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Optimum Resources Allocation in Fourth-party Logistics

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ABSTRACT

Fourth-party logistics, as a new concept, has been impacting the logistics industry. Along with the development of Fourth-party logistics theory, logistics industry will make great progress in developing. This paper gives a brief introduction of operation mode of fourth-party logistics and a comprehensive analysis on the integration mode. Based on those researches, this paper also builds a model of optimum distribution of resources in fourth-party logistics, regarding minimum cost and time as objective functions, which are solved after being transformed into path, and provides countermeasures of customers. This paper may make contributions to the forth-party logistics and gives direction on the integration of resources in logistics network from the perspectives of time and cost.

Keywords: Fourth-party Logistics, Logistics Network, Resource Allocation

1. INTRODUCTION

Fourth-party logistics, is short for 4PL, a new logistics operation mode in recent years, which has plenty of advantages of the integration of logistics resources. It mainly provides integrated solutions of supply chain with integrating scattered third-party logistics companies. From the perspective of fourth-party logistics, this paper gives integration and optimum allocation of logistics resources. Fourth-party logistics can improve operation efficiency by reintegrating, coordinating and optimizing the resources, meanwhile, provide the solutions and countermeasures according to customers' demand. In this paper, we regard the minimum cost and time as objective functions and make tasks and resources matched in logistics activities. This paper may help to explore an efficient approach to integrating the logistics resources with systematic research on the characteristics, operation mode and resource allocation of 4PL, with deep insight into the logistics theory, and make contributions to the development of fourth-party logistics.

In the 1992, some scholars have already put forward the concept of fourth-party logistics. Actually, fourth-party logistics is an integrator in supply chain, which provides an overall solution with its resource in information and management, instead of offering service in a node[1]. The main players in fourth-party logistics are consulting companies or computer service suppliers[2]. There is no corresponding link in existing logistics system. So the fourth-party logistics is constructed with the base of third-party logistics, regarding information technology as its core[3].4PL and supply chain management may have positive effect on enterprises. So logistics company should pay much attention to integrating the upstream and downstream enterprises, and even get cooperated with the enterprises those at same level to achieve the goal[5]. In summary, the fourth-party logistics is based on the existing logistics systems, which can be regarded as the integration of social resource.

As for resource integration, at the end of 20 century, there was some scholars put forward the idea of selecting logistics service suppliers with mixed integer programming model[7]. Other scholars research the problem that 3PL service suppliers selection under the forth-party logistics, and solve the model which regards optimal cost and customer-satisfied time with Ant Colony Optimization. Based on these, Paul put forward the definition of virtual organization and its functions, recognizing that the reason why the organization can exist is being supported by a long-term cooperative network, which ultimate goal is to provide the solution of logistics integration to customers within certain times.

According to those researches, it can be concluded that the research on fourth-party logistics is concentrated on logistics alliance, virtual logistics alliance and supply chain network. The research on allocation of fourth-party logistics is limited in theory, whose practice is still being explored.

First, this paper gives a brief analysis of fourth-party logistics based on its current situation. Second, it proposes an integration mode of 4PL and points out that the key to improving the efficiency is having dynamic optimization and decent coordination on integrated third-party logistics and customers' demand. Finally, this paper gives the resource allocation mode, which considers minimum cost and time as objective functions, and solves the function to gain the optimal solution.

