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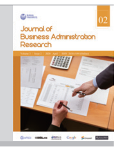

ARTICLE

Study on Task Assignment of Two-stage Multi-service Capability Port Logistics Service Providers

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ARTICLE INFO

Article history
Received: 14 February 2020
Accepted: 20 February 2020
Published Online: 30 April 2020

Keywords:
Port logistics service supply chain
Multi-service capability provider
Provider evaluation
Task assignment

ABSTRACT

This paper mainly studies the problem of multi-task assignment of providers in port logistics service supply chain. As a core enterprise, port plays the role of logistics service integrator.With the continuous development of industrial integration, logistics service providers not only provide one kind of logistics service, but also develop into composite suppliers who capable of providing a variety of logistics services . This paper studies the task assignment problem of multi-service capability providers in the port logistics service supply chain. The two-stage logistics service provider task assignment model was built ,which is based on the mixed evaluation method (including MOORA and FMEA) and the multi-objective planning method. Eventually, the effectiveness of the model method was verified by combining with an example.

1. Introduction

In recent years, outsourcing services have become more and more popular, especially in the logistics service supply chain (LSSP), where the logistics service integrator (LSI) integrates the service capabilities of multiple functional logistics service providers (LSPs) to provide logistics services according to customer needs [1].

As the hub of a variety of transportation modes, the port is more complex in integrating logistics providers(that provides transportation, storage, handling, processing, distribution, customs clearance, freight forwarding, financial services and other services) [2]. It should not only consider the service cost and service time, but also strive to ensure that the customer are satisfied with the service. Integrator enterprises begin to consider the involvement of service outsourcing providers to help improve the satisfaction of end customers. When providers are satisfied, they are more willing to help enterprises meet customer needs. Therefore, the integrator enterprise needs to combine the satisfaction of providers and customers to achieve the optimal service [3]. However, in practice, some logistics providers gather and integrate their functional logistics capabilities(such as transportation, warehousing, distribution, etc.) to realize the re-subcontracting of logistics, and they no longer only provide a single logistics capability, but become a composite logistics service provider that can provide a variety of logistics service capabilities [4].Compared with a single functional logistics service provider, the selection of functional providers who have multiple capabilities not only facilitates the coordinated operation of transportation services, but also reduces service costs. For example, in the case that the service price is the same,

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 DOI: https://doi.org/10.30564/jbar.v3i2.1703

one logistics service provider can provide warehousing, processing and distribution services, while another can only provide warehousing services.It is Conceivable that logistics service integrators prefer to choose the former. Therefore, when the port assigns tasks to its long - term logistics service providers, it should not be limited to its service quality and quotation, but put it into the logistics service process to consider the coordination and rationality of task assignment.

Due to the differences in the qualification, reputation, operation standardization and customer satisfaction level of provider enterprises, and the customer's needs vary widely. Moreover, the service efficiency and quality of different services are also different for providers who are of multi-service capabilities. Therefore, it is necessary to evaluate the providers of port logistics service before task assignment. Researchers usually use multi-criteria decision making (MCDM) to evaluate the performance of providers. However, with the deepening of research, the risk faced by providers is also a key factor in the evaluation. Consider, for example, that a provider provides a lower cost of service, but pays 50 percent more than normal in an unsTablesituation.That is, taking into account only overall performance and ignoring the risk of increased costs [5].

In this paper, two methods which including ratio analysis (MOORA) and failure mode and impact analysis (FMEA), are used to evaluate the performance and risk of port logistics service providers respectively. And then a multi-objective planning model was built to assign tasks to providers with multiple logistics service capabilities. The structure of other parts of this paper are as follows: in Section 2, there is a literature review of logistics service provider evaluation and task assignment. Problem definition are stated in Section 3. Section 4 is the construction of provider evaluation and task assignment model. Section 5 validates the model with an example. Finally, conclusiona are provided in Section 6.

2. Literature Review

The evaluation of logistics providers is the premise of task assignment of port logistics service supply chain, which is of great significance to the development of port logistics. Provider evaluation is a multi-criteria decision problem. Common methods include analytic hierarchy process (AHP), analytic network analysis (ANP), case-based reasoning (CBR), data envelopment analysis (DEA), fuzzy set theory, genetic algorithm (GA), mathematical programming, simple multi-attribute rating technique (SMART) and a combination of them [6].At present, more and more new methods are used in provider evaluation and selection, such as VIKOR method, ratio analysis (MOORA), fuzzy MULTIMOORA and so on. Based on DEA and ANP, Zou Yong [7] established a two-stage logistics provider selection model to select the best provider. Zheng Yuxing [8] used AHP method to obtain the weight of the evaluation index of port logistics service provider, so as to select the provider. However, these methods only consider the performance of the evaluation indicators but ignore the risks of these indicators. For example, although the price of a provider's service is very low, if the price fluctuates greatly over a period of time and is difficult to detect, the evaluation result will be less scientific. You Jianxin [9] and Liu Wei applied the improved FMEA method to the provider's risk assessment. Amir Arabsheybani [10] used the fuzzy multi-criteria decision model based on ratio analysis (MOORA) to evaluate the overall performance of providers of household evaporative coolers, and assessed the provider's risk using failure mode and impact analysis (FMEA).

