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Network transformation algorithm for Supply chain plant location problem

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Abstract: - Through analyzing the product structure tree, the complete supply chain network (SCN) including materials supplying, products manufacturing and distribution is established. The directions of all the flows in the original SCN are narrowed down into one single way by dividing up all the possible circulation of both manufacturing and transportation. Each node of the SCN is simplified according to its different functions, outputs and raw material sources. According to the layer of the product structure tree, all the divided nodes are combined so that each route includes all the raw material sources of the finished product. The most suitable plants location under the time constraints are worked out through the application of generalized permanent labeling algorithm on the combined SCN. Finally, by tracing backward to the original SCN according to the most suitable plants location and routes selection, the real optimal plants location and routes selection can be found out.
Key-Words: - Supply chain management, Plant location, Route selection, Network transformation

1 Introduction

Nowadays, living in a complex market environment whose situations including fierce competition, quickly changed consumer's taste, shorter and shorter product's life cycle, all the enterprises are forced to meet the consumer's demand as soon as possible with lower cost and shorter production cycle. To achieve these goals, enterprises are no longer only absorbed in improving their interior production procedures, but extend the feeler of management to other enterprises in the SCN. That is to say, enterprises want to control, operate and plan the total supply chain correlated with its products entirely. With the popularization of the supply chain and the development of the information technology, supply chain management (SCM) have been greatly spread and applied. How to plan and design the SCN from the view of the whole product, such as the suppliers selection, plants location, distribution network designing, becomes the focal issue in the study of the SCM [1]. According to the classification by Cohen and Mallik [2], the problem studied in this paper refers to the plant location of the SCN model.

To the plant location problem, there are two kinds of solutions mainly. One is using various kinds of optimization algorithms to find out the most suitable plant combination. And the other is to confirm the plant combination, assess the tactics by using computer to simulate the situation of the actual supply chain. All those kinds of optimization algorithms can be divided into two categories roughly as following. The first one includes those various kinds of mathematics analytic methods based on the linear programming or mixed-integer programming, which contribute to find out the best solution of the maximal or minimal object functions under some assumptions and limitations. Cortinhal [3], Tjendera [4] have done great contribution researches to this. And Lagrangean heuristic algorithm, which brought forward by Correia [5], is commonly used in large-scale multi-facility location problems, such as Yuri [6]. Besides the aforementioned methods, simulation, which used by Jung [7], *et ac*, is another one to confirm the plant location and policy evaluation.

But the following question generally exists in these methods. Firstly, the plant location belongs to *NP*-hard problem usually, and the algorithm complexity presents the index increase with the range. Secondly, most solutions do not consider the product structure tree. Thirdly, many researchers divide the supply chain into different sub-network, and calculate each sub-network as the optimum solving of the total supply chain. But the concatenation of each sub-network optimum solving might not the best solving of the entire supply chain. Last, the time factor is seldom considered. But actually, the time factor should be studied as an important goal in the new market environment [8].

From all above-mentioned researches, it lacks a simple, general and feasible method to solve the plant location in the SCN. In that, Chen tries to transform the original supply chain and applies the *shortest path algorithm, the maximal flow algorithm* to solve the plant location [9]. The most defect of Chen's research does not consider the time restriction among supply chain nodes. So the plant location and routes selection of the SCN merged with the product structure tree under the time window is studied emphatically.

2 Model and methodology

2.1 Description, assumptions and notations

For any supply chain with a final product, there is a dendrite product containing all the materials/modules used in the supply chain to produce the final product, and showing the hierarchical composition relationships between these materials/modules, as the example shown in Fig.1.The raw material P_{01} and P_{02} are used to produce the semi-final product P_{03}. And the raw material P_{04} and the P_{03} are used to make the final product P_0. In addition, the letter in the parentheses after each component in the product tree indicates the quantity of that component needed to make one above level component.

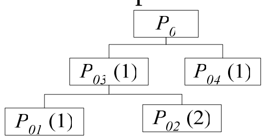

Fig.1. Product structure tree of P_0

SCN, shown in Fig.2, is the *network of facilities that performs the functions of procurement of material, transformation of material to intermediate and finished products, and distribution of finished products to customers* [10]. In this network, there are four modality nodes: supplier (S), manufacturer (M), distributor (D) and retailer (R).

