Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 15, No. 1, 2024

Optimal carrier Selection Based on Reliability Under Delivery Spoilage and Cost Constraint

Mengmeng Yuan

School of Modern Posts, Chongqing University of Posts and Telecommunications, Chongqing 400065, China

Abstract: In a highly competitive market environment, outsourcing of logistics service is one of the most significant strategies for enterprises to enhance competitiveness. However, how to construct an efficient and reliable logistics network by selecting suitable logistics carriers is a complex but important practical issue. In general, there are multiple carriers to provide freight service along each route of a logistics network. Moreover, the transportation capacity of each carrier has multiple states due to various factors, which can be portrayed by a capacity probability distribution. In addition, delivery spoilage and cost constraint are the key indicators affecting carrier selection. Therefore, this paper studies the logistics carrier selection problem from the perspective of multi-state network reliability under delivery spoilage and cost constraint, and apply the minimal path (MP) method to solve the problem. The practicality of the algorithm is verified by example analysis.

Keywords: Logistics network, reliability, carrier selection, delivery spoilage, delivery cost.

1. Introduction

With the development of globalization and the intensification of market competition, many enterprises tend to outsource logistics services to carriers. The carrier selection has a direct impact on the enterprise's profit and service level. As a result, enterprises with logistics outsourcing demand face the problem of how to determine the optimal carrier selection. Speaking generally, the decision criteria of carriers can be categorized into two types: cost and service[1]. Mohammaditabar and Teimoury[2] constructed an optimal carrier selection model that simultaneously achieves the objectives of maximizing total profit and minimizing inventory and delivery cost. In order to address the overall decision problem of carrier selection and supplier selection, Meixell and Norbis[3] developed a multi-objective optimization model aiming to minimize cost, transportation time, and security risks. It is worth noting that the above studies assume that the carrier's transport capacity is determined.

However, based on the fact that each carrier has probabilistically distributed multiple available capacities, Lin and Yeh[4] first studied the carrier selection problem based on network reliability and defined network reliability as the probability that the network is able to successfully transport d units of the commodity from the supply origin to the demand origin. Based on this, Lin and Yeh[5] studied the carrier selection problem based on multi-commodity network reliability, where multi-commodity network reliability was defined as the probability that a logistics network can satisfy customer demand for multiple commodity. It is worth noting that the models of Lin and Yeh[4-5] only consider the stochastic capacity of carriers without considering the delivery spoilage and cost constraint problems.

From the perspective of supply chain management, the delivery process is an important part of the supply chain. However, some commodity may deteriorate during the delivery process due to weather, crash etc. Under delivery spoilage, the quantity of intact commodity transported from the source to the sink by the logistics network may not be sufficient to meet the market demand. Therefore, some scholars have studied the reliability of logistics networks under delivery spoilage. Assuming that each minimal path is associated with a spoilage rate, Lin et al[6] proposed a strategy for distributing the commodity flow on each minimal path based on the fact that delivery spoilage causes the output flow to be smaller than the input flow, and defined the network reliability as the probability of being able to satisfy the market demand under delivery spoilage and budget constraint. Under the same assumptions, Lin et al[7] provided a new approach to assess the reliability of logistics distribution network with multiple suppliers and multiple markets. Lin et al[8] developed a model for assessing the reliability of the logistics distribution network with respect to three important factors in the logistics network: delivery, cost constraint, and the limited production capacity of the suppliers. Lin et al[9] proposed a multimodal intermodal network reliability assessment method and defined network reliability as the probability that the number of intact commodity transported to the destination by the network can meet the market demand under delivery spoilage and time constraint. In order to better characterize the relationship that exists among the minimal paths, Niu et al[10] investigated the problem of logistics distribution network reliability assessment under delivery spoilage and cost constraint based on associating a spoilage rate to each route. In addition, Niu et al[11] improved the computational efficiency of network reliability by introducing a method to remove repeated d-MP more efficiently. Huang et al[12] proposed a network reliability assessment method based on d-MP in order to deal with non-integer types of data efficiently.

A carrier potentially has multiple available capacities with a probability distribution. As a result, a logistics network is a typical multi-state logistics network. In a real logistics network, there are multiple carriers available to provide transportation services on each route, and each carrier has a capacity probability distribution. There are multiple capacity probability distributions on each route, and this capacity probability distribution indicates the transportation capacity of different carriers. Thus, a carrier selection indicates the logistics service level of the network. Based on this, this type of network is called a multi-distribution multi-state logistics network.