In previous studies, provider selection was typically followed by task assignment for the selected provider. However, in the actual task execution, it is impossible for an integrator to establish a cooperative relationship with only one provider to complete a logistics task, but to select the best one or several qualified providers from multiple functional supply enterprises for simultaneous cooperation. A logistics service of the integrator can be assigned to one or more suppliers, and the task assignment of the whole service supply chain can be combined into hundreds of results. Therefore, the optimal combination of providers can be selected through reasonable task assignment. Zhang wei [11] established a multi-objective programming model with the objectives of lowest total service cost, shortest service time, maximum provider satisfaction and minimum penalty intensity, and then transformed the multi-objective programming into a single-objective programming by using constraint method and linear weighting method. Although the above studies consider that a task can be assigned to multiple providers, they all focus on the task assignment of the provider with a single logistics capability, but regardless of the task assignment of the composite provider with multiple service capabilities. By classifying functional providers, Zhang Jingyang [12] successively constructed provider task assignment models with single logistics capability and multiple logistics capabilities. In this study, logistics integrators dominated, and providers could only choose to execute assigned tasks. Nevertheless, in the port logistics service chain, when the provider's satisfaction with the assigned task is low, the cooperation is likely to be abandoned. Liu Weihua [13] studied the task assignment problem of

  DOI: https://doi.org/10.30564/jbar.v3i2.1703

logistics service providers with uncertain demand for multi-logistics service capabilities, and constructed a task assignment model based on conditions such as integrator cost minimization, provider satisfaction maximization and penalty intensity minimization, and maximum matching between different capabilities.

All of the above studies are separate studies of provider evaluation and task assignment. But in practice, the limitation of service capability, service cost and time efficiency should also be considered when evaluating providers. Xiaojian Hu [14] established the optimal selection strategy and order distribution strategy of the functional logistics service provider under mass customization, and verified the model by using the improved genetic algorithm. The results of numerical analysis show that the optimal selection strategy of providers and order allocation strategy affect each other, but the weight of evaluation index is not considered in this study. Hacer GünerGören [15] improved this defect by using the decision fuzzy decision testing and evaluation laboratory (DEMATEL) method to improve the accuracy of evaluation results. Korpela J [16] proposed that the assignment of supply chain tasks should take into not only cost, efficiency and satisfaction, but also the importance and risk of providers, and proposed a solution combining AHP and MIP methods.

To sum up, this paper considers the establishment of a two-stage task assignment model for port logistics providers. In the first stage, the comprehensive evaluation value of port logistics service providers was obtained by using MOORA method and FMEA method. When a provider is assigned a task, its importance can be obtained by using the ratio of the provider's comprehensive evaluation value to the sum of the comprehensive evaluation values of all the provides who actually participate in the task. In the second stage, the evaluation results of the first stage were taken as input parameters, and the task assignment model of multi-objective planning port logistics service provider was established with the goal of minimum total supply chain cost and maximum overall satisfaction, which including customer satisfaction and provider satisfaction.

3. Problem Definition

The supply chain of port logistics service is a continuous process, different links need different logistics service providers who is of different service capabilities to complete. At present, in order to win a larger market share, nodal enterprises have begun to extend their business to form an operation branch chain with the enterprise as the core. At this point, the service capacity of enterprises is enhanced, forming a composite provider with a variety of logistics capabilities.

When the port enterprises as the core of the supply chain enterprises, it first divides the logistics task after receiving the customer's logistics order, and then selects the appropriate provider from the current database for task assignment. In order to improve the scientificity and rationality of task assignment, it is necessary to evaluate the providers to obtain their importance. Finally, the importance is taken as the input to analyze the task assignment problem of single port, multi-task and multi-provider, so as to achieve the optimal distribution of logistics tasks with the minimum total supply chain cost and the highest overall satisfaction.

4. Methods and Model

The method and model flow chart are shown in Figure 2:

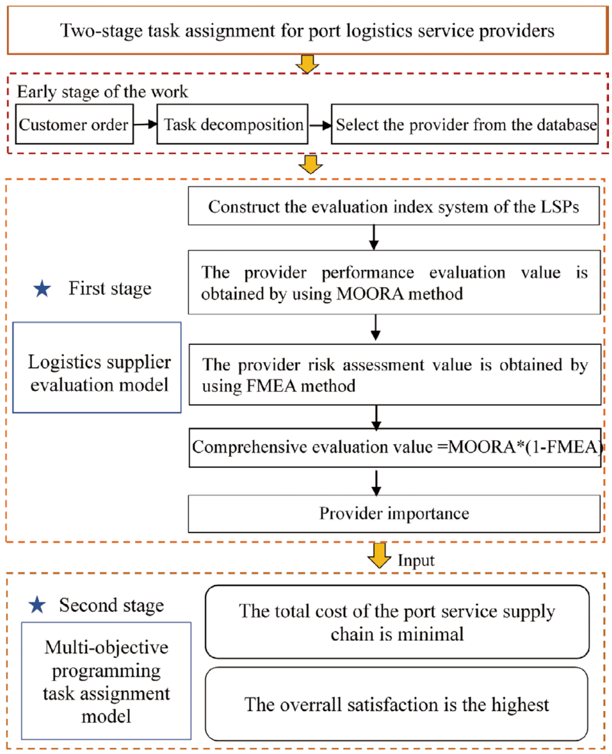

Figure 2. Method and model flow chart

4.1 Evaluation of Port Logistics Service Providers

(1) LSP performance was evaluated by fuzzy MOORA method

Ratio analysis multi-objective optimization (MOORA) is a multi-criteria decision-making method, which has great application potential for evaluating alternatives with multiple effective factors, while fuzzy MOORA method makes multi-criteria decision on qualitative conditions by using fuzzy language. The calculation steps of fuzzy MOORA method [17] are as follows:

Step 1. The decision matrix of *m* LSP and *n* evaluation indexes is expressed as:

$$\tilde{X}=\begin{bmatrix} \left[x_{11}^L, x_{11}^M, x_{11}^U\right] & \left[x_{12}^L, x_{12}^M, x_{12}^U\right] & \cdots & \left[x_{1n}^L, x_{1n}^M, x_{1n}^U\right] \\ \cdots & \cdots & \cdots & \cdots \\ \left[x_{m1}^L, x_{m1}^M, x_{m1}^U\right] & \left[x_{m2}^L, x_{m2}^M, x_{m2}^U\right] & \cdots & \left[x_{mn}^L, x_{mn}^M, x_{mn}^U\right] \end{bmatrix} \quad (1)$$

Step 2. Standardize the decision matrix $\tilde{X}$ in Step 1 through Eq.(2) - (5):

$$\tilde{r}_{ij}=\left(r_{ij}^L, r_{ij}^M, r_{ij}^U\right)=\left(\frac{x_{ij}^L}{x_{ij}^{L^*}}, \frac{x_{ij}^M}{x_{ij}^{M^*}}, \frac{x_{ij}^U}{x_{ij}^{U^*}}\right) \quad (2)$$

$$x_{ij}^{L^*}=\sqrt{\sum_{i=1}^{m}\left(x_{ij}^L\right)^2} \quad (3)$$

$$x_{ij}^{M^*}=\sqrt{\sum_{i=1}^{m}\left(x_{ij}^M\right)^2} \quad (4)$$

$$x_{ij}^{U^*}=\sqrt{\sum_{i=1}^{m}\left(x_{ij}^U\right)^2} \quad (5)$$

Step 3. Obtain the weight vector $\tilde{w}_j$ of experts' subjective evaluation of evaluation indicators by fuzzy AHP method [18]:

① Determine the hierarchical structure of the analytic hierarchy process according to the problem.

② The pairwise comparison matrix is formed by fuzzy evaluation of the indicators by experts, as shown in Table1.

③ Sum over all fuzzy Numbers.

④ Calculate the fuzzy number of each line and the ratio of Step 3 neutralization.

⑤ The weight of each index wj is obtained by the arithmetic mean value of each row.

⑥ Consistency checking.

Table 1. Fuzzy evaluation value of fuzzy AHP

Linguistic variables	Crisp Number	Triangular fuzzy number	Reciprocal triangular fuzzy number
Equal	1	(1,1,1)	(1,1,1)
Moderate	3	(1,1,3/2)	(2/3, 1,1)
Strong	5	(1,3/2,2)	(1/2,2/3,1)
Very strong	7	(3/2,2,5/2)	(2/5,1/2,2/3)
Extreme	9	(2,5/2,3)	(1/3,2/5,1/2)

Step 4. The weighted normalized decision matrix is obtained by multiplying the criteria by the weight *w*.

$$\tilde{v}_{ij}=\left(v_{ij}^L, v_{ij}^M, v_{ij}^U\right) \quad (6)$$

Step 5. The evaluation value of each LSP is obtained based on the ratio system.

$$\tilde{y}_i=\sum_{j=1}^{g}\tilde{v}_{ij}-\sum_{j=g+1}^{n}\tilde{v}_{ij} \quad (7)$$

where, *g* and *n-g* represent the number of benefit-type indicators and cost-type indicators, respectively. The higher $\tilde{y}_i$ is, the higher the evaluation of the corresponding LSP is.

Step 6. The normalized fuzzy performance value is converted to the non-fuzzy BPN value by the central method (COA).

$$BPN_i\left(\tilde{y}_i\right)=\frac{\left(y_i^U-y_i^L\right)+\left(y_i^M-y_i^L\right)}{3}+y_i^L \quad (8)$$

where, $\tilde{y}_i=\left(y_i^L, y_i^M, y_i^U\right)$.

(2) Evaluate LSP risk by fuzzy FMEA method

Failure mode and impact analysis (FMEA) which is an analytical method is used to determine the potential failure or risk of a product or system. The traditional FMEA method is to score the importance degree (S), occurrence degree (O) and difficulty degree (D) of the risk by the evaluator, then multiply the three and represent by RPN. The greater RPN is, the greater the risk of the corresponding failure mode is. However, the traditional FMEA method has many defects. This paper uses an improved method to calculate the risk value [17], and the calculation is as follows:

$$RPN_i=\left(\frac{(L-1)}{99}\right)^{ep}*100 \quad (9)$$

where, $L=S*O$, $ep=-0.1*D+1.55$.

The evaluation steps of FMEA method are as follows:

① The indexes of providers who were evaluated by historical data.

② Alculate the risk value of each provider by using Eq. (1) - (7).

(3) Calculate the comprehensive evaluation value

Performance value expresses the evaluation of LSP performance, while risk value expresses the evaluation of LSP risks.The comprehensive evaluation value of the ith

DOI: https://doi.org/10.30564/jbar.v3i2.1703

LSP can be expressed as:

$$P_i = BPN_i\left(y_i\right)\times\left(1-RPN_i\right) \tag{10}$$

Then the importance of the *i*th LSP is:

$$\beta_i = \frac{P_i}{\sum_{i=1}^{m} P_i} \tag{11}$$

4.2 Build a Multi-objective Task Assignment Model

(1) Model describes

This model is used to solve the task assignment problem of multi-logistics capability providers.The logistics service integrator (LSI) breaks the logistics service into a sub-task by type and then assigns the task to the logistics service provider (LSP).Customer satisfaction is one of the service objectives of the supply chain. In addition, when LSP is not satisfied with the tasks assigned to it, it will have a negative attitude towards the tasks assigned to it, which will cause instability of the supply chain. Therefore, LSP's satisfaction needs to be considered. The purpose of this model is to achieve optimal task assignment for LSP with the goal of minimum total supply chain cost and maximum overall satisfaction.