2 THE ANALYSIS ON OPERATION MODE OF 4PL

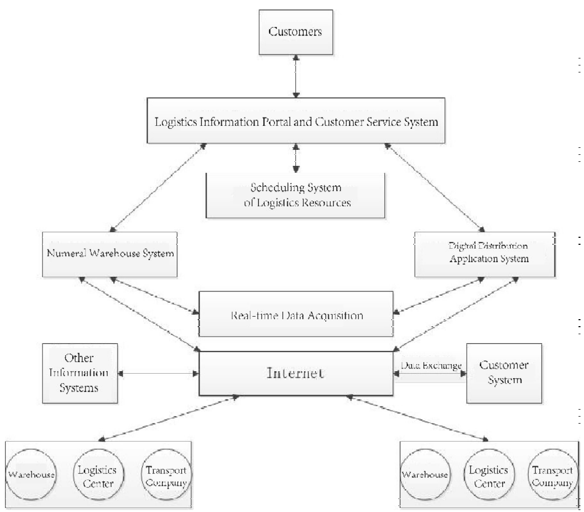

Fig.1 The Flow Chart of Fourth-party Logistics

Fourth-party logistics is compromised with multiple enterprises, which are supported by third-party logistics service supplier, excellent technique service suppliers, consulting companies and management companies that cooperate with each other and provide customers with excellent solutions. The operation mode of 4PL can be divided into three types[10]:

Coordination mode: The enterprises in fourth party logistics can be seen as part of third-party logistics, what is working in the 3PL enterprises and managed by 3PL enterprises. And the 3PL enterprises provide various solutions to different customers.

Integration mode: It is an integration of the whole industry and providing a public information platform. 4PL enterprises integrate the functions, information resource, science technology and their abilities of 3PL service suppliers. In this mode, 4PL enterprises can be seen as a band connecting the 3PL service suppliers and customers, as well as a leader of whole organization alliance. But there is a problem that if there is no enough business and expected revenue, they cannot integrate the 3PL enterprises.

Innovation mode: 4PL enterprises play a role of manager and leader, integrating the multiple resources and considering the differences of various industries, provide service with various customers and fill the shortcomings of 3PL enterprises.

It can be concluded that 4PL service suppliers allocate the logistics task and resources with the perspective of whole supply chain. They can redesign and rebuild the transportation paths and nodes, optimize the operation efficiency, strengthen the strain capability and shorten the delivery time. Meanwhile, 4PL service suppliers can strengthen the ability of management and controlling in the accurate transportation, storage and delivery, so as to achieve the goal of sharing advantages and resources. Under the dynamic situation, 4PL service suppliers can allocate the resources and make the warehouse, vehicles and logistics distribution centers run smoothly to improve the efficiency, optimize the paths and reduce cost.

3 THE ANALYSIS ON RESOURCE ALLOCATION OF LOGISTICS RESOURCES

This paper proposes the idea that the key to allocation of logistics resources is distributing the logistics transport tasks of logistics demander according to the various request and constraints to alternative logistics resources reasonably, which major task is choosing the logistics service suppliers and resource nodes and complementing the optimal allocation of tasks and resources. Its goal is meeting the various demand of customers and proposing the different solution. That means using the optimal combination of logistics and resources to make suppliers try their best to obtain advantages.

During the optimum allocation process of logistics resources, the 4PL enterprises are supported by the 3PL service suppliers to provide their customers with various solutions of supply chain. So it is of vital importance to make use of 3PL service suppliers reasonably to provide service with high quality and efficiency, which refers to the scheduling of 4PL service suppliers and integrating the resources, information and abilities of 3PL service suppliers. In this paper, we recognize that what mentioned above is the main idea of the process of logistics resources allocation, which is shown as figure2.

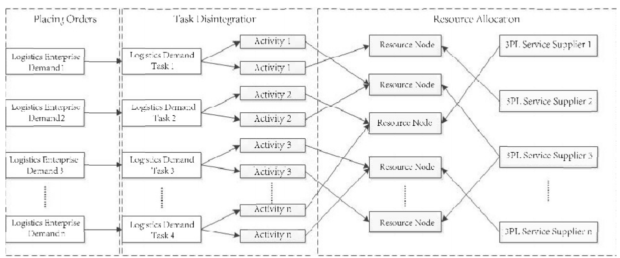

Fig2. The mode of logistics resources in 4PL

After customers playing an order and forming a logistics task, 4PL enterprises integrate those tasks and separate them into different part. Then, they use reasonable allocation system to distribute the tasks to different resource nodes, which implement the task of transportation and other logistics activities. As shown in the figure2, different logistics service suppliers provide the different resource nodes. Because of that, during completing the allocation of resource nodes, the 4PL enterprises complete the choosing of logistics service suppliers. At final, they transform the question into the optimal routing and solve and optimize the question.