Therefore, this paper focuses on the optimal carrier selection problem based on network reliability under delivery spoilage and cost constraint. The network reliability under the delivery spoilage and cost constraint is defined as the probability that the number of intact commodity transported by the network from the source to multiple sinks can meet the demand under the condition that the total transportation cost does not exceed the given upper limit when there is delivery spoilage on each transportation route. For the carrier selection model based on network reliability, a model solution method is proposed based on MP. The validity of the algorithm is analyzed through arithmetic examples. It provides theoretical guidance for managers to determine the optimal carrier selection under the network reliability perspective.

2. Network Model and Problem Description

2.1. Network model

Denote by $Q\ (V, R)$ a logistics network with a single source point s and multiple sinks t_φ, where $\varphi = 1, 2, ..., T$. In $Q\ (V, R)$, V is the set of all nodes and R is the set of n routes, i.e., $R = \{r_i | 1 \le i \le n\}$. Assuming that there are z_i carriers to be selected for each route r_i, carrier e_{iu} denotes the uth carrier on r_i, where $u = 1, 2, ..., zi$. Carrier e_{iu} has M_{iu} capacity states, i.e., $0 = c_{iu}(1) < c_{iu}(2) < ... < c_{iu}(M_{iu})$, where $c_{iu}(h)$ ($h = 1, 2, ..., M_{iu}$) and $c_{iu}(M_{iu})$ are the hth capacity state and the maximum capacity state of e_{iu}, respectively. When a carrier e_{iu} is selected to provide transportation services for r_i, assuming $x_i = u$, a carrier selection can be represented as $X = (x_1, x_2, ..., x_n)$. Under the carrier selection X can be defined the corresponding spoilage pattern of the network $A(X) = (a_{1u}, a_{2u}, ..., a_{nu})$, the capacity probability distribution $B(X) = \{b_{1u}, b_{2u}, ..., b_{nu}\}$ and the transportation cost model $O(X) = (o_{1u}, o_{2u}, ..., o_{nu})$. The network model in this paper need to fulfill the following assumptions:

1. Flow in $Q\ (V, R)$ must satisfy the flow-conservation law.
2. The capacities of the various carriers are statistically independent.
3. Only one carrier provides service on each route.
4. Flow in $Q\ (V, R)$ is non-negative integer values.

2.2. Problem description

In a multi-distributed multi-state network, $X = (x_1, x_2, ..., x_n)$ denotes the designation of a carrier on each route to provide transportation services. Thus, given a carrier selection X, a multi-distribution multi-state network can be simplified to a multi-state network with a deterministic capacity probability distribution $B(X)$, a spoilage pattern $A(X)$, and cost pattern $O(X)$. Given a market demand vector D, the network reliability $R_{D,A(X),C}$ considering delivery spoilage and cost constraint under carrier selection X is the probability that a flow of intact commodity successfully transported from the source to multiple sinks can satisfy the demand vector D and the total cost does not exceed the cost constraint. Therefore, the problem of interest in this paper is to determine the optimal carrier choice in a multi-distributed multi-state network and to maximize the network reliability $R_{D,A(X),C}$ considering delivery spoilage and cost constraint. Given the market demand vector D, the model of carrier selection based on network reliability under delivery spoilage and cost constraint is as follows:

$$\text{Maximize } R_{D,A(X),C} \tag{1}$$

$$s.t.\ x_i = u,\ u \in \{1, 2, ..., z_i\};\ i = 1, 2, ..., n \tag{2}$$

Condition (1) represents the maximum network reliability corresponding to the optimal carrier selection. Condition (2) is designed to ensure that each route is served by only one carrier.

3. Network Reliability Calculation Under Delivery Spoilage and Cost Constraint

When given a carrier selection X, a multi-distributed multi-state network can be simplified to a multi-state network with a specific capacity probability distribution $B(X)$, spoilage pattern $A(X)$, and cost pattern $O(X)$. Therefore, this section investigates the problem of calculating the reliability of multi-state networks with consideration of delivery spoilage and cost constraint.