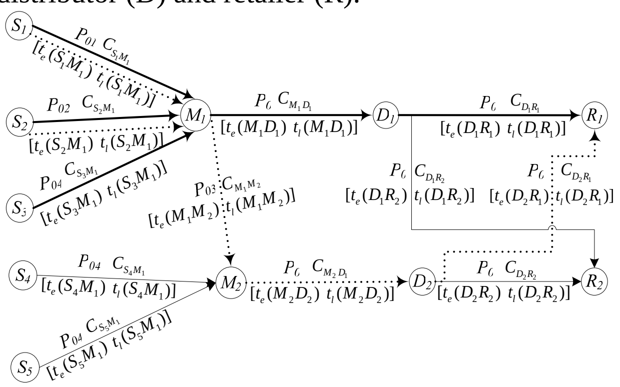

Fig.2. SCN of P_0

In Fig.2, the M_1 receives the P_{01}, P_{02} and P_{04} supplied by the S_1, S_2 and S_3 to produce the P_o and the P_{o3}. And the M_2 receives the P_{04} supplied by the S_4, S_5 and the P_{o3} supplied by the M_1 to produce the P_o. The P_o manufactured by the M_1 and the M_2 are transported to the D_1 and the D_2 respectively. Last, the D_1 and the D_2 distribute the P_o to the R_1 and the R). The letters beside each arc are the components produced or shipped from one entity to another, and according to the actual needs, the production or transportation cost, time restriction are added beside each arc.

However, in a SCN, not all entities are necessary to transport, produce, and distribute from the raw material to the final product. For instance, one possible way to produce and deliver the P_o is S_1, S_2, S_3, M_1, D_1, R_1, as arrows shown in bold lines in Fig.2. Another possible way, as shown in Figure 2 with bold dotted arrow lines, would go through S_1, S_2, S_4, M_1, M_2, D_2, and R_1. Nevertheless, as the example shown in Fig.1, all components, from the raw material P_{01}, P_{02} and P_{04} to the semi-finished product P_{03}, must be used in the process of manufacturing the final product P_0, therefore it is necessary for these components to appear in the production sub-networks for the corresponding SCN, such as the example sub-networks shown in Fig.2.

A node in a SCN may be a raw material supplier, a factory, or a distribution center. Hence, in this study, such a node is said to have either ***production function*** or ***distribution function*** or both [9]. If a node performs manufacturing work, which means transforming some materials, it will have received into another semi-finished or final product in a supply chain, it is said to have the production function, such as M_1 and M_2 in Fig.2. Moreover, a production node, which is a node with production function, is further classified into an ***external production*** node, an ***internal production*** node, or a production node with both functions. An external production node uses only what it receives as materials to produce items without using what it produces as materials. At last, a one-item production node is the one that ships out exactly one kind of item, such as M_2 in Fig.2. An internal production node is a production node, and moreover, it does not only use the components receiving as materials for production, but also takes the items producing again as materials to further produce other items. For example, node M_1 in Fig.2 is a good example of both external node (it imports the component P_{01} and P_{02} to produce the P_{03} and transports the P_{03} to the M_2) and internal production node (it imports the P_{01} and P_{02} to produce the P_{03}, and still more, the node M_1 again takes the P_{03} as one raw material, along with the component P_{04} that it imports, to make the final product P_0).

If a node ships out what it receives without manufacturing work, it is said to have the distribution function, such as D_1 and D_2 in Fig.2. For instance, the D_1 in Fig.2 is a node with distribution function only.

2.2 SCN transformation: decomposition and composition

Before applying any network flow algorithms, a SCN have to be transformed into another topology graph

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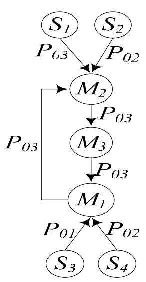
to satisfy the regarding requirements of those algorithms. And the basic ideas of the SCN transformation are as following.

- Analyzing the product structure tree and setting up the original SCN;
- Simplifying each node of the SCN according the different nodal functions, outputs, and raw material sources;
- Combining the new supply chain node according to the layer of the product structure tree;
- Applying the optimization algorithm to the SCN after decomposition and composition and seeking out the most suitable plants and routes;
- Tracing backward to the original SCN to find the real optimal plant location and routes.

2.2.1 Product structure tree and SCN analyzing

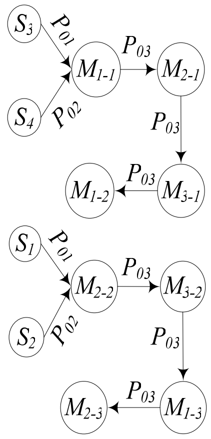
As the description and assumption, different nodes are connected with directed arcs. Because the nodal type is not appointed at ahead, it is necessary to check out the circulation in the original SCN before analyzing the function of supply chain nodes. The transformation of product structure and SCN when decomposing supply chain circulations is divided into two parts: one is to check and transform the manufacturing process circulation and the other is to check and transform the distribution process circulation.