So the essence of 4PL management mode is being supported by the resources provided by 3PL service suppliers and offering logistics services to customers with high quality, efficiency and variety. It may help to utilize and coordinate the 3PL service suppliers to satisfy the demand of customers. Its ultimate purpose is to distribute the various logistics tasks to 3PL service providers which settle in the network, according to customers' demand, providing the two sets of solutions from the perspective of shortest time and minimum cost.

In this paper, the 4PL network is seen as a whole. We separate the logistics demand into two parts, which are logistics tasks and logistics activities. The logistics resources in 4PL network reflect its information, technology, 3PL service suppliers and the logistics nodes provided by those 3PL service suppliers.

There is little possibility to reach the condition that resources and information are shared completely, for the reason that it's of great difficulty to integrate the resources of multiple logistics service suppliers. Base on the circumstances mentioned above, in this paper, we assume that those logistics service suppliers cooperate with each other and provide their logistics nodes. But they still attach to their logistics enterprises and keep their independent paths.

It is of top priority to disintegrate the logistics demand tasks and logistics resources, from the perspective of 4PL, and optimize the allocation according to a reasonable system. The detail operation situation is shown as Fig.3, which consists of the logistics tasks disintegrating, matching logistics resources, selecting 3PL service suppliers tentatively and making decision of logistics resource node.

First, there is a disintegration of logistics demand and resources. Every logistics task can be divided into delivery, transportation, warehousing, processing and so on. The logistics resources can be divided into different resource node according to the various enterprises.

Second, there is a tentative selection of logistics suppliers settling into the network. Because of the differences of their resources, abilities and those provided services, there is no possibility that all the logistics service enterprises can meet every logistics task. So in order to improve the service quality and efficiency, there should be an evaluation system to select the service suppliers.

At last, the logistics resource nodes of logistics service suppliers should be sorted out, analyzed and selected. For the reason that different logistics resource node has different service capability, the selection should be conducted according to the customers' demand and specific condition to choose the most suitable resource node to complete the final mission.

Different tasks have different request for the uncertainty and fuzziness of logistics activities. In order to face that problem, the preliminary work is conducted by manual operation, which consists of making decision of the scale of logistics tasks, requested time of customers and each kind of cost. Then according to the different situation, the optimization and allocation of logistics resources should be conducted. Fig3. shows the mode of optimization of resource allocation.

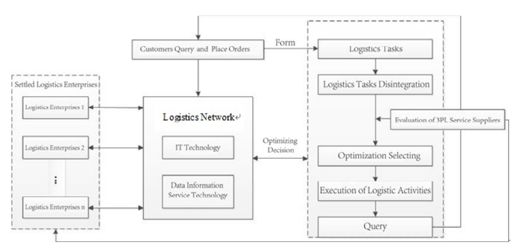

Figure3 The mode of logistics resources allocation

In the Fig.3, the logistics task gathered in orders will be sort out according to actual condition. Theoretically, every logistics task consists of delivery, transport, warehousing and processing. In this article, in order to simplify the calculation and consider the practice, we only take delivery and warehousing into account.

Generally, it is necessary to integrate the network and form a brand new logistics network system for the reason that there is an overlap of transport paths and resources among the 3PL service suppliers. Based on these, we build the model with multiple target, considering time(T), cost(C), quality(Q) and strength(S). Commonly, there should be a reintegration of logistics network formed by logistics enterprises, and forming a brand new logistics network system. In this article, the logistics resource nodes are integrated by logistics network, belonging to different logistics service suppliers. The resource integration of 3 PL network is shown in Fig.4.