(2) Model assumes

① A service may be assigned to one or more LSP, and a LSP may provide one or more logistics services.

② The port is LSI, and LSPs are subject to its distribution.

③ The services are conducted in sequence.

④ There is no damage or shortage of goods.

(3) Meaning of model index/parameters/decision variable

The meanings of model index/parameters/decision variable are shown in Table 2. In the table, logistics service providers are represented by LSP and ports are represented by LSI.

Table 2. Meaning of model index/parameters/decision variable

Index/ Parameters/ Decision variable	Meaning
S	The number of service types provided by the port logistics service integrator to the customer, S≥1
N	Number of LSPs, N ＞ 1
K	Number of customers where goods are received
s	Index number of type of service (or task), $s\in\{1,2,...,S\}$
i, j	Index number of LSPs, $i, j\in\{1,2,...,N\}$
k	Index number destination customer
W	Total amount of goods
a_i	The order in which the services are provided by the *i*th LSP, $a_i\in\{1,2,...,S\}$
m	The LSP's index number that provides the end-to-end logistics service, $m\in\{m \mid a_m = S\}$
$\left[\theta_{is}^-, \theta_{is}^+\right]$	Capability interval of LSP *i* for the service in item *s*
$\theta_{is}^{\max}$	Maximum capacity of LSP *i* for the service in item *s*
θ_k	The quantity of goods required at the place of receipt *k*
β_{is}	Importance for the service in item s LSP i (which obtained from the previous stage)
l_{ij}	The distance between LSP *i* and the next LSP *j*, $j\in\{j \mid a_j = a_i + 1\}$
$l_{mk}^{'}$	Distance between end LSP *m* and customer *k*
$\left[t_{is}^-, t_{is}^+\right]$	The time interval in which LSP *i* could provide the service in ite*m* s
$\left[tc_k^-, tc_k^+\right]$	The time interval for the final completion of the service requested by customer *k*
x_{is}	The proportion of the total number of tasks assigned by LSP *i* to provide services under the service in item *s*
λ_{is}	If LSP*i* is assigned the task of the service in item *s*, that is $x_{is}>0$, $\lambda_{is}=1$；otherwise $\lambda_{is}=0$
r_{ij}	If there is a connection between LSP *i* and LSP *j*, then $r_{ij}=1$； otherwise $r_{ij}=0$
$r_{mk}^{'}$	If there is a connection between LSP *m* and customer *k*, then $r_{mk}^{'}$=1, otherwise $r_{mk}^{'}=0$
d_{is}^0	The initial satisfaction of LSP *i* with the assigned service in item *s*
d_{is}	The final satisfaction of LSP *i* with the assigned service in item s
$\tilde{d}$	The total satisfaction of all LSPs for all logistics services
tE_k	The most satisfactory time point for the delivery of goods to customer *k*
te_{is}	The point in time at which LSP *i* completes the service in item s(before the goods are transferred to LSP *j*)
ta_{ij}	The time point at which LSP *i* transfers the goods to LSP *j*, $j=\{j \mid r_{ij}=1\}$
ta_i	The time at which the goods arrive at LSP *i*
$ta_{mk}^{'}$	The time point at which LSP *m* transfers the goods to customer *k*, $m=\{m \mid r_{mk}^{'}=1\}$
ta_k	The time when the goods arrive at customer *k*

tw_i	The time when the goods wait to be served at LSP i(The short storage time when the goods arrive earlier than the earliest start time t_{is}^-)
$c1_k$	Unit waiting cost for goods to arrive at customer before tc_k^-
$c2_k$	Unit delay cost of goods arriving at customer after tc_k^+
$CS_{is}\left(x_{is}\right)$	The cost function of the service cost ,which is the cost of service in item s provided by LSP i
$CT_{ij}\left(x_{is},l_{ij}\right)$	The cost function of transfer cost of goods from LSPi to LSP j
$CH_{is}\left(x_{is},tw_i\right)$	The cost function of LSP i for the short-term storage cost of the goods
$CT_{mk}^{'}\left(x_{ms},l_{mk}^{'}\right)$	The transfer cost function of goods from LSPi to customer k
$CF_{mk}\left(ta_k^{'},x_{ms}\right)$	The penalty cost function that provider m failed to deliver to customer k within the time frame $\left[tc_k^-,tc_k^+\right]$
$TS_{is}\left(x_{is}\right)$	The time function of the time required for LSP i to provide the service in item s
$TT_{ij}\left(x_{is},l_{ij}\right)$	The time function that is required for the transfer of goods from LSPi to LSPj
$TT_{mk}^{'}\left(x_{ms},l_{mr}^{'}\right)$	The time function that is required for the transfer of goods from LSPm to customer k
$E_{mk}\left(ta_k^{'}\right)$	The satisfaction function of customer k's satisfaction with the delivery time of m

(4) Model building

The objective function and constraints are as follows:

$$\min Z=\sum_{i=1}^{N}\sum_{s=1}^{S}\lambda_{is}\left(CS_{is}+CH_{is}\right)+\sum_{i=1}^{N}\sum_{j=1}^{N}r_{ij}CT_{ij}+\sum_{m}\sum_{k=1}^{K}r_{mk}^{'}\left(CT_{mk}^{'}+CF_{mk}\right) \tag{11}$$

$$\max M=\tilde{d}+\sum_{m}\sum_{k=1}^{K}E_{mk}/K \tag{12}$$

s.t.