Manufacturing process circulation-Start and end in the same node. All nodes in this circulation are manufactures, so this circulation can be viewed as the manufacturing process to the same entity. Just as shown in Fig.3, the M_1、M_2 and M_3 form a circle to transport $P_{03.}$ Firstly, it needs to decompose this circle to express as the manufacturing process. And because both the M_1 and M_2 contains the P_{01} and P_{02} to produce $P_{03,}$ so both the M_1 and M_2 can be acted as the starting of the manufacturing process. Transforming this sub-network in Fig.3 and revising the corresponding cost and time window on each route, the sub-network and the cost and time window after decomposition are presented in Fig.4 respectively.



Route	Cost	Time Window
$S_1 \rightarrow M_2$	$C_{S_1M_2}$	$[\, t_e(S_1M_2)\ \ t_l(S_1M_2)\,]$
$S_2 \rightarrow M_2$	$C_{S_2M_2}$	$[\, t_e(S_2M_2)\ \ t_l(S_2M_2)\,]$
$M_2 \rightarrow M_3$	$C_{M_2M_3}$	$[\, t_e(M_2M_3)\ \ t_l(M_2M_3)\,]$
$M_3 \rightarrow M_4$	$C_{M_3M_4}$	$[\, t_e(M_3M_4)\ \ t_l(M_3M_4)\,]$
$M_4 \rightarrow M_2$	$C_{M_4M_2}$	$[\, t_e(M_4M_2)\ \ t_l(M_4M_2)\,]$
$M_2 \rightarrow M_5$	$C_{M_2M_5}$	$[\, t_e(M_2M_5)\ \ t_l(M_2M_5)\,]$

Fig.3. Original manufacturing circulation network and its data

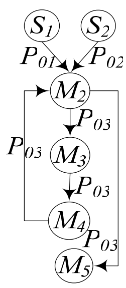


Route	Cost	Time Window
$S_3 \rightarrow M_{1\text{-}1}$	$C_{S_3M_1}$	$[\, t_e(S_3M_1)\ \ t_l(S_3M_1)\,]$
$S_4 \rightarrow M_{1\text{-}1}$	$C_{S_4M_1}$	$[\, t_e(S_4M_1)\ \ t_l(S_4M_1)\,]$
$M_{1\text{-}1} \rightarrow M_{2\text{-}1}$	$C_{M_1M_2}$	$[\, t_e(M_1M_2)\ \ t_l(M_1M_2)\,]$
$M_{2\text{-}1} \rightarrow M_{3\text{-}1}$	$C_{M_2M_3}$	$[\, t_e(M_2M_3)\ \ t_l(M_2M_3)\,]$
$M_{3\text{-}1} \rightarrow M_{1\text{-}2}$	$C_{M_3M_1}$	$[\, t_e(M_3M_1)\ \ t_l(M_3M_1)\,]$
$S_1 \rightarrow M_{2\text{-}2}$	$C_{S_1M_2}$	$[\, t_e(S_1M_2)\ \ t_l(S_1M_2)\,]$
$S_2 \rightarrow M_{2\text{-}2}$	$C_{S_2M_2}$	$[\, t_e(S_2M_2)\ \ t_l(S_2M_2)\,]$
$M_{2\text{-}2} \rightarrow M_{3\text{-}2}$	$C_{M_2M_3}$	$[\, t_e(M_2M_3)\ \ t_l(M_2M_3)\,]$
$M_{3\text{-}2} \rightarrow M_{1\text{-}3}$	$C_{M_3M_1}$	$[\, t_e(M_3M_1)\ \ t_l(M_3M_1)\,]$
$M_{1\text{-}3} \rightarrow M_{2\text{-}3}$	$C_{M_1M_2}$	$[\, t_e(M_1M_2)\ \ t_l(M_1M_2)\,]$

Fig.4. Manufacturing process network and its data after transformation

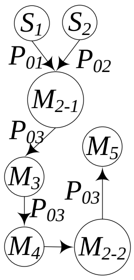
Manufacturing process circulation--Start from the node A, transit and return to the node B. All nodes in this kind circulation are also manufactures, so this kind circle can also be viewed as the manufacturing process to the same entity. Shown in Fig.5, the process route of P_{03} is $M_1 \rightarrow M_2 \rightarrow M_3 \rightarrow M_4 \rightarrow M_2 \rightarrow M_5$. The start node of this process route is M_1, and the end node is M_5. Transforming this sub-network and revising the cost and time window on each route, the sub-network and the cost and time window after decomposition is presented in Fig.6 respectively.

