The Multi-Objective Approach for Supply Chain Modeling – An Example of Supplier Selection

Wen-Yau Liang
Department of Information Management,
National Changhua University of Education, Taiwan
EMAIL: wyliang@cc.ncue.edu.tw

Abstract: In recent years, supply chain management (SCM) has been touted as one of the major strategies of improving organizational performance and generating a competitive advantage. Many companies are discovering that effective supply chain management is the next step they need to take in order to increase profit and market share. Design of the chain should be able to integrate the various elements of the chain and should strive for the optimization of the chain rather than the entities or group of entities. A growing number of firms have begun to realize the strategic importance of planning, controlling, and designing a supply chain as a whole. In an effort to help firms capture the spirit of integration and coordination across the supply chain and to subsequently make better supply chain decisions, synthesize of past supply chain modeling efforts and a novel approach to modeling supply chain are required. This paper develops the multi-objective label correcting algorithm (MLC) to solve supply chain modeling problems. The proposed approach extends label correcting algorithm to apply to multi-objective problems so as to make a trade-off between different criteria at the same time.

Keywords: Supply Chain Modeling, Multi-Objective, Label Correcting Algorithm, Supplier Selection.

I. Introduction

Mithun et al. say that design of the chain should be able to integrate the various elements of the chain and should strive for the optimization of the chain rather than the entities or group of entities [10]. The strategic importance of the supply chain was also emphasized by the recent observation of John Gossman, Vice President of materials management at AlliedSignal: "Competition is no longer company to company, but supply chain to supply chain" [17]. Over the years, most firms have focused their attention on the effectiveness and efficiency of separate business functions. As new ways of doing business, however, a growing number of firms have begun to realize the strategic importance of planning, controlling, and designing a supply chain as a whole.

Modeling is crucial work in supply chain since this is done in an effort to help firms capture the synergy of inter-functional and inter-organizational integration and coordination across the supply chain and to subsequently make better supply chain decisions. Supply chain modeling can be characterized as a primary method- or algorithm-oriented approach towards SCM. Supply chain model is often represented as a resource network. The nodes in the network represent facilities, which are connected by links that represent direct transportation connections permitted by the company in managing its supply chain. Supply chain modeling has to configure this network and to program the flows within the configuration according to a specific objective function based on algorithms [16]. Therefore, supply chain can be modeled as a configurable and flow-programmable resource network. The network employs a completely different and very selective view of what is going on in the supply chain. But as literature and practice prove, it is a quite powerful way of improving the chain [12]. Supply chain modeling offers short-, medium- or long-term optimization potentials. Elements within the optimization scope may be plants, distribution centers, suppliers, customers, orders, products, or inventories. The standard problems for supply chain modeling are formulated in the following manner. A set of goals should be achieved by minimizing the costs of transfer and transformation. In partial solutions, particular goals are selected, such as securing a certain service level to minimize lead time and maximize capacity utilization, or to secure availability of resources [12]. The standard solutions in supply chain modeling can be found in the establishment of certain algorithms, which identify the optimal solution for the problem.

The label correcting algorithm has been proven to be extremely efficient through solving a certain supply chain modeling problem – the shortest path problem [1, 2]. The label correcting algorithm in previous literature was modeled to solve only one objective problem. However, many researches also propose that many areas of the industry as, for example, telecommunications, transportation, aeronautics, chemistry, mechanical, and environment, deal with multi-objective, where various conflicting objectives have to be considered simultaneously [3]. Due to these reasons, this paper develops a multi-objective label correcting algorithm to achieve a trade-off but consider different criteria at the same time.

II. Modeling Methodologies

Understanding the structural dimensions of a supply chain is a pre-requisite for analyzing and modeling the supply chain. In general, there are two structural dimensions: horizontal and vertical structure. The horizontal structure refers to the number of tiers across the supply chain [7]. Salema et al. proposed a multi-product, multi-period model for the design and planning of supply chain with reverse flows [14]. Together with the strategic location of facilities, the planning of production, storage and distribution is performed for a time horizon divided in two-interconnected time scales. As such, an increase or reduction in the number of suppliers and/or customers will alter the dimension of the supply chain. For example, as some companies make strategic moves toward either supply base reduction or customer selectivity, the supply chain becomes narrower. Outsourcing (inclusion of third-party logistics providers) or functional spin-offs will also alter the supply chain dimension by lengthening and widening the supply chain. Although the supply chain dimension is somewhat arbitrary and ambiguous, it is still important for a model builder to understand the key boundaries of a supply chain network and then determine which aspects (or ranges) of the supply chain network should be modeled [10].

