Dynamic modelling of container transport modes between inland terminals and seaports

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Abstract

Container transport has played an important role in international trade. This paper mainly focuses on the container transport modes selection between inland terminals and seaports through a comprehensive comparison of multiple decision factors. According to the multi-object fuzzy mathematics decision-making theory and the container transport processes, the main factors influencing the container transportation mode decision are analyzed. Moreover, a fuzzy decision model of container transport modes between inland terminals and seaports is built by introducing varied weight factors. Thereafter, the proposed model for the final selection of container transport modes between Changsha city and Shanghai harbor is demonstrated through an illustrative example. The results of this example indicate that the model can reflect dynamically importance degrees of related decision factors and different demands of decision makers, and this approach provides a more accurate, effective, and systematic decision support tool for the optimized intermodal mode selection between inland terminals and seaports.

*Keywords: c*ontainer transport, transport mode, route optimization, fuzzy decision making

1 Introduction

The vast majority of liner cargo is containerized – that is, it is carried in sealed metal containers from point of origin to destination. Containers are moved with common handling equipment enabling high-speed intermodal transfers in economically large units [1]. The container, therefore, serves as the load unit rather than the cargo contained therein, making it the foremost expression of intermodal transportation. As an advanced mode of transport [2], container transport has been an important element of not only maritime activity, but also of world trade and of global industrial structure. Since the 1970s, with growing container transport as the main driver, most seaports have evolved into port communities [3].

At present, seaport business is increasingly focused on inland terminals through which the hinterland is served. Seaports are no longer purely considered intermodal transfer centers, but are now becoming comprehensive flow-through areas within logistics chains, which are functionally linked to distribution developments in the hinterland. Seaports and inland terminals belong to a tiered intermodal transport system serving the whole supply chains [4]. Intermodal transport mode involves the use of at least two different modes in a trip from an origin to a destination through an intermodal transport chain, which is facilitated by the use of containers allowing the transport by different modes of transport namely ship, truck and rail [5]. Each transport mode has different economic and technical structures, and provides different quality of transport services. The decision on mode choice is complex. As for how to get the optimum scheme, a suitable method is needed to make a comprehensive, reasonable and comparative study. The wide application of the fuzzy mathematics theory has offered a scientific way to solve the transportation route decision issue.

2 Influence factor analysis of container transport mode selection

2.1 TRANSPORTATION COST

Transport cost is important for transport mode selection. Transport cost includes rates, loading and unloading charges, and special services available (e.g., stopping in transit) from carriers [6]. Transport cost varies from mode to mode owing to the different cost structures of the modes, whereas there are cost variations among carriers within a transport mode because of their dissimilarities in cost structure [7]. While choosing the transport route, different schemes will produce different transport costs, and this factor usually becomes a primary one.

2.2 TRANSPORTATION TIME

In general, transport time includes the time required for pickup, handling, and delivery [8]. Containers transport time between inland terminals and seaports should be linked up with the lading time of arrived liner ships, and more fees such as storing fees, keeping fees should be paid if containers are delivered more ahead of time.

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2.3 TRANSPORTATION SECURITY

In the container transport industry, the importance of adopting technology for enhancing transport security has been well acknowledged [9]. To guarantee the security of the containers, delivered goods and the bills enclosed during the process of transporting is the basic requirement for transportation, and also it is a primary condition that must be considered while drafting all the transportation schemes that are prepared to be chosen.

2.4 TRANSPORTATION RELIABILIGY

Transport reliability refers to the carrier's capability and accessibility for providing the service over the route in question, and it determines whether a particular carrier can physically perform the transport service desired. While choosing the transportation route schemes, it is necessary to make an investigation and analysis about the possibility degree of gaining transportation capacity and the punctual conditions of transportation.

3 Decision making issue description of container transport modes

Consignors want to choose the optimal container transport mode between inland terminals and seaports, and the consignors have specified the nature of goods and transportation requirements [10]. After a detailed market has been conducted to identify the potential transport modes, m schemes available are educed through the initial screening. As for the m schemes available such as $b_1, b_2, \cdots, b_m$ between inland terminals and seaports. There are n evaluation factors such as $a_1, a_2, \cdots, a_n$ (transport time, transport cost, transport security, transport reliability, etc.), respectively corresponding to the varied weight of decision factors $w_1, w_2, \cdots, w_n$. Every scheme $b_j (j = 1, 2, \cdots m)$ in reserve has one index eigenvector $f_{ij} (i = 1, 2, \cdots, n; j = 1, 2, \cdots, m)$ corresponding to n evaluation factors $a_i (i = 1, 2, \cdots n)$ and the membership degree of its eigenvalue is r_{ij} to individual appraisal factor "excellent". To utilize a method that weighted relative warp interval is the minimum to choose the optimum scheme. Thereby, it is necessary to calculate the ideal scheme. The standard value vector of the ideal scheme is:

$$f^0 = (r_{11} \vee r_{12} \vee \cdots \vee_{1m}, r_{21} \vee r_{22} \vee \cdots \vee r_{2m}, \cdots, r_{n1} \vee r_{n2} \vee \cdots \vee r_{nm}) = (f_1^0 \wedge f_2^0 \wedge \cdots \wedge f_n^0) . \quad (1)$$

The eigenvector of each available scheme that is the most close to the ideal scheme is illustrated as: $R_j = (r_{1j}, r_{2j}, \cdots, r_{nj})^T$, the weight of decision factors:

$$W = ((1+\varepsilon_1)w_1, (1+\varepsilon_2)w_2, \cdots, (1+\varepsilon_n)w_n)^T .$$

Among them: $\varepsilon_1, \varepsilon_2, \cdots, \varepsilon_n$ and $w_1, w_2, \cdots, w_n$ are respectively the varied weight factor and constant weight items of each factor index. Hamming closing degree with weight is used to describe the quality degree of the scheme in reserve [11], namely:

$$N(f^0, R_j) = 1 - \sum_{i=1}^{n} W_i (f_i^0 - r_{ij}) . \quad (2)$$

If $T_j = \max[N(f^0, R_j)]$, $1 \le j \le m$, scheme b_j is an optimum scheme.

4 Building the fuzzy decision model of container transport modes

4.1 CALCULATING MEMBERSHIP DEGREE OF QUANTITATIVE FACTOR INDEX

When the index value f_{ij} of factor index i corresponding to scheme j is a quantitative index, the membership degree of the factor index is calculated based on the comprehensive decision-making method as:

$$r_{ij} = \begin{cases} 0.1 + \dfrac{f_{i\max} - f_{ij}}{d} & \text{if } f_i \text{ is a minus index} \\ 0.1 + \dfrac{f_{ij} - f_{i\min}}{d} & \text{if } f_i \text{ is a plus index} \end{cases} . \quad (3)$$

In the Equation (3), d is a grading value $d = \dfrac{f