3.1. Flow direction conversion

Assuming that $p_{\varphi,j}$ is the jth minimal path connecting the source s to the sink t_φ, where $j = 1, 2, ..., m_\varphi$, then the vector $F = (f_{1,1}, \ldots, f_{1,m_1}, f_{2,m_2}, \ldots, f_{\varphi,1}, \ldots, f_{\varphi,m_T}, \ldots, f_{T,1}, \ldots, f_{T,m_T})$ denote the ideal flow vectors in the network, where $f_{\varphi,j}$ is the ideal commodity flow through $p_{\varphi,j}$ without considering the delivery spoilage. Given a market demand vector $D = (d_1, d_2, ..., d_T)$, where d_φ denotes the demand in market t_φ, the ideal flow vector F exactly satisfies the market demand vector D if and only if the following equation is satisfied.

$$\sum_{j=1}^{m_\varphi} f_{\varphi,j} = d_\varphi,\ \varphi = 1, 2, ..., T \tag{3}$$

Equation (3) indicates that, without considering delivery spoilage, the ideal commodity flow arriving at the destination t_φ is exactly equal to the market demand d_φ However, commodity may have spoilage during transportation due to weather or collisions, resulting in the quantity of intact commodity arriving at the sink may not meet the market demand. Based on the spoilage rate a_{iu} for each route, the delivery spoilage rate $a_{\varphi,j}$ for each $p_{\varphi,j}$ is:

$$a_{\varphi,j} = 1\text{-}\prod_{r_i \in p_{\varphi,j}} (1\text{-}a_{iu}) \tag{4}$$

$f_{\varphi,j} \times (1\text{-}a_{\varphi,j}) = f_{\varphi,j} \times \prod_{r_i \in p_{\varphi,j}} (1\text{-}a_{iu})$ is the perfect commodity flow through the $p_{\varphi,j}$. In order to ensure that the intact commodity flow transported to the destination t_φ is exactly equal to the market demand d_φ, the actual flow vector K is used to represent the set of actual commodity flows $k_{\varphi,j}$ that pass through the $p_{\varphi,j}$ under delivery spoilage. The following equation transforms the ideal commodity flow $f_{\varphi,j}$ into the actual commodity flow $k_{\varphi,j}$.

$$k_{\varphi,j} = \left\lceil f_{\varphi,j} / (1\text{-}a_{\varphi,j}) \right\rceil \tag{5}$$

3.2. Capacity vector

When $x_i = u$, $c_{ix_i}(M_{ix_i}) = c_{iu}(M_{iu})$ is the maximal capacity state on route r. Then the maximal capacity vector is $M_X = (c_{1x_1}(M_{1x_1}), c_{2x_2}(M_{2x_2}), \ldots, c_{nx_n}(M_{nx_n}))$. Denote by w the capacity consumed per unit of commodity flow, any actual flow vector K is feasible under the maximum capacity vector M_X as long as the following conditions are satisfied.

$$\left\lceil w \sum_{\varphi=1}^{T} \sum_{j: r_i \in p_{\varphi,j}} k_{\varphi,j} \right\rceil \le c_{ix_i}(M_{ix_i}),\ i = 1, 2, ..., n \tag{6}$$

$$\left\lceil w k_{\varphi,j} \right\rceil \le min\{c_{ix_i}(M_{ix_i}) | r_i \in p_{\varphi,j}\},\ j = 1, 2, ..., m \tag{7}$$

Condition (6) ensures that the capacity consumed by the actual commodity flow through route r_i does not exceed the maximum capacity of route r_i. Condition (7) ensures that the capacity consumed by the actual flow through $p_{\varphi,j}$ does not exceed the maximum capacity of $p_{\varphi,j}$. Theorem 1 shows that conditions (7) are redundant.

Theorem 1: Any actual flow vector K satisfying condition (6) satisfies condition (7).

Proof: Condition (6) leads to $\lceil wk_{\varphi,j} \rceil \le c_{ix_i}(M_{ix_i})$ for each i: $r_i \in p_{\varphi,j}$, which implies that $\lceil wk_{\varphi,j} \rceil \le min\{c_{ix_i}(M_{ix_i}) | r_i \in p_{\varphi,j}\}$.