$$\sum_{i=1}^{N}\lambda_{is}=1,s\in\{1,2,..,S\} \tag{13}$$

$$\sum_{j=1}^{N}r_{ij}=1,\forall i\in\{1,2,...,N\} \tag{14}$$

$$0\le x_{is}W\le\theta_{is}^{\max},\forall i\in\{1,2,...,N\} \tag{15}$$

$$ta_i+TS_{is}\le t_{is}^+,\forall i\in\{i\mid\lambda_{is}=1\} \tag{16}$$

$$\beta_{is}=\frac{P_{is}}{\sum_{i=1}^{m}\lambda_{is}P_{is}} \tag{17}$$

$$\sum_{i=1}^{N}\beta_{is}=1,s\in\{1,2,...,S\} \tag{18}$$

$$tw_i=\max\left\{0,t_{is}^- - ta_i\right\},i\in\{i\mid\lambda_{is}=1\} \tag{19}$$

$$te_{js}=\lambda_{js}\left(\max\left\{\max_j\left\{ta_{ij}\right\},t_{js}^-\right\}+TS_{js}\right),i\in\{1,2,...,N\},\ j\in\{j\mid r_{ij}=1\} \tag{20}$$

$$ta_{ij}=te_{is}+TT_{ij},i\in\{1,2,...,N\},j\in\{j\mid r_{ij}=1\} \tag{21}$$

$$CF_{mk}\left(ta_k^{'},x_{ms}\right)=\begin{cases}c1_k\,x_{ms}W\left(tc_k^- - ta_k^{'}\right), & 0<ta_k^{'}<tc_k^-\\ 0, & tc_k^-\le ta_k^{'}\le tc_k^+\\ c2_k\,x_{ms}W\left(ta_k^{'}-tc_k^+\right), & tc_k^+<ta_k^{'}\end{cases} \tag{22}$$

$$d_{is}=\begin{cases}\dfrac{\theta_{is}^+}{x_{is}W}d_{is}^0, & \theta_{is}^+<x_{is}W\le\theta_{is}^{\max}\\ d_{is}^0+\dfrac{x_{is}W-\theta_{is}^-}{\theta_{is}^+-\theta_{is}^-}\left(1-d_{is}^0\right), & \theta_{is}^-\le x_{is}W\le\theta_{is}^+,i\in\{1,2,...,N\}\\ \dfrac{x_{is}W}{\theta_{is}^-}d_{is}^0, & 0\le x_{is}W<\theta_{is}^-\end{cases} \tag{23}$$

$$\tilde{d}=\sum_{i=1}^{N}\sum_{s=1}^{S}\beta_{is}d_{is} \tag{24}$$

$$E_{mk}\left(ta_k^{'}\right)=\begin{cases}\left[1+\dfrac{\left(ta_k^{'}-tE_K\right)^2}{tE_K}\right]^{-1}, & tc_k^-\le ta_k^{'}\le tc_k^+\\ 0,\text{Others}\end{cases} \tag{25}$$

Objective function (11) represents the minimum total cost of the port logistics service supply chain, while objective function (12) represents the highest total satisfaction of providers and customers. Constraint (13) and (14) indicate that the port logistics service provider must complete logistics services for all goods. Constraint (15) limits the

DOI: https://doi.org/10.30564/jbar.v3i2.1703

amount of goods allocated to the ith LSP to no more than its maximum service capacity. Constraint (16) requires that the ith LSP complete the task within the time interval during which the service is available. Equation (17) is the calculation of importance.In constraint (18), the sum of the importance of the LSP who providing the same service is 1. Constraint (19) represents the time for goods to wait for service at the ith LSP. Equation (20) represents the time point at which the jth LSP completes the service task of item s. Equation (21) is the point in time at which the goods are transferred from i to j. Equation (22) represents the penalty cost for failure to deliver within the time frame required by the customer. Equation (23) represents LSP's satisfaction with assigned tasks, and equation (24) represents the total satisfaction of all suppliers for all logistics services. Customer satisfaction with delivery time is expressed in equation (25).

(5) Solution method of model

The above model belongs to the multi-objective programming model and aims to minimize the total cost and maximize the overall satisfaction.In this paper, the objective function (11) is transformed into a constraint condition by using the constraint method, so that the multi-objective function is transformed into a single-objective function. The specific steps are as follows:

Without considering the objective function (12), the optimal solution Z* is obtained by solving the single-objective programming model with the minimum total service cost as the objective.When the objective function (11) is transformed into a constraint condition (26), the multi-objective programming problem is transformed into a single-objective programming problem to obtain the maximum overall satisfaction.

$$Z \le \left(1+\delta\right) Z^{*} \tag{26}$$

where, δ is a relatively small integer, which is called "relational cost coefficient". For example, when δ=10%, it can be understood that in order to establish a good cooperative relationship with LSPs, the LSI is willing to bear the "relationship cost" 10% higher than the minimum cost, and thinks that this investment can get greater returns in the future.

5. Case Study and Results

5.1 Case Description

There is a batch of 100t of goods in port A that needs to be transported to the factories of two customers in city B, B1 and B2. The demand for B1 and B2 is 40t and 60t respectively. The goods need to be processed simply and transported by sea and land. As shown in Figure4, the goods start from port A and arrive at port C, which is closer to B, and then are delivered to the customer's factory B1 and B2.