Transportation process circulation. In the actual SCN, the product transshipment among distributors to support retailers' demands is existed generally. Shown in Fig.7, the products are transshipped from D_2 to D_1 to support the retailer R_1 when the products is out of stock in D_1, and so as to the retailer R_2. Decomposing these transportation nodes, which transships the products each other, and the transformed SCN is Fig.8.



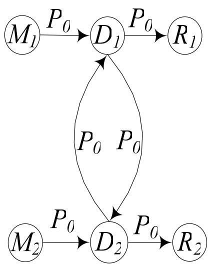
Route	Cost	Time Window
$S_1 \rightarrow M_2$	$C_{S_1M_2}$	$[\, t_e(S_1M_2)\ t_l(S_1M_2)\,]$
$S_2 \rightarrow M_2$	$C_{S_2M_2}$	$[\, t_e(S_2M_2)\ t_l(S_2M_2)\,]$
$S_3 \rightarrow M_1$	$C_{S_3M_1}$	$[\, t_e(S_3M_1)\ t_l(S_3M_1)\,]$
$S_4 \rightarrow M_1$	$C_{S_4M_1}$	$[\, t_e(S_4M_1)\ t_l(S_4M_1)\,]$
$M_1 \rightarrow M_2$	$C_{M_1M_2}$	$[\, t_e(M_1M_2)\ t_l(M_1M_2)\,]$
$M_2 \rightarrow M_3$	$C_{M_2M_3}$	$[\, t_e(M_2M_3)\ t_l(M_2M_3)\,]$
$M_3 \rightarrow M_1$	$C_{M_3M_1}$	$[\, t_e(M_3M_1)\ t_l(M_3M_1)\,]$

Fig.5. Original manufacturing circulation network and its data (Type 2)



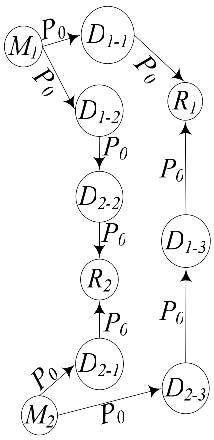
Route	Cost	Time Window
$S_1 \rightarrow M_{2-1}$	$C_{S_1M_2}$	$[\, t_e(S_1M_2)\ \ t_l(S_1M_2) \,]$
$S_2 \rightarrow M_{2-1}$	$C_{S_2M_2}$	$[\, t_e(S_2M_2)\ \ t_l(S_2M_2) \,]$
$M_{2-1} \rightarrow M_3$	$C_{M_2M_3}$	$[\, t_e(M_2M_3)\ \ t_l(M_2M_3) \,]$
$M_3 \rightarrow M_4$	$C_{M_3M_4}$	$[\, t_e(M_3M_4)\ \ t_l(M_3M_4) \,]$
$M_4 \rightarrow M_{2-1}$	$C_{M_4M_2}$	$[\, t_e(M_4M_2)\ \ t_l(M_4M_2) \,]$
$M_{2-2} \rightarrow M_5$	$C_{M_2M_5}$	$[\, t_e(M_2M_5)\ \ t_l(M_2M_5) \,]$

Fig.6. Manufacturing process network and its data after transformation (Type 2)



Route	Cost	Time Window
$M_1 \rightarrow D_1$	$C_{M_1D_1}$	$[\, t_e(M_1D_1)\ \ t_l(M_1D_1) \,]$
$D_1 \rightarrow R_1$	$C_{D_1R_1}$	$[\, t_e(D_1R_1)\ \ t_l(D_1R_1) \,]$
$D_1 \rightarrow D_2$	$C_{D_1D_2}$	$[\, t_e(D_1D_2)\ \ t_l(D_1D_2) \,]$
$M_2 \rightarrow D_2$	$C_{M_2D_2}$	$[\, t_e(M_2D_2)\ \ t_l(M_2D_2) \,]$
$D_2 \rightarrow R_2$	$C_{D_2R_2}$	$[\, t_e(D_2R_2)\ \ t_l(D_2R_2) \,]$
$D_2 \rightarrow D_1$	$C_{D_2D_1}$	$[\, t_e(D_2D_1)\ \ t_l(D_2D_1) \,]$