One approach is to model supply chain as queuing networks, which a supply chain system is a network with nodes representing various resources where products or services are processed through a set of operations and, thus, experience waiting times, service times, transit times, and so on. The different resources are linked together with arcs representing possible routings [6]. Path finding problems have been extensively studied [15]. McElreath et al. approximate the optimal assortment for make-to-order and static substitution environments [8]. They test the appropriateness and compare the performance of three metaheuristic methods. These metaheuristics can easily be modified to accommodate different consumer preference distribution assumptions. Guerriero and Talarico propose a general approach for finding the critical path in a deterministic activity-on-the-arc network, considering three different types of time constraints. They introduced in this paper has been developed by redefining and combining together two procedures well-known in the scientific literature [5]. Angelica and Giovanni consider a label correcting approach to find the shortest viable hyperpath from an origin to a destination for different values of the upper limit of modal transfers [2]. Pinto and Pascoal present an enhanced method that computes shortest paths in subnetworks, obtained by restricting the set of arcs according to the bottleneck values in order to find the minimal complete set of Pareto-optimal solutions, and taking into account the objective values of the determined shortest paths to reduce the number of considered subnetworks, and thus the number of solved shortest path problems [13].The study also implemented the algorithm and tested it with the label correcting algorithm. The label correcting algorithm has been proven to be extremely efficient through solving a certain supply chain modeling problem – the shortest path problem [2]. However, the label correcting algorithm in previous literature was modeled to solve only one objective problem.

From the previous literature, we can find out that vector optimizing each objective function is rarely feasible as the objectives are often in conflict. Therefore, many researches had proposed that many areas of the industry as, for example, telecommunications, transportation, aeronautics, chemistry, mechanical, and environment, deal with multi-objective, where various conflicting objectives have to be considered simultaneously [3]. Due to this reason, in the next section, a multi-objective label-correcting algorithm incorporating the various supply chain modeling problems is proposed.

III. The Multi-Objective Label-Correcting Algorithm

Notations

c:the criterion, c = 1,2…n.
i:the node preceding node j
j:the node succeeding node i
s:the source node
rj:the path between node i and node j
d(rj):the value between node i and node j
cij: the values of node j and different preceding node i
Sj: the set of path(s) determined between the source node s and node j
pred(j):the node set preceding node j
I0:the initial value of the source node
Ij:the value determined between the source node and node j
S0: the initial set of path(s)
Wc:the weight value of criterion c
N(rj)c:the normalized value between node i and node j of criterion c

The main idea behind the label-correcting algorithm is that the value (cost, weight, reliability) between any two node *i* and *j* satisfies the following optimality condition, $d(j) \le d(i) + cij$ *for all* $(i, j) \in$ *{set of edges}* [4]. At each stage, the algorithm maintains a set of distance labels d(.). The label (*j*) is either ∞; indicating that a directed path from source to node *j* has not been determined, or it is the length of a directed path from the source to node *j*. All nodes in the path are tracked by a predecessor index pred(*j*). The following is a formal description of the label-correcting algorithm [11]:

begin

$d(s) := 0$ *and* $pred(s) := 0$

$d(j) := \infty$ *for each* $j \in N - \{s\}$

while some edge (i, j) satisfies $d(j) > d(i) + cij$ *do* *begin*

d(j) = d(i) + cij

pred(j): = i

end

end

However, the label correcting algorithm in previous literature was modeled to solve only one objective. Due to this reason, this paper develops a multi-objective label correcting algorithm to achieve a trade-off but consider different criteria at the same time. The algorithm performs a forward search from a selected output point to all accessible points. It processes the Stack of nodes based on the last-in-first-out (LIFO) rule. For the serial way, a node in the stack is pulled out for exploration and its subsequent node(s) is (are) pushed into the stack in each iteration. Then the MLC determines and updates the paths. The algorithm terminates when all nodes in the stack are pulled. The algorithm consists of 3 steps. In the Initialization step, the user needs to set up all criteria' weights. In each iterative computation, the value between a node and its preceding node is based on the total value of each node's value multiplying by each weight. In addition, we have to normalize each criterion value during each iterative computation.

MLC-Step 1 (Initialization)

Initialization set:

Set So = Null, Io = 0

Set Wc（c = 1,2…n，ΣWc = 1）

MLC-Step 2 (Finding the path)

Step 2.1 If there is no succeeding node in the path (MLC ends), go to Step 3. Otherwise, go to Step 2.2.