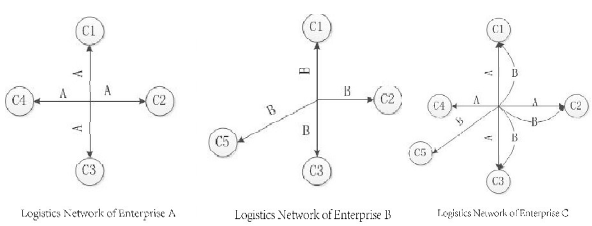

Fig.4 The resource integration of logistic enterprises

It is shown in the Fig.4 that the logistics resource nodes which covered by enterprise A is not completely same with enterprise B. The nodes covered by enterprise A are C_1, C_2, C_3, C_4 and the node covered by enterprise B are C_1, C_2, C_3, C_5. We can see that there is a duplicate part of nodes.

After being integrating the network of enterprise A and enterprise B, the duplicate part of resource nodes are C_1, C_2, C_3. The logistics task in the duplicate city and the start city can be completed by enterprise A and enterprise B together or chooses only one enterprise. So there is arising the problem that selecting the service suppliers. This part will be analyzed in the follows. Also, the parts C_4, C_5 that don't have an overlap still belong to the logistics service suppliers. As mentioned above, it reflect the complementarity of logistics network and expanding the range of logistics service.

In the integrating process of logistics network mentioned above, the advantages can be concluded as follows.

First, after the integrating the network of logistics enterprise whose coverage used to be limited, it may help to expand the cover of service and increasing the number of customers in the whole system.

Second, the logistics network system may help every enterprise to share the logistics infrastructures. It can make great contribution to achieving the goal of sharing the infrastructures in a complete system with dealing the order, transportation and warehousing to improve the resource utilization rate, avoid the resource waste and decrease the cost in the logistics process.

Last, the logistics network helps to reduce the response time greatly. After received the orders, the network can ordinate the logistics resources and achieves the goal of resource sharing, promoting the cooperation among logistics enterprises and cutting down the response time.

4 RESOURCE OPTIMAL ALLOCATION MODEL

4.1 Model Assumptions

It is assumed that there exist three third-party logistics service providers whose quality of service rank high so that customers' demand can be completely satisfied after customers' placing an order and logistics tasks being formed. Figure.5 shows an allocated logistics network picture.

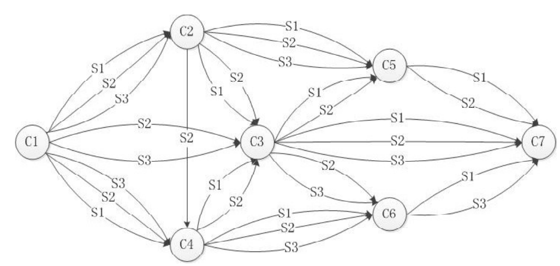

Fig.5 Logistics network schematic diagram of CAINIAO Network

At first, transportation costs of each logistics service providers among urban resources nodes should be ensured. The thesis counts the quantity of logistics resources nodes provided by logistics service providers and the nodes' scope, then ensures the required conversion costs when there occur logistics conversion activities in each urban resources node(conversion cost among all enterprises in each urban node is consistent and fixed.). Secondly, logistics resources having been allocated, corresponding storage and handling costs would be generated when there occur conversion activities of logistics service providers at logistics resources nodes so some other fees brought by conversion should be ensured.

Table.1 model symbol specification

Index value			
C_i	Allocated resources nodes of CAINIAO Network	(C_i, C_j)	multiple service providers between resources node i, j
$a_{ij(k)}$	corresponding information of company k between city i, j $a_{ij(k)} = (C, T, S, Q)$	e_{ijk}	choosing company k between resources node i, j
R_s	collection of all optional paths and urban nodes	H	collection of logistics enterprises $H = \{H_1, H_2, \cdots, H_n)$
		P	collection of optional paths
Parameters			
C_{ijk}	transportation costs of logistics enterprise k between resources node i, j	T_{ijk}	time spent of enterprise k between resources node i, j
S_{ijk}	logistics capability of enterprise k between resources node i, j	Q_{ijk}	quality of service of enterprise k between resources node i, j
$C_j^{'}$	storage and handling costs of logistics enterprises conversion at resources node j	$T_j^{'}$	the time needed for loading , unloading and storage of logistics enterprises conversion at resources node j
Decision variables			
x_{ijk}	0-1 variables; when choosing service provider k , the value =1	y_j	0-1 variables; when there occurs conversion activities of logistics service providers at resources node j ,the value=1
$y_j^{'}$	0-1 variables; when R_s passed resources node j , the value =1		

Through the above table, we can see its significance represented by each symbol:

(1) C_i represents logistics resources node city after allocating logistics network.

