximize service level. Vipul et al [42] stated that only price criterion, in Single sourcing decision, should not be the performance measure for evaluating supplier performance because it is not the only factor that affects supplier assessment. As a result, some articles formulate this problem as multiobjective rather than single objective. Multiobjective model can take the form of some mathematical models such as Mixed Integer Programming, and Goal Programming [43].

Weber and Current [32] propose multiobjective approach to solve problem comprising of three objectives: Min Z_1 (total price), Min Z_2 (delivery time), and Max Z_3 (quality). To take decision of this situation is necessary to generate feasible noninferior solutions, using any of the common methods. First method is weighting: all objectives will be assigned weight and then combined to be one objective. Another is the constraint method that will investigate solution by optimizing one of all objectives with setting the others as constraints. The result, comparing with goal programming, shown that proposed approach outweigh in several ways. For example, it is not necessary to need manager's judgment of weighting for each objective, and it can specific the number of suppliers to be selected and the quantities that need to be assigned to such vendors.

2.1) Fuzzy multiobjective model

Due to several uncertainties in multiobjective problem, some unknown data is unable to be drawn exactly and need to be estimated. In addition, as mention previously, converting multiobjective into single objective by assigning weight to all objectives is an alternative to find solution, but unfortunately how to assign exactly weight is not easy and seem to be inaccurate. With this respect, fuzzy logic can be applied to tackle such situation to reduce uncertainties by applying fuzzy set to all imperfect or vague data instead of using crisp number. This may result in more flexible range and low level of deviation of those data.

Zarandi et al [43] proposed Fuzzy Multi-objective model for automotive industry and draw the conclusion that such method can convert all objectives into single one by using fuzzy operators, resulting in much more easier to solve than multiple objective problem. Amid et al [41] also proposed Fuzzy multiobjective linear models to help decision makers decide on the quantities that have to be assigned to selected suppliers. They studied based on three objectives: cost, quality, and time delivery that are different weighted by using fuzzy logic.

From all aforementioned of supplier selection method, each method is more suitable for a specific situation. Apparently, the more objective applied in model, the more reasonable solution but the more complex and the more time consuming to solve.

One of the significant objectives affecting total cost of system is transportation cost that is mostly considered as a lump sum figure rather than in detail as part of a model. This is possibly because transportation model comprises of several factors such as lead time, mode and capacity of transport, policy of carriage-full or less than truck load, distance, etc. In addition, as mentioned in Facility location section, the transportation problem is NP-complete. These lead supplier selection problem to be difficult to solve. However, transportation is a significant cost affecting the total cost, it might be more reasonable if it is taken in to consideration in detail to study how it affects the supplier selection decision. This is a subject of interest to the authors for future investigations.

6. Conclusion and Future Work

From reviewed literature of four main areas of supply chain, namely, inventory management, facility location, information technology, and sourcing, this paper found that the first three aspects still challenge to improve efficiency, and also can consider other factors that are not mentioned but still importance to be a part of model. For supplier selection problem, it is still interested topic to study because there are three main gaps: 1) considering transportation cost in detail in objective function; 2) considering other criteria, as mentioned in criteria section, apart from three most popular criteria like cost, delivery, and quality, to evaluate suppliers; 3) and formulating problem as multiobjective model and find efficient methods that take less computing time to find the optimal solution. These are taken as parts of PhD research.

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