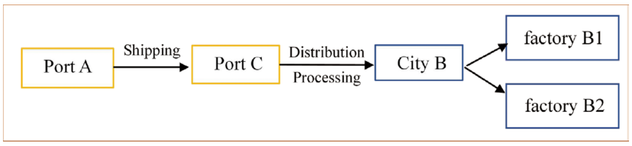

Figure 4. Schematic diagram of a port logistics transportation service

After being screened by the provider database, There are 3, 1, 3 and 3 logistics service providers respectively providing shipping services, port services, simple processing services and distribution services in the whole service supply chain, as shown in Table3 (there S_i represents the ith LSP). The LSPs information of each service is shown in Table3-6, the customer information of the place where the goods are received is shown in Table7, and Table8 represents the distance between SLPs and SLPs and the customer.

Table 3. The types of services that the port LSPs can provide in the service supply chain

Service item type	S1	S2	S3	S4	S5	S6	S7	Number of LSPs
Shipping	√	√	√					3
Port service				√				1
Processing		√			√	√		3
Distribution			√			√	√	3

Table 4. Shipping and port service provider information

Index	Shipping service SLPs			Port service SLPs
	S1	S2	S3	S4
$\left[\theta_{is}^{-},\theta_{is}^{+}\right]$	[20,50]	[30,120]	[30,70]	[50,200]
$\theta_{is}^{\max}$	60	150	100	300
$\left[t_{is}^{-},t_{is}^{+}\right]$	[0,10]	[0,7]	[0,9]	[3,10]
d_{is}^{0}	0.5	0.6	0.5	0.8
$CS_{is}\left(x_{is}\right)$	$1500+200x_{11}W$	$2000+450x_{21}W$	$1000+270x_{31}W$	$200+150x_{42}W$
$CH_{is}\left(x_{is},tw_{i}\right)$	0	0	0	$\left(100+300x_{i1}W\right)tw_{4}$
$CT_{ij}\left(x_{is},l_{ij}\right)$	0	0	0	$100+20x_{j3}l_{4j}W$
$TS_{is}\left(x_{is}\right)$	3.2	2.0	2.5	$0.05+0.03x_{42}W$
$TT_{ij}\left(x_{is},l_{is}\right)$	0	0	0	$0.03+0.01l_{4j}$

DOI: https://doi.org/10.30564/jbar.v3i2.1703

Table 5. Processing service provider information

Index	Processing sercice SLPs		
	S2	S5	S6
$\left[\theta_{is}^{-},\theta_{is}^{+}\right]$	[40,80]	[50,80]	[30,60]
$\theta_{is}^{\max}$	120	100	80
$\left[t_{is}^{-},t_{is}^{+}\right]$	[6,15]	[2,15]	[3,12]
d_{is}^{0}	0.5	0.7	0.6
$CS_{is}\left(x_{is}\right)$	$250{+}155x_{23}W$	$300{+}150x_{53}W$	$200{+}130x_{63}W$
$CH_{is}\left(x_{is},tw_{i}\right)$	$\left(130{+}42x_{23}W\right)tw_{2}$	$\left(150{+}40x_{53}W\right)tw_{5}$	$\left(100{+}30x_{63}W\right)tw_{6}$
$CT_{ij}\left(x_{is},l_{ij}\right)$	$70+18x_{23}l_{2j}W$	$70+20x_{53}l_{5j}W$	$65+14x_{63}l_{6j}W$
$TS_{is}\left(x_{is}\right)$	$0.1+0.03x_{23}W$	$0.1+0.04x_{53}W$	$0.08+0.02x_{63}W$
$TT_{ij}(x_{is},l_{is})$	$0.02+0.01l_{2j}$	$0.02+0.015l_{5j}$	$0.02+0.012l_{6j}$

Table 6. Distribution service provider information

Index	Distribution service SLPs		
	S3	S6	S7
$\left[\theta_{is}^{-},\theta_{is}^{+}\right]$	[50,80]	[40,100]	[50,100]
$\theta_{is}^{\max}$	120	120	120
$\left[t_{is}^{-},t_{is}^{+}\right]$	[4,20]	[2,22]	[0,15]
d_{is}^{0}	0.6	0.7	0.7
$CS_{is}\left(x_{is}\right)$	$300{+}10x_{34}W$	$200{+}12x_{64}W$	$150{+}16x_{74}W$
$CH_{is}\left(x_{is},tw_{i}\right)$	$\left(90{+}22x_{34}W\right)tw_{3}$	$\left(100{+}14x_{64}W\right)tw_{6}$	$\left(150{+}20x_{74}W\right)tw_{7}$
$CT_{mk}^{'}(x_{is},l_{ml}^{'})$	0	0	0
$TT_{mk}^{'}\left(x_{ms},l_{mr}^{'}\right)$	$0.015+0.015l_{3k}^{'}$	$0.015+0.001l_{6k}^{'}$	$0.02+0.001l_{7k}^{'}$

Table 7. Customer information sheet of the place where the goods were received

Index	θ_k	β_k	$\left[tc_{k}^{-},tc_{k}^{+}\right]$	$c1_k$	$c2_k$	tE_k
1	40	0.5	[18,28]	0.8	1.2	18
2	60	0.5	[15,19]	0.7	1.4	15

Table 8. Distance between SLPs, SLPs and customers

SLP/ Customer S4		**Port**	**Processing**			**Distribution**			**Customer**	
		S2	**S5**	**S6**	**S3**	**S6**	**S7**	**K1**	**K2**	
Port	**S4**		4.0	3.5	3.0					
Process-ing	**S2**					2.0	2.3	1.5		
	S5					3.1	1.8	2.0		
	S6					2.8	0	3.5		
Distribu-tion	**S3**								7.5	8.3
	S6								8.8	6.2
	S7								5.2	7.0

5.2 Providers' Importance Calculation

In the form of questionnaires, the provider evaluation index system of the port logistics service supply chain is constructed from three aspects which including economy, resources and society, as shown in Table 9, and the evaluation index is fuzzy evaluated through Table 10.