(2) Lines between resources node cities represent different logistics service providers and one line stands for one logistics service provider. (C_i, C_j) represent multiple logistics service providers between two resources node cities. For example, (C_1, C_2) means that there are three optional logistics service providers between urban resources node 1, 2.

(3) $a_{ij(k)}$ is a multi-dimensional vector. It represents corresponding information of corresponding logistics service providers. i, j respectively represent connected urban resources nodes of $a_{ij(k)}$. K represents the label of corresponding logistics service provider.

(4 $a_{ij(k)} = (C, T, S, Q)$ represents corresponding information of resources node i, j : C stands for corresponding costs; T represents corresponding time; S represents corresponding logistics capability; Q represents corresponding quality of service.

(5) R_s is a collection of all optional paths and resources node cities. For example, $R_s = \{v_s, 2, v_1, 1, v_3, 3, v_t\}$ represents that from originating station s to terminal station t, logistics service provider 2 is chose between originating station and resources node city 1 when passing by resources node city 1 and 3; logistics service provider 1 is chose between resources node city 1 and 3; logistics service provider 3 is chose between resources node city 3 and terminal station and so on.

(6) All the above-mentioned optional logistics service providers are high-quality suppliers who can meet the requirements of service. They all have sufficient capability to complete customers' logistics tasks. Logistics factors between urban resources nodes include logistics enterprises' conversion costs and conversion time among logistics service providers. Meanwhile, originating station and terminal station are all known and time at the originating station is set to zero moment.

4.2 MODELING

A path optimization model of CAINIAO network's logistics tasks based on costs, time, logistics capability and service quality is set up here. The above analysis can obtain:

Total cost W = transportation cost C_1 among resources nodes + conversion costs C_2 of service providers at resources nodes. Introducing decision variable x_{sjk}, when x_{sjk} =1, it means that the k logistics service provider is chose to provide service between urban resources node i, j; otherwise x_{sjk} = 0.

$$C_1 = \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k\in H} C_{ijk}x_{ijk}(R_s) \quad (1)$$

Not every logistics resources node would take place providers conversion activities. In order to conveniently study conversion costs generated at the nodes. the thesis introduces two decision variables $y_j, y_j^{'}$. When $y_j^{'}$=1, it means that R_s passes by logistics resources node j, otherwise $y_j^{'}$ = 0; $y_j^{'}$ = 1 means that logistics service providers' conversion would take place at logistics resources node j, otherwise $y_j^{'}$ = 0.

$$C_2 = \sum_{j=1}^{n} C_j^{'} y_j y_j^{'}(R_s) \quad (2)$$

So during the transportation process of entire logistics tasks, total cost of logistics process can be expressed as:

$$C = C_1 + C_2 = \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k\in H} C_{ijk}x_{ijk}(R_s) + \sum_{j=1}^{n} C_j^{'} y_j y_j^{'}(R_s) \quad (3)$$

Time factor: Logistics time mainly includes transportation time T_1 among logistics resources nodes and logistics enterprises conversion time T_2 at logistics resources nodes in the thesis. Among them:

$$T_1 = \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k\in H} T_{ijk}x_{ijk}(R_s), \quad T_2 = \sum_{j=1}^{n} T_j^{'} y_j y_j^{'}(R_s) \quad (4)$$

Total logistics time can be expressed as:

$$T_1 = T_1 + T_2 = \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k\in H} T_{ijk}x_{ijk}(R_s) + \sum_{j=1}^{n} T_j^{'} y_j y_j^{'}(R_s)$$