Now introduce the capacity vector $Y = (y_1, y_2, ..., y_n)$ where y_i denotes the current capacity of r_i. Obviously, the range of values of y_i is $[c_{ix_i}(1), c_{ix_i}(M_{ix_i})]$. Any K is a feasible actual flow vector under the capacity vector Y if the following condition is satisfied.

$$\left\lceil w \sum_{\varphi=1}^{T} \sum_{j:r_i \in p_{\varphi,j}} k_{\varphi,j} \right\rceil \le y_i,\ i = 1, 2, ..., n \tag{8}$$

The constraint (8) means that the capacity occupied by the actual commodity flow through r_i cannot exceed the current capacity of r_i. For convenience, K_{M_X} and K_Y are introduced to denote the set of all feasible actual flow vectors satisfying the conditions (6) and (8), respectively.

3.3. Cost constraint

This paper focuses on transportation cost in the reliability assessment of logistics networks. The total transportation cost is derived by summing the transportation cost on each route, and the transportation cost on each route depends on the capacity consumed by the actual commodity flow through route r_i. Given cost constraint C, any K is said to satisfy the cost constraint C if it satisfies the following condition.

$$\sum_{i=1}^{n} \left(o_{iu} \times \left\lceil w \sum_{\varphi=1}^{T} \sum_{j:r_i \in p_{\varphi,j}} k_{\varphi,j} \right\rceil \right) \le C \tag{9}$$

Where o_{iu} is the unit transportation cost of r_i. The constraint (9) is that the total transportation cost in the network cannot exceed given cost constraint C.

Definition 1: A capacity vector Y satisfies $(D, A(X), C)$ if there exists an actual flow vector $K \in K_Y$.

3.4. Network reliability calculation

Given the market demand vector D and the carrier selection X, the network reliability $R_{D,A(X),C}$ is defined as the probability that the number of intact commodity that can be transported successfully from a single origin to multiple sinks can satisfy the demand vector D and that the total transportation cost does not exceed the cost constraint C under delivery spoilage and cost constraint. A network is considered to satisfy condition $(D, A(X), C)$ if there exists a feasible actual flow vector $K \in K_Y$ under the capacity vector Y that satisfies the cost constraint C. Therefore, $R_{D,A(X),C} = \Pr\{Y | Y$ satisfies condition $(D, A(X), C)\}$. For convenience, let $\Psi = \{ Y | Y$ satisfies condition $(D, A(X), C)\}$, then $R_{D,A(X),C} = \Pr(\Psi) = \sum_{Y \in \Psi} \Pr(Y)$, where $\Pr(Y) = \prod_{i=1}^{n} \Pr(y_i)$ is the probability of all capacity vectors Y that satisfy conditions $(D, A(X), C)$.

Based on the enumeration method to obtain all $Y \in \Psi$ and then sum up their probability values can get the network reliability $R_{D,A(X),C}$. However, the computational complexity of this method is high in the case of large network size. Therefore, this paper introduces the minimal capacity vector to reduce the computational complexity of network reliability and denotes the minimal capacity vector satisfying the condition $(D, A(X), C)$ by $(D, A(X), C)$-MCV.

Definition 2: $Y \le L$: $(y_1, y_2, ..., y_n) \le (l_1, l_2, ..., l_n)$, if and only if for each i it is consistent with $y_i \le l_i$.

Definition 3: $Y < L$: $(y_1, y_2, ..., y_n) < (l_1, l_2, ..., l_n)$, if and only if $Y \le L$ and there exists at least one y_i satisfying $y_i < l_i$.

Definition 4: A $(D, A(X), C)$-MCV is a capacity vector $Y \in \Psi$, that satisfies $L \notin \Psi$ for any $L < Y$.

Suppose there are q $(D, A(X), C)$-MCVs: $Y_1, Y_2, ..., Y_q$, then Ψ is the set of these vectors, i.e., $\Psi = \{\cup_{i=1}^{q} \{Y | Y \ge Y_i\}\}$. Therefore $R_{D,A(X),C} = \sum_{Y \in \Psi} \Pr(Y) = \Pr\{\cup_{i=1}^{q} \{Y | Y \ge Y_i\}\}$. In particular, if $\Psi = \emptyset$, then $R_{D,A(X),C} = 0$. $\Pr\{\cup_{i=1}^{q} \{Y | Y \ge Y_i\}\}$ can be computed by the Recursive Sum of Disjoint Product (RSDP) method.