Table 9. Evaluation index system of port logistics service providers

	First-class index	Second-class index
Evaluation of port logistics service providers (A)	Economic(B_1)	Operating conditions(C1)
		Cost(C2)
		Service(C3)
		Management(C4)
	Resources(B_2)	Pollution(C5)
		Technology(C6)
	Social(B_3)	Cooperation and sharing(C7)
		Quality of employees(C8)
		Enterprise image(C9)

Table10. The corresponding trigonometric fuzzy value of the language variable of the evaluation index

Linguistic variable	**Level**	**Triangular fuzzy value**
Very low(VL)	1	(1, 1, 3)
Low(L)	2-4	(1, 3, 5)
Medium(M)	5-6	(3, 5, 7)
High(H)	7-9	(5, 7, 9)
Very high(VH)	10	(7, 9, 9)

In order to facilitate the calculation, shipping service is taken as an example for calculation. The evaluation results of experts are shown in Table13.

Table 11. Evaluation results of shipping service providers

LSP / Indexc	**S1**	**S2**	**S3**
C1	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)
C2	(5, 7, 9)	(5, 7, 9)	(1, 3, 5)
C3	(7, 9, 9)	(5, 7, 9)	(3, 5, 7)
C4	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)
C5	(1, 3, 5)	(3, 5, 7)	(1, 3, 5)
C6	(5, 7, 9)	(7, 9, 9)	(3, 5, 7)
C7	(3, 5, 7)	(5, 7, 9)	(7, 9, 9)
C8	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)
C9	(5, 7, 9)	(3, 5, 7)	(1, 3, 5)

The fuzzy AHP method in Step 3 of MOORA method is used to obtain the weight vector $\tilde{w}_j$ which is experts' subjective evaluation of the evaluation index,and the results are shown in Table 12. Then, as shown in Table 13,

 DOI: https://doi.org/10.30564/jbar.v3i2.1703

Table 12. Evaluation index weight calculation

A-B	B_1		B_2		B_3		Weight	Final weight
B_1	(1,1,1)		(3/2,2,5/2)		(1,3/2,2)		(0.500,0.532,0.523)	(0.500,0.532,0.523)
B_2	(2/5,1/2,2/3)		(1,1,1)		(2/3, 1,1)		(0.211,0.217,0.191)	(0.211,0.217,0.191)
B_3	(1/2,2/3,1)		(1,1,3/2)		(1,1,1)		(0.289,0.251,0.286)	(0.289,0.251,0.286)
B_1-C	C_1	C_2		C_3		C_4	Weight	——
C_1	(1,1,1)	(1/2,2/3,1)		(1/2,2/3,1)		(1,1,3/2)	(0.214,0.202,0.222)	(0.107,0.107,0.116)
C_2	(1,3/2,2)	(1,1,1)		(2/3, 1,1)		(1,1,3/2)	(0.274,0.273,0.264)	(0.137,0.145,0.138)
C_3	(1,3/2,2)	(1,1,3/2)		(1,1,1)		(1,3/2,2)	(0.303,0.302,0.314)	(0.152,0.161,0.164)
C_4	(2/3, 1,1)	(2/3, 1,1)		(1/2,2/3,1)		(1,1,1)	(0.208,0.223,0.200)	(0.104,0.119,0.105)
B_2-C	C_5			C_6			Weight	——
C_5	(1,1,1)			(1,1,3/2)			(0.551,0.500,0.551)	(0.116,0.109,0.105)
C_6	(2/3, 1,1)			(1,1,1)			(0.449,0.500,0.449)	(0.095,0.109,0.086)
B_3-C	C_7		C_8		C_9		Weight	——
C_7	(1,1,1)		(3/2,2,5/2)		(1,1,3/2)		(0.492,0.440,0.465)	(0.781,0.691,0.751)
C_8	(2/5,1/2,2/3)		(1,1,1)		(1/2,2/3,1)		(0.180,0.180,0.196)	(0.469,0.431,0.482)
C_9	(2/3, 1,1)		(1,3/2,2)		(1,1,1)		(0.328,0.381,0.339)	(0.617,0.632,0.625)

the weighted normalized decision matrix of maritime service providers is obtained by combining Table 11.

Table 13. Weighted normalized decision matrix

Indexc \ LSP	S1	S2	S3
C1	(0.022, 0.048, 0.106)	(0.037, 0.068, 0.136)	(0.037, 0.068, 0.136)
C2	(0.050, 0.098, 0.174)	(0.050, 0.086, 0.143)	(0.010, 0.037, 0.080)
C3	(0.073, 0.116, 0.162)	(0.052, 0.090, 0.162)	(0.031, 0.065, 0.126)
C4	(0.033, 0.068, 0.109)	(0.033, 0.068, 0.109)	(0.033, 0.068, 0.109)
C5	(0.012, 0.050, 0.159)	(0.035, 0.083, 0.222)	(0.012, 0.050, 0.159)
C6	(0.033, 0.061, 0.085)	(0.046, 0.078, 0.085)	(0.020, 0.044, 0.066)
C7	(0.161, 0.278, 0.577)	(0.269, 0.389, 0.742)	(0.376, 0.500, 0.742)
C8	(0.175, 0.303, 0.662)	(0.105, 0.217, 0.515)	(0.105, 0.217, 0.515)
C9	(0.248, 0.486, 0.951)	(0.149, 0.374, 0.740c)	(0.050, 0.208, 0.528)

According to Eq.(1)-(7), the performance value of each SLP is calculated through the implementation of the the MOORA method, and the clear value is obtained according to equation (8), as shown in Table 14.