The logistics capability and service quality of service providers only need to meet customers' requirements, which have been retreated in the above-mentioned supplier logistics comprehensive evaluation process and passed the initial screening. It can be expressed as:

Customers' commissioned amount

$$A = Loadingx_{ijk}(R_s) \quad (5)$$

Customers' expected service value

$$R = Credibilityx_{ijk}(R_s) \quad (6)$$

Through above analysis, mathematical model of this chapter can be expressed as:

$$W = \quad (7)$$

$$\min \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k\in H} C_{ijk}x_{ijk}(R_s) + \sum_{j=1}^{n} C_j^{'} y_j y_j^{'}(R_s)$$

$$s.t \ \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k\in H} T_{ijk}x_{ijk}(R_s) + \sum_{j=1}^{n} T_j^{'} y_j y_j^{'}(R_s) \le TIME \quad (8)$$

$$Loadingx_{ijk}(R_s) \le A_{ijk} \quad (i = 1,2,\cdots,n;\ j = 1,2,\cdots,n; k \in H) \quad (9)$$

$$Credibilityx_{ijk}(R_s) \le R_{ijk} \quad (i = 1,2,\cdots,n;\ j = 1,2,\cdots,n; k \in H) \quad (10)$$

$$R_s = (v_s,\cdots,v_i,k.v_j,\cdots,v_t) \in P \quad (i = 1,2,\cdots,n;\ j = 1,2,\cdots,n) \quad (11)$$

In the above formula, this chapter respectively takes formula 7 and 8 as objective functions. The objectives are respectively the lowest cost and the shortest time: when calculating the lowest cost, formula 8 is taken as time constraints to ensure time requirement; formula 9 is taken as service capacity constraints to ensure that selected logistics service providers are able to complete logistics tasks; formula 10 is service quality constraints so as to ensure that service quality of logistics service providers can meet customers' demand; formula 11 guarantees that selected transportation routes are subsets of P.

To simplify the calculations, the thesis establishes virtual nodes. For example, C_1 is set to virtual paths of three providers under different nodes C_{11}, C_{12}, C_{13}. Following the principle of never turning back, the cost of blocked nodes is infinite, which is set to 10000 for convenience. Then through corresponding collating, a corresponding table is obtained. By lingo programming, optimal path integration can be solved, which is also named as the lowest cost and the shortest time.

5 EXAMPLE ANALYSIS

Now there are a group of small electrical appliances which need to be shipped from city C_1 to city C_7. During the transportation process, they would pass by five transitional cities $C_2, C_3, \cdots, C_6$. The thesis assumes that there are three logistics service providers S_1, S_2, S_3 in the network to satisfy the requirements of logistics tasks. The logistics network composed of these logistics service providers is shown in Fig.6. Now we need to choose appropriate logistics nodes and logistics service providers in the logistics network to achieve the lowest cost in the shortest time. Then the question converts into path optimization question.

Before solving the model, several hypothesis should be made: after customers' completing the orders, the system would respond in time so some problems like time delay or postponing would not happen during the process; cargo conversion time is ignored during the cargo transshipment process when calculating because the time is very short; conversion costs of logistics cargo at the same city's resources node is fixed and unchanged. Referring to some related thesis and literature, logistics enterprise conversion costs among all urban nodes can be obtained.

Due to the process of evaluating and choosing service providers, selected logistics service providers are all able to meet the customers' demand of service quality and logistics capability. So information matrix of logistics service providers $a_{ij(k)} = (C, T, S, Q)$ can be simplified into $a_{ij(k)} = (C, T)$. Transportation cost C_{ijk} and time T_{ijk} among nodes mainly include two section, which are cost during transportation process, cost during conversion process and transportation time. Logistics enterprise conversion time is ignored in the hypothesis so only includes transportation time.