The current problem is to determine all $(D, A(X), C)$-MCVs. Based on Definition 1 and Definition 4, if Y is a $(D, A(X), C)$-MCV, then this implies that there exists a feasible actual flow vector $K \in K_Y$ satisfying $(D, A(X), C)$ Therefore, the actual flow vector K can be converted to the corresponding capacity vector under the maximum capacity vector M_X by the following equation.

$$y_i = c_{ix_i}(h),\ c_{ix_i}(h\text{-}1) < \left\lceil w \sum_{\varphi=1}^{T} \sum_{j:r_i \in p_{\varphi,j}} k_{\varphi,j} \right\rceil \le c_{ix_i}(h) \tag{10}$$

Obviously, any Y that satisfies the condition $(D, A(X), C)$ is derived from $K \in K_{M_X}$ by the transformation of Eq. (10). Therefore, such a capacity vector Y is regarded as a candidate $(D, A(X), C)$-MCV. To further understand the relationship between candidate $(D, A(X), C)$-MCV and $(D, A(X), C)$-MCV Theorem 2 illustrates the relationship.

Theorem 2: If Y is a $(D, A(X), C)$-MCV, then there exists at least one feasible actual flow vector $K \in K_{M_X}$ that satisfies $(D, A(X), C)$ and that is transformed by Eq. (10).

Proof: If Y is a $(D, A(X), C)$-MCV, then there exists at least one real flow vector $K \in K_Y$ that satisfies $(D, A(X), C)$. Obviously, this also implies that $K \in K_{M_X}$, which leads to the constraint being satisfied $\left\lceil w \sum_{\varphi=1}^{T} \sum_{j:r_i \in p_{\varphi,j}} k_{\varphi,j} \right\rceil \le yi$ for each i, where $i = 1, 2, ..., n$. Suppose there exists an route r_o with $y_o > c_{ox_o}(h) \ge \left\lceil w \sum_{\varphi=1}^{T} \sum_{j:r_i \in p_{\varphi,j}} k_{\varphi,j} \right\rceil > c_{ox_o}(h\text{-}1)$ and there is $y_i = c_{ix_i}(h) \ge \left\lceil w \sum_{\varphi=1}^{T} \sum_{j:r_i \in p_{\varphi,j}} k_{\varphi,j} \right\rceil$ for any $i \ne o$. Furthermore, there exists a capacity vector $L = (l_1, l_2, \ldots, l_n)$ with $l_o = c_{ox_o}(h)$ and $l_i = y_i$ for any $i \ne o$. It can be deduced that $L < Y$, and satisfies the constraint $\left\lceil w \sum_{\varphi=1}^{T} \sum_{j:r_i \in p_{\varphi,j}} k_{\varphi,j} \right\rceil \le l_i$ for each i. Therefore, the actual flow vector K is feasible under the capacity vector L. This indicates $L \in \Psi$ and contradicts that Y is a $(D, A(X), C)$-MCV.

According to Theorem 2, any $(D, A(X), C)$-MCV can be transformed by the $K \in K_{M_X}$ satisfying $(D, A(X), C)$. Note that the capacity vector Y converted by the actual flow vector $K \in K_{M_X}$ may not be a true $(D, A(X), C)$-MCV, and thus is regarded as a candidate $(D, A(X), C)$-MCV. For convenience, assume that Φ is the set of all candidate $(D, A(X), C)$-MCVs, and Φ_{min} is the set of Φ in which set of all $(D, A(X), C)$-MCVs, then the following theorem shows that Φ_{min} is the set of all $(D, A(X), C)$-MCVs.

Theorem 3: Φ_{min} is the set of all $(D, A(X), C)$-MCVs.