Table 14. Evaluation results of shipping service providers

SLP	Fuzzy performance value	Non-fuzzy performance values	Rank
S1	(0.684, 1.212, 2.318)	1.405	1
S2	(0.606, 1.088, 2.122)	1.272	2
S3	(0.630, 1.082, 1.983)	1.232	3

Similarly, the evaluation results of other service providers (as the optional port service only has S4, it is not evaluated) are shown in Table15.

Table 15. Other LSP performance evaluation results were obtained by using MOORA method

Service type	SLP	Fuzzy performance value	Non-fuzzy performance values
Processing	S2	(0.505,0.936,1.949)	1.431
	S5	(0.713,1.250,2.331)	1.130
	S6	(0.684,1.206,2.355)	1.415
Distribution	S3	(0.610,1.054,1.926)	1.367
	S6	(0.657,1.137,2.219)	1.338
	S7	(0.668,1.187,2.217)	1.197

The FMEA method was implemented with shipping service as an example. Experts evaluated the S, O and D with risks in all SLPs evaluation indicators according to the questionnaire results. The risk indicators were described as shown in Table 16.

Table 16. Risk indicators description

Module	Index	Potential risk
Economic (B1)	C1	It mainly refers to financial risks, such as debt service, profitability, reduced operational and reduced development capacity
	C2	It mainly refers to the price fluctuation, the cost is higher than the market price
	C3	Delivery of goods with low accuracy and completeness
	C4	Poor management and coordination skills

Resources (B2)	C5	Carbon emission overshoot
	C6	Low ownership of technical facilities and equipment or low application rate in this service
Social (B3)	C7	The degree of information sharing is low
	C8	Staff professional quality is low and education level is not high
	C9	Poor customer evaluation

RPN of each SLP is obtained from equation (9), which is multiplied by the weight of each indicator to obtain the comprehensive RPN value. Finally, according to equations (10) and Table 14 and Table 15, the comprehensive evaluation value as shown in Table 17 can be obtained.

Table 17. Assessment results of all LSPs

Service type (*s*)	**SLP(*i*)**	**RPN value**	**Comprehensive evaluation value (P_{is})**
Shipping	S1	0.133	1.218
	S2	0.247	0.958
	S3	0.339	0.814
Port service	S4	--	--
Processing	S2	0.119	1.429
	S5	0.523	1.124
	S6	0.259	1.411
Distribution	S3	0.139	0.801
	S6	0.247	1.007
	S7	0.614	1.038

5.3 The Multi-objective Task Assignment Model is Used to Solve the Problem

Tasks were assigned to logistics service providers according to the model, and the evaluation results obtained in Section 4.2 were represented by P_{is}, which was input into the model to obtain the importance of the supplier. The model was solved by combining with an example. In this paper, Lingo12.0 programming was used to solve the problem [19].

(1) Considering only the objective function where the service cost is minimal, the minimum value of the total logistics service cost is Z^*=75793.8. Here we take δ =1%, and convert Eq.(11) into the constraint condition Z≤ (1+1%) ×Z^*, that is, Z≤76551.6.

(2) Under the premise of satisfying the constraint (13) - (16), the single objective program with the greatest overall satisfaction is obtained. The results of task assignment are as follows:

x_{11}=58%, x_{21}=15%, x_{31}=27%, x_{42} =100%, x_{23} =40%, x_{63} =60%, x_{64} =60%, x_{74} =40%. Overall satisfaction M=0.581, Total cost Z=76082.2.

(3) Results contrast

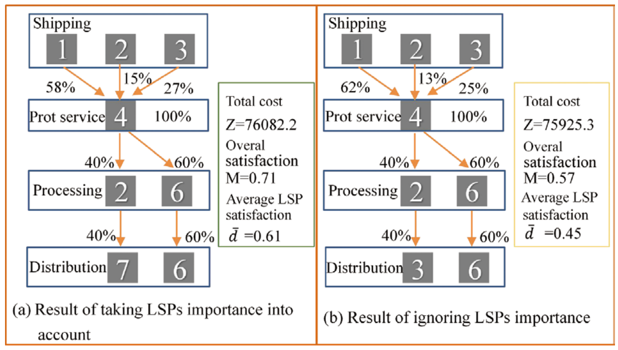

Figure 5. Result of considering importance and ignoring importance

As shown in Figure 5, when the importance of providers is not considered, the overall satisfaction is 0.57, and the average provider satisfaction is 0.45. On the other hand, when considering the importance of providers, although the total cost increased by 156.9, the overall satisfaction reached 0.71, and the satisfaction of providers also improved.

6. Conclusion

This paper mainly studies the task assignment of port logistics service providers with multi-service capabilities. In addition, the concept of provider's importance is also introduced. The calculation results show that the selection of multi-service capability providers can reduce the cost. For example, the selection of processing and distribution services from provider S6 can effectively reduce the transfer cost and transfer time, thus improve the efficiency of the supply chain. Furthermore, considering the importance of providers increase the overall satisfaction although it increases the cost slightly, which is of great significance to maintain the stability of the supply chain.

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  DOI: https://doi.org/10.30564/jbar.v3i2.1703

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