Step 2.2 If only one succeeding node exists, go to Step 2.4. Otherwise, go to Step 2.3

Step 2.3 If one *Sj* is not found and his precedent Si also is not found, go to Step2.4. Otherwise, go to Step 2.1.

Step 2.4 If only one precedent of Sj exists, go to Step2.6. Otherwise, go to Step 2.5.

Step 2.5 If exist one *Sj* not been found and his precedent Si also is not found, go to Step2.4. Otherwise, go to Step 2.7.

Step 2.6 *Ij = Ii + d(rj)；d(rj) = Σ(N(rj)c * Wc)；Sj = Si + { rj }. Go to Step 2.2*

Step 2.7 *d(j)= Ii +* c_{ij}.

IF d(j) ≧ d(i) + cij Then

*Ij = Ii + d(rj)；d(rj) = Σ(N(rj)c * Wc)；Sj = Si + { rj }*. Go to Step 2.3.

MLC-Step 3 (Detailed Design)

The path has been found: S_j ; And the value is I_j. Instantiate all the remaining attributes, if possible, considering the relations between the path and the various constraints.

IV. Example Illustration

Consider a scenario where the supplier selection process of a plastic dyeing company is being designed and where the design has reached the stage where the manufacturing process and alternative suppliers have been completed. The product synthesized of five parts is exemplified. Each part is to select a supplier to outsource. The supplier selection is a multi-criteria problem which includes both qualitative and quantitative feature. The reduction of final network of the SC is presented in Fig. 1. Next, the MLC algorithm is applied to select the desired path to determine the supplier in Fig. 1. Table 1 shows the manufacturing process and alternative suppliers.

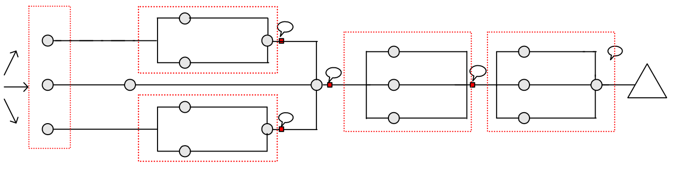

Fig. 1. The workflow of the plastic dieing company

Table 1 The ranking data for the alternative supplier

Supplier/Path	From	To	Process	Time	Cost	Reliability
R1	M1	N5、N6	Rough-wrought	7	5000	0.98
R2	M2	N4	Rough-wrought	5	6500	0.95
R3	M3	N7、N8	Rough-wrought	6	4800	0.95
R4	N5	N9	machining	12	8900	0.92
R5	N6	N9	machining	10	10000	0.88
R6	N4	M11	machining	22	22000	0.87
R7	N7	N10	machining	11	12000	0.92
R8	N8	N10	machining	9	9000	0.91
R9	N9	M11	Machining	13	16000	0.98
R10	N10	M11	Machining	11	19000	0.96
R11	M11	N12、N13、N14	Assembly	8	6000	0.98
R12	N12	N15、N16、N17	Tryout	12	8500	0.98
R13	N13	N15、N16、N17	Tryout	9	7600	0.92
R14	N14	N15、N16、N17	Tryout	11	7800	0.91
R15	N15	M18	Decorate	6	5000	0.95
R16	N16	M18	Decorate	5	6400	0.92
R17	N17	M18	Decorate	7	4900	0.89
R18	M18	M19	Inspect	3	7200	0.98

* The data is refined form the company's database

It is necessary to make a trade off between these tangible and intangible factors (time, cost, reliability), some of which may conflict. The following are steps of the MLC applied to this problem:

MLC-Step 1 (Initialization)

Initialization set:

Set S_o *= Null,* I_o *= 0*

Set W_1 *(Weight of Time Criterion) = 0.3*

W_2 *(Weight of Cost Criterion) = 0.4*

W_3 (Weight of Reliability Criterion) = 0.3

MLC-Step 2 (Finding the path)

Iteration 1

Step 2.1 Exist succeeding node, MLC does not end. Go to Step 2.2.

Step 2.2 Find succeeding node N4、N5、N6、N7、N8. Go to Step 2.3

Step 2.3 Exist one S_j (N4).

Step 2.4 Only one precedent R2 of S_j exists, go to Step 2.6.