Proof: Suppose Y is a $(D, A(X), C)$-MCV, but $Y \notin \Phi_{min}$, which implies there exists a $L \in \Phi$ such that $L < Y$. i.e., the capacity vector Y is not a $(D, A(X), C)$-MCV. Therefore, this

Table 1. Data for carriers on each route in **Figure 1**

				Capacity State (TEU)				
				$c_{iu}(1)=0$	$c_{iu}(2)=1$	$c_{iu}(3)=2$	$c_{iu}(4)=3$	$c_{iu}(5)=4$
r_i	e_{iu}	o_{iu} (USD)	a_{iu}	State Probability				
r_1	e_{11}	5	0.040	0.003	0.004	0.050	0.090	0.853
	e_{12}	4	0.052	0.015	0.026	0.067	0.892	0.000
	e_{13}	3	0.061	0.010	0.020	0.070	0.900	0.000
r_2	e_{21}	2	0.015	0.004	0.005	0.008	0.019	0.964
	e_{22}	1	0.030	0.021	0.050	0.100	0.829	0.000
	e_{23}	1	0.021	0.010	0.012	0.978	0.000	0.000
r_3	e_{31}	2	0.022	0.005	0.010	0.030	0.080	0.875
	e_{32}	1	0.028	0.025	0.080	0.100	0.795	0.000
	e_{33}	3	0.017	0.010	0.025	0.030	0.034	0.901
r_4	e_{41}	5	0.050	0.020	0.035	0.050	0.070	0.825
	e_{42}	3	0.069	0.050	0.130	0.160	0.660	0.000
	e_{43}	4	0.055	0.040	0.050	0.060	0.850	0.000
r_5	e_{51}	4	0.051	0.010	0.025	0.045	0.050	0.870
	e_{52}	3	0.057	0.024	0.040	0.100	0.836	0.000
	e_{53}	4	0.048	0.005	0.070	0.925	0.000	0.000
r_6	e_{61}	2	0.059	0.010	0.025	0.045	0.920	0.000
	e_{62}	4	0.039	0.020	0.050	0.080	0.100	0.750
	e_{63}	3	0.045	0.015	0.020	0.100	0.865	0.000
r_7	e_{71}	2	0.023	0.010	0.035	0.050	0.070	0.835
	e_{72}	3	0.016	0.008	0.010	0.015	0.020	0.947
	e_{73}	1	0.031	0.005	0.040	0.955	0.000	0.000

conclusion contradicts the premise assumption that Y is a (D, $A(X)$, C)-MCV. Conversely, suppose that $Y\in\Phi_{min}$ but Y is not a (D, $A(X)$, C)-MCV, which means that there exists a capacity vector L satisfying $L < Y$ and $L\in\Phi$, i.e., the capacity vector $Y\notin\Phi_{min}$. Therefore, this conclusion contradicts $Y\in\Phi_{min}$. It follows that Φ_{min} is the set of all (D, $A(X)$, C)-MCVs.

According to Theorem 3, each candidate (D, $A(X)$, C)-MCV has to be further checked whether it is a (D, $A(X)$, C)-MCV or not. This paper checks it based on the comparison method.

4. An Example Analysis

In this paper, a simple logistics network is used as an example to illustrate the models and algorithms discussed above. There exist four minimal paths in this logistics network: $p_{1,1} = \{r_1, r_4\}$, $p_{1,2} = \{r_2, r_5\}$, $p_{2,1} = \{r_2, r_6\}$, $p_{2,2} = \{r_3, r_7\}$, as shown in **Figure 1**. The whole network contains six routes and each route has three optional carriers. **Table 1** shows the available capacity information of the carriers, the unit transportation cost, and spoilage rate, which are based on historical data. Assuming that each unit of commodity flow takes up 0.9 units of capacity during transportation, i.e., $w = 0.9$. Given the cost constraint $C = 29$ (USD), an enumeration method is used to obtain the optimal carrier selection that maximizes network reliability for different demand levels.

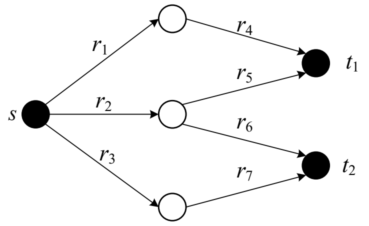

Figure 1. A single-source, multi-sink logistics network

In the above simple example, the enumeration method enumerates a total of 2187 possible carrier selections. The optimal carrier selection with maximum network reliability is obtained for different demand levels, and the computational results are shown in **Table 2**. Obviously, the maximum network reliability is 0.9827613 and the corresponding optimal carrier choices are (3, 1, 1, 3, 2, 1, 2) for the cost constraint $C = 29$ (USD) and the demand vector $D = (1, 2)$. Note that the optimal carrier selection corresponding to the maximum network reliability may not be unique. For example, for the cost constraint $C = 29$ (USD) and the demand vector $D = (1, 1)$, there are two optimal carrier selections with maximum network reliability $R_{D,A(X),C} = 0.9948832$.