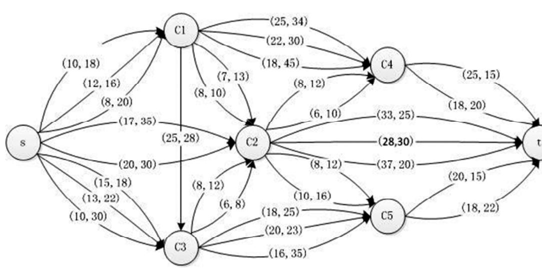

Fig.6 Logistics costs schematic diagram of CAINIAO Network

Table.2 conversion costs at logistics urban nodes

		Enterprise S1	Enterprise S2	Enterprise S3
Node C1	Enterprise S1	0	5	4
	Enterprise S2	5	0	7
	Enterprise S3	4	7	0
Node C2	Enterprise S1	0	4	7
	Enterprise S2	4	0	8
	Enterprise S3	7	8	0
Node C3	Enterprise S1	0	5	8
	Enterprise S2	5	0	6
	Enterprise S3	8	6	0
Node C4	Enterprise S1	0	6	8
	Enterprise S2	6	0	10
	Enterprise S3	8	10	0
Node C5	Enterprise S1	0	7	6
	Enterprise S2	7	0	9
	Enterprise S3	6	9	0

After calculation, the lowest-cost route is $s \overset{2}{-} C_{22} \overset{2}{-} C_{42} \overset{2}{-} D_2(t)$. It means that node C_2 is chose from originating station s and logistics service provider 2 is responsible for transportation; then node C_4 is chose and logistics service provider 2 is responsible for transportation; finally reaching terminal station t, logistics service provider 2 is chose in the transportation process from node city to destination. Total cost is RMB 41. Because transfer process takes less time, the thesis ignore the time spent on transfer process. Network diagram as shown in Fig.7 can be obtained when reselecting the lowest time of each journey.

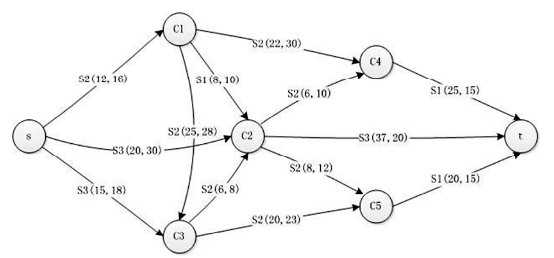

Fig.7 Logistics Time Schematic Diagram

The obtained shortest path is . It means that node is chose from originating stationand logistics service provider 2 is responsible for transportation; then nodeis chose and logistics service provider 1 is responsible for transportation; finally reaching terminal station, logistics service provider 3 is chose during the transportation process from node city to destination. The total time spent is 46 hours.

It can be concluded from the above operating results that logistics transportation tasks are divided into three stage and logistics service provider 2 is responsible for transportation task in every stages after calculation so that the matching of logistics tasks and service providers is achieved in the lowest-cost transportation process. In the transportation process, the cost spent is lower than other three paths. In the same way, in the shortest-time transportation process, logistics transportation tasks are divided into three stages and logistics service provider 2,1,3 are respectively responsible for transportation tasks so as to achieve the matching of logistics transportation tasks and service providers. In this transportation process, transportation time needed is shorter than other transportation paths'. Compared the model with single logistics service provider's completing the same tasks alone, time spent of the former model is shorter, which verifies the feasibility of the model.

6 CONCLUSION

The thesis establishes 4PL resources optimum collocation model and the lowest cost and the shortest time are respectively taken as objective functions so as to provide several solutions for customers. The thesis hopes that research of this article can not only give some reference to 4PL's development but also play a guiding role for resource integration of logistics network from the perspective of time and economic cost. Certainly, the situation will become more complicated and cumbersome in the actual operation process so some further systematic research and exploration are needed in the future. The cooperation of logistics service providers is bound to involve interests distribution problems. However, the thesis fails to do research on this section, which is the premise and key factor of 4PL's integrating resources and is worth further research. In the resources optimization allocation problem, the thesis assumes that cost and time are all known but fails to consider additional time and cost caused by some emergencies and additional request of some large package. So, the model needs to be strengthened and improved into a model which is closer to real situation and real operating procedures.

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