Fig.7. Original transportation circulation network and its data



Route	Cost	Time Window
$M_1 \rightarrow D_{1-1}$	$C_{M_1D_1}$	$[\, t_e(M_1D_1)\ \ t_l(M_1D_1) \,]$
$D_{1-1} \rightarrow R_1$	$C_{D_1R_1}$	$[\, t_e(D_1R_1)\ \ t_l(D_1R_1) \,]$
$M_1 \rightarrow D_{1-2}$	$C_{M_1D_1}$	$[\, t_e(M_1D_1)\ \ t_l(M_1D_1) \,]$
$D_{1-2} \rightarrow D_{2-2}$	$C_{D_1D_2}$	$[\, t_e(D_1D_2)\ \ t_l(D_1D_2) \,]$
$D_{2-2} \rightarrow R_2$	$C_{D_2R_2}$	$[\, t_e(D_2R_2)\ \ t_l(D_2R_2) \,]$
$M_2 \rightarrow D_{2-1}$	$C_{M_2D_2}$	$[\, t_e(M_2D_2)\ \ t_l(M_2D_2) \,]$
$D_{2-1} \rightarrow R_2$	$C_{D_2R_2}$	$[\, t_e(D_2R_2)\ \ t_l(D_2R_2) \,]$
$M_2 \rightarrow D_{2-3}$	$C_{M_2D_2}$	$[\, t_e(M_2D_2)\ \ t_l(M_2D_2) \,]$
$D_{2-3} \rightarrow D_{1-3}$	$C_{D_2D_1}$	$[\, t_e(D_2D_1)\ \ t_l(D_2D_1) \,]$
$D_{1-3} \rightarrow R_1$	$C_{D_1R_1}$	$[\, t_e(D_1R_1)\ \ t_l(D_1R_1) \,]$

Fig.8. Transportation process network and its data after transformation

Other supply chain circulations. To the other circulation including manufacturers, distributors or retailers, it just happens in the situations as follows; (1) the inferior products returned to re-work, or (2) the adverse logistics considered the castoff recycle. In this paper, just one directed SCN is studied, so these situations above-mentioned do not considered.

And in this paper, each node in the SCN should link to at lest one node. It is to ensure that no unattached node in the SCN. To a general, common SCN, this assumption is reasonable and accord with practice.

2.2.2 Node function decomposition

After analyzing and setting up the product structure tree and the SCN, then the primitive network structure needs to be changed into a new SCN according to the composition of the products and nodal function to make any node on this new network only bear the single function of single output. But to the production function node, the cost and time of obtaining raw materials from different sources are different. So when the production function node which has a lot of sources is of obtaining the same raw materials, this node should be spitted too. In other words, in the new SCN, each node is responsible for the single function. The distribution function node can sends the products to different nodes, and the production function node can only have one output, and to each component, this node can only be received from one supplier. And just as the distribution function node, the production function node sends the products to different nodes.

Among all SCN nodes, only the ***manufacturer node*** might possess two kinds of functions together. So while simplifying the nodal functions, all nodes which are involved the manufacture process only need to be checked. The method to generate the single function node is divided into three steps:

- Checking and isolating all nodal distribution functions;
- Isolating different outputs to the remainder production function nodes;
- Checking the production node after isolating different outputs and splitting the same raw materials with different sources.

After these three steps, because new nodes have replaced all old nodal functions and outputs, all these old nodes and their arcs are deleted and the nodes with the same inputs and outputs are amalgamated.

Exampling as the node M_1 in Fig.9, P_0 is produced by P_{03} and P_{04}, P_{03} is composed by P_{01} and P_{02}. Seeing Fig.9, M_1 has three functions: (1) transports P_{02} to M_2, (2) produces and transports P_{03} to M_3, (3) transports P_0 to D_1. The Function 1 of M_1 belongs to the distribution function ($S_2 \rightarrow M_1 \rightarrow M_2$), so it needs to generate a new node to replace this function, as shown in Fig.10(a). The function 2 of M_1 is to produce P_{03} (S_1+$S_2 \rightarrow M_1 \rightarrow M_3$), so it needs to generate another new node to replace this function, as shown in Fig.10(b). The function 3 of M_1 is to produce P_0, so it needs to generate the third node M_{1-3} to replace this function, as shown in Fig.10(c). And because there are two different supplies (S_3 and S_4) to offer the same material P_{04} to produce P_0, so the node M_{1-3} needs to be split into two nodes (M_{1-4} and M_{1-5}) on behalf of different supplies combination, as shown in Fig.10(d). Checking the new network, the inputs and outputs of