Step 2.6 $I_{N4} = 0 + d(R2) = N(R2)_1 * W_1 + N(R2)_2 * W_2 + N(R2)_3 * W_3$

$= N(1-(5-3)/(22-3)) * 0.3 + N(1-(6500-4800)/(22000-4800)) * 0.4 + 0.95 * 0.3$

$= 0.912$； $S_{N4} = S_o + \{R2\}$. Go to Step 2.2

Iteration17

Step 2.1 MLC ends, go to Step 3

MLC-Step 3 (Detailed Design)

S_{M19} ={R3, R8, R10, R11, R13, R15, R18}；I_{M19} =5.242。 At final, the path has been found from R1 to R18 {R1, R3, R8, R10, R11, R13, R15, R18} (see Fig. 2) and the value is 5.242.

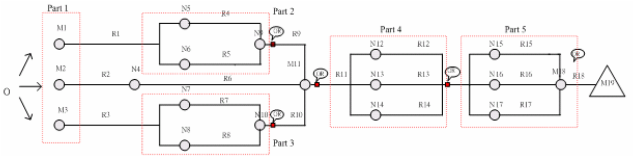

Fig. 2. The final path

V. Conclusion

The label correcting algorithm is proven to be extremely efficient for the shortest path problem. However, the label correcting algorithm in previous literature was modeled to solve only one objective problem. This paper develops the multi-objective label correcting algorithm (MLC) to solve supply chain modeling problems. The proposed approach extends label correcting algorithm to apply to multi-objective problems where various conflicting objectives have to be considered simultaneously so as to make a trade-off between different criteria at the same time.

Acknowledgement

This work was partially supported by funding from the Nation Science Council of the Republic of China (NSC 96-2416-H-018-005-MY3).

References

[1] Angelica, L. and Giovanni, S., 2001. Shortest Viable Path Algorithm in Multimodal Networks, *Transportation Research Part A: Policy and Practice*, 35 (3), 225-241.

[2] Angelica, L. and Giovanni, S., 2002. Shortest Viable Hyperpath in Multimodal Networks, *Transportation Research Part B: Methodological*, 36 (10), 853-874.

[3] Figueira, J.R., Liefooghe, A., Talbi, E.-G., and Wierzbicki, A.P., 2010. A parallel multiple reference point approach for multi-objective optimization, *European Journal of Operational Research*, 205, 390-400.

[4] Ford, L. R. and Fulkerson, D. R., 1962. Flows in Networks, Princeton University Press, NJ.

[5] Guerriero, F. and Talarico, L., 2010. A solution approach to find the critical path in a time-constrained activity network, *Computers & Operations Research*, 37 (9), 1557-1569.

[6] Kerbache, L. and Smith, J.M., 2004. Queuing networks and the topological design of supply chain systems, *International Journal of Production Economics*, 91, 251-272.

[7] Lambert, D.M., Cooper, M.C. and Pagh, J.D., 1998. Supply chain management: Implementation issues and research opportunities, *The international Journal of Logistics management*, 9 (2), 1-19.

[8] McElreath, M.H., Mayorga, M.E., and Kurz, M.E., 2010. Metaheuristics for assortment problems with multiple quality levels, *Computers & Operations Research*, 37 (10), 1797-1804.

[9] Min, H. and Zhou, G., 2002. Supply chain modeling：past, present and future, *Computers & Industrial Engineering*, 43, 231-249.

[10] Mithun, J.S., Ilkyeong, M., and Hyerim, B., 2008. Analytic hierarchy process to assess and optimize distribution network, *Applied Mathematics and Computation*, 202 (1), 256-265.

[11] Moore, E.F., 1957. The Shortest Path through a Maze, Proceedings of the International Symposium on the Theory of Switch, Part II, 285-292.

[12] Otto, A. and Kotzab, H., 2003. Does supply chain management really pay? Six perspectives to measure the performance of managing a supply chain, *European Journal of Operational Research*, 144 (2), 306–320.

[13] Pinto, L.L., and Pascoal, M.M.B., 2010. On algorithms for the tricriteria shortest path problem with two bottleneck objective functions, *Computers & Operations Research*, 37 (10), 1774-1779.

[14] Salema, M.I., Barbosa-Povoa, A.P., and Novais, A.Q., 2009. A strategic and tactical model for closed-loop supply chains, OR Spectrum, 31, 573-599.

[15] Schenk, L. and Klabjan, D., 2010. Intra market optimization for express package carriers with station to station travel and proportional sorting, *Computers & Operations Research*, 37 (10), 1749-1761.

[16] Tayur, S., Ganeshan, R. and Magazine, M., 1999. *Quantitative Models for Supply Chain Management*. Boston: Kluwer Press.

[17] Vickery, S., Calantone, R., and Droge, C., 1999. Supply chain flexibility: an empirical study, *The Journal of Supply Chain Management*, 35 (3), 16-24.