Table 2. The calculation result

D	Maximum Reliability	Optimal Carrier Solution
(1, 1)	0.9948832	(3, 1, 1, 1, 1, 3, 2)/2
(1, 2)	0.9827613	(3, 1, 1, 3, 2, 1, 2)/1
(1, 3)	0.8425748	(3, 2, 1, 2, 1, 1, 1)/1
(1, 4)	0	No Solution.
(2, 1)	0.9629340	(3, 1, 1, 3, 1, 1, 3)/2
(2, 2)	0.7824731	(3, 2, 2, 2, 2, 1, 1)/1
(2, 3)	0.5063553	(1, 2, 1, 1, 2, 1, 1)/27
(2, 4)	0	No Solution.
(3, 1)	0.7168408	(1, 1, 2, 1, 1, 1, 3)/27
(3, 2)	0	No Solution.

5. Conclusion

This paper focuses on the carrier selection problem based on the reliability of single-source multi-sink network under delivery spoilage and cost constraint. Firstly, this paper discusses the calculation method of single-source multi-sink logistics network reliability under delivery spoilage and cost constraint based on the conversion relationship between ideal flow vector and actual flow vector. Secondly, a logistics carrier selection model is constructed with network reliability maximization as the objective function and carrier selection as the decision variable; a model solution method is proposed based on the minimal path method. Finally, the effectiveness of the algorithm is demonstrated through an example analysis, which provides decision-making information for managers to determine the optimal carrier selection with maximum network reliability within the budgeted cost. Note that the model developed in this paper is for a commodity. In future research, the multi-commodity case can be considered to further extend the applicability of the model.

References

[1] P D Fanam, L Ackerly. Evaluating ocean carrier selection criteria: perspectives of Tasmanian shippers[J]. Journal of Shipping and Trade, 2019, 4: 1-16.

[2] D Mohammaditabar, E Teimoury. Integrated freight transportation carrier selection and network flow assignment: methodology and case study[J]. Journal of Applied Sciences, 2008, 8(17): 2928.

[3] M J Meixell, M Norbis. Integrating carrier selection with supplier selection decisions to improve supply chain security[J]. International Transactions in Operational Research, 2012, 19(5): 711-732.

[4] Y K Lin, C T Yeh. Optimal carrier selection based on network reliability criterion for stochastic logistics networks[J]. International Journal of Production Economics, 2010, 128(2): 510-517.

[5] Y K Lin, C T Yeh. Determine the optimal carrier selection for a logistics network based on multi-commodity reliability criterion[J]. International Journal of Systems Science, 2013, 44(5): 949-965.

[6] Y K Lin, C T Yeh, C F Huang. Reliability evaluation of a stochastic-flow distribution network with delivery spoilage[J]. Computers & Industrial Engineering, 2013, 66(2): 352-359.

[7] Y K Lin, C T Yeh, C F Huang. Reliability assessment of a multistate freight network for perishable merchandise with multiple suppliers and buyers[J]. International Journal of Systems Science, 2017, 48(1): 74-83.

[8] Y K Lin, C F Huang, C T Yeh. Network reliability with deteriorating product and production capacity through a multi-state delivery network[J]. International Journal of Production Research, 2014, 52(22): 6681-6694.

[9] Y K Lin, C F Huang, Y C Liao. Reliability of a stochastic intermodal logistics network under spoilage and time considerations[J]. Annals of Operations Research, 2019, 277: 95-118.

[10] Y F Niu, C He, D Q Fu. Reliability assessment of a multi-state distribution network under cost and spoilage considerations[J]. Annals of Operations Research, 2022: 1-20.

[11] Y F Niu, X Z Xu, C He, et al. Capacity reliability calculation and sensitivity analysis for a stochastic transport network[J]. IEEE Access, 2020, 8: 133161-133169.

[12] C F Huang, D H Huang, Y K Lin. Network reliability evaluation for multi-state computing networks considering demand as the non-integer type[J]. Reliability Engineering & System Safety, 2022, 219: 108226.