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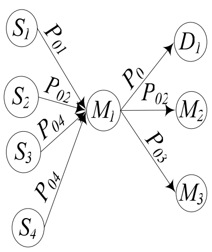
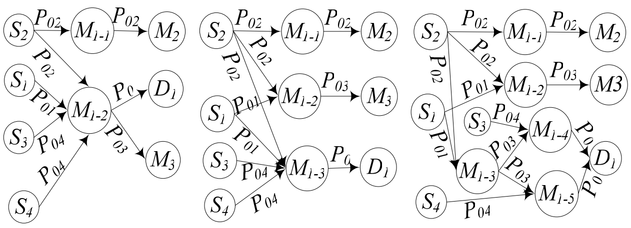
the node $M_{1\text{-}2}$ and $M_{1\text{-}3}$ are completely the same, so one node of both can be amalgamated and some related arcs are deleted.

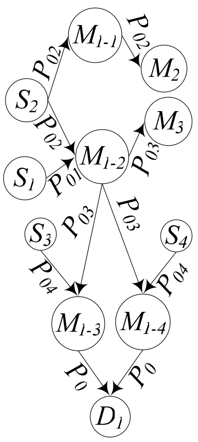


Route	Cost	Time Window
$S_1 \rightarrow M_1$	$C_{S_1M_1}$	$[\ t_e(S_1M_1)\ \ t_l(S_1M_1)\ ]$
$S_2 \rightarrow M_1$	$C_{S_2M_1}$	$[\ t_e(S_2M_1)\ \ t_l(S_2M_1)\ ]$
$S_3 \rightarrow M_1$	$C_{S_3M_1}$	$[\ t_e(S_3M_1)\ \ t_l(S_3M_1)\ ]$
$S_4 \rightarrow M_1$	$C_{S_4M_1}$	$[\ t_e(S_4M_1)\ \ t_l(S_4M_1)\ ]$
$M_1 \rightarrow D_1$	$C_{M_1D_1}$	$[\ t_e(M_1D_1)\ \ t_l(M_1D_1)\ ]$
$M_1 \rightarrow M_2$	$C_{M_1M_2}$	$[\ t_e(M_1M_2)\ \ t_l(M_1M_2)\ ]$
$M_1 \rightarrow M_3$	$C_{M_1M_3}$	$[\ t_e(M_1M_3)\ \ t_l(M_1M_3)\ ]$

Fig.9. Original SCN and its data of M_1



(a) Network of of M_1 splitting function 1 (b) Network of of M_1 after splitting function 1,2 (c) Network of of M_1 after splitting function 1,2 and 3



(d):Network of M1 after combination the same function nodes

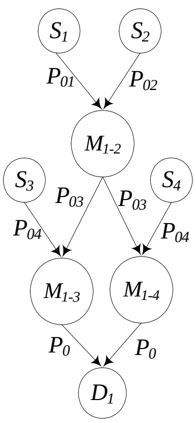
Route	Cost	Time Window
$S_2 \rightarrow M_{1\text{-}1}$	$C_{S_2M_1}$	$[\ t_e(S_2M_1)\ \ t_l(S_2M_1)\ ]$
$M_{1\text{-}1} \rightarrow M_2$	$C_{M_1M_2}$	$[\ t_e(M_1M_2)\ \ t_l(M_1M_2)\ ]$
$S_2 \rightarrow M_{1\text{-}2}$	$C_{S_2M_1}$	$[\ t_e(S_2M_1)\ \ t_l(S_2M_1)\ ]$
$S_1 \rightarrow M_{1\text{-}2}$	$C_{S_1M_1}$	$[\ t_e(S_1M_1)\ \ t_l(S_1M_1)\ ]$
$M_{1\text{-}2} \rightarrow M_3$	$C_{M_1M_3}$	$[\ t_e(M_1M_3)\ \ t_l(M_1M_3)\ ]$
$M_{1\text{-}2} \rightarrow M_{1\text{-}3}$	0	$[\max(t_l(S_2M_1), t_l(S_1M_1))$ $\max(t_l(S_3M_1), t_l(S_4M_1))\ ]$
$M_{1\text{-}2} \rightarrow M_{1\text{-}4}$	0	$[\max(t_l(S_2M_1), t_l(S_1M_1))$ $\max(t_l(S_3M_1), t_l(S_4M_1))\ ]$
$S_3 \rightarrow M_{1\text{-}3}$	$C_{S_3M_1}$	$[\ t_e(S_3M_1)\ \ t_l(S_3M_1)\ ]$
$M_{1\text{-}3} \rightarrow D_1$	$C_{M_1D_1}$	$[\ t_e(M_1D_1)\ \ t_l(M_1D_1)\ ]$
$S_4 \rightarrow M_{1\text{-}4}$	$C_{S_4M_1}$	$[\ t_e(S_4M_1)\ \ t_l(S_4M_1)\ ]$
$M_{1\text{-}4} \rightarrow D_1$	$C_{M_1D_1}$	$[\ t_e(M_1D_1)\ \ t_l(M_1D_1)\ ]$

Fig.10. Function decomposition of the node M_1

2.2.3 SCN composition based on product structure tree

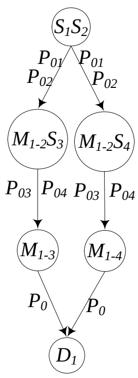
The SCN composition based on the product structure tree has two main steps: (1) the composition of production node with the same material, (2) the composition of production node without the same material. For a one-item production node-producing component, it needs to compose all the nodal upstream nodes that provide the component into one node set, and also combine all the relating arcs into one arc that imports the entire component. In addition, before applying the optimization algorithms on the SCN, two extra virtual nodes (the source node *S* the sink node *T*) and some arcs have to be added in the SCN.

After the SCN composition, every nodal input contains all components for its outputs and each component is just offered by one supplier. The amalgamating process is to amalgamate the nodes of same layer according to the product structure downstream from the root to the bottom. Only a route amalgamated out like this includes producing all compositions of the finished product. All manufacturer nodes changed in the SCN composition need to be deleted. Taking Fig.11 as an example, P_0 is the final product and the transformed network after composition is shown in Fig.12.



Route	Cost	Time Window
$S_2 \rightarrow M_{1\text{-}2}$	$C_{S_2M_1}$	$[\ t_e(S_2M_1)\ \ t_l(S_2M_1)\ ]$
$S_1 \rightarrow M_{1\text{-}2}$	$C_{S_1M_1}$	$[\ t_e(S_1M_1)\ \ t_l(S_1M_1)\ ]$
$S_3 \rightarrow M_{1\text{-}3}$	$C_{S_3M_1}$	$[\ t_e(S_3M_1)\ \ t_l(S_3M_1)\ ]$
$M_{1\text{-}2} \rightarrow M_{1\text{-}3}$	0	$[\max(t_l(S_2M_1), t_l(S_1M_1))$ $\max(t_l(S_3M_1), t_l(S_4M_1))\ ]$
$M_{1\text{-}2} \rightarrow M_{1\text{-}4}$	0	$[\max(t_l(S_2M_1), t_l(S_1M_1))$ $\max(t_l(S_3M_1), t_l(S_4M_1))\ ]$
$S_4 \rightarrow M_{1\text{-}4}$	$C_{S_4M_1}$	$[\ t_e(S_4M_1)\ \ t_l(S_4M_1)\ ]$
$M_{1\text{-}3} \rightarrow D_1$	$C_{M_1D_1}$	$[\ t_e(M_1D_1)\ \ t_l(M_1D_1)\ ]$
$M_{1\text{-}4} \rightarrow D_1$	$C_{M_1D_1}$	$[\ t_e(M_1D_1)\ \ t_l(M_1D_1)\ ]$

Fig.11. Original network and its data of M_1



Route	Cost	Time Window
$S_1S_2 \rightarrow M_{1\text{-}2}\ S_3$	$C_{S_1M_1}$ + $C_{S_2M_1}$	$[\max(t_e(S_2M_1), t_e(S_1M_1))$ $\max(t_l(S_2M_1), t_l(S_1M_1))\ ]$
$S_1S_2 \rightarrow M_{1\text{-}2}\ S_4$	$C_{S_1M_1}$ + $C_{S_2M_1}$	$[\max(t_e(S_2M_1), t_e(S_1M_1))$ $\max(t_l(S_2M_1), t_l(S_1M_1))\ ]$
$M_{1\text{-}2}\ S_3 \rightarrow M_{1\text{-}3}$	$C_{S_3M_1}$	$[\max(t_l(S_2M_1), t_l(S_1M_1), t_e(S_3M_1))$ $\max(t_l(S_2M_1), t_l(S_1M_1), t_l(S_3M_1))\ ]$
$M_{1\text{-}2}\ S_4 \rightarrow M_{1\text{-}4}$	$C_{S_4M_1}$	$[\max(t_l(S_2M_1), t_l(S_1M_1), t_e(S_4M_1))$ $\max(t_l(S_2M_1), t_l(S_1M_1), t_l(S_4M_1))\ ]$
$M_{1\text{-}3} \rightarrow D_1$	$C_{M_1D_1}$	$[\ t_e(M_1D_1)\ \ t_l(M_1D_1)\ ]$
$M_{1\text{-}4} \rightarrow D_1$	$C_{M_1D_1}$	$[\ t_e(M_1D_1)\ \ t_l(M_1D_1)\ ]$

Fig.12. Network composition and its data of M_1

2.2.4 Appling the optimization algorithm to the transformed SCN

After all conversion operations above-mentioned in the SCN, the relevant algorithm can be applied to the transformed network to find out the best node association. The optimization algorithm adopted in this research is the ***generalized permanent labeling algorithm (GPLA)*** of the ***single source shortest path with time window (SSP-TW)*** [11]. That is to say, the specific route of the minimum cost under the time constrains from the starting point to the terminal point should be searched out. And all nodes in this route are the optimal plant location in production and distribution.

2.2.5 Seeking the optimal plant location of original SCN

The shortest route found out after using the *GPLA* to the transformed network includes all nodes of the optimal plant location. Now, the real plant location should be confirmed from this route according to the amalgamated nodes, outputs and components. The corresponding method to find these is to take apart and return to the original SCN.

3 Discussion and conclusion

Unlike many studies done in the SCM field, this research takes a different approach by transforming the SCN with the product structure tree under the time restriction of the SCN, then makes use of the *GPLA* algorithm to develop supply chain algorithms that are good for SCM decision-makings. The most important results learnt from the research are summarized as follows.

First, these supply chain algorithms provide a simple yet practical fashion to build supply chain models that are useful for SCM without a large amount of money or professional knowledge. Second, in the academic research for a more general model to represent and discuss the SCM, the algorithms built here and the way to transform the SCN is a great candidate that serves as a good starting point. It is possible to add more new considerations into the representation and algorithms to improve its representative ability. Third, since these supply chain algorithms, along with the basic decomposition and composition of the SCN are designed closely connected to the product structure tree, it can be seen that there seems to be different ***sections*** or ***cuts*** existing in the supply chain after composition, as examples shown in previous chapters. Last, a manager in a centralized SCN can use this supply chain algorithm to generate initial results regarding output, cost or both factors for his SCM decisions. In a SCN that exists a dominate player, such as Acer in its personal computer supply chains, it is also a similar situation since the powerful player is able to choose his suppliers or customers to optimize the benefits for the whole supply chain.

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References:

[1] Tan K.C. A framework of supply chain management literature, *European Journal of Purchasing & Supply Management*, Vol.7, No.1, 2001, pp. 39-48.

[2] Cohen M., Mallik S. Global supply chains: research and applications, *Production and Operations Management*, Vol.6, No.3, 1997, pp. 193-210.

[3] Cortinhal M.J.，Captivo M.E. Upper and lower bounds for the single source capacitated location problem, *European Journal of Operational Research*, Vol.151, No.2, 2003, pp.333-351.

[4] Tjendera S., Shabbir A., Marc G., *etc.* A stochastic programming approach for SCN design under uncertainty, *European Journal of Operational Research,* Vol.167, No.1, 2005, pp.96-115.

[5] Correia I., Captivo M.E. A Lagrangean Heuristics for a Modular Capacitated Location Problem, *Annals of Operations Research*, Vol.122, 2003, pp.141-161.

[6] Yuri L., Adi B.-I. A heuristic method for large-scale multi-facility location problems, *Computers and Operations Research,* 2004, Vol.31, No.2, pp. 257-272.

[7] Jung J.Y., Blau G., Pekny J.F., *etc.* A simulation based optimization approach to supply chain management under demand uncertainty, *Computers and Chemical Engineering*, Vol.28, No.10, 2004, pp.2087-2106.

[8] Yusuf Y.Y., Gunasekaran A., Adeleye E.O., *etc.* Agile supply chain capabilities: Determinants of competitive objectives, *European Journal of Operational Research*, Vol.159, No.2, 2004, pp. 379-392.

[9] Chen S. Y., Network Flow Problems for Supply Chain Management with Product Tree Structure, *Doctor dissertation of National Taiwan University*, Taiwan, 2000.

[10] Lee H.L., Corey B. Material Managing in Decentralized Supply Chains, *Operations Research*, Vol.4, No.5, 1993, pp.835-847.

[11] da Cunha C.B., Swait J. New dominance criteria for the generalized permanent labelling algorithm for the shortest path problem with time windows on dense graphs, *International Transactions in Operational Research*, Vol.7, No.2, 2000, pp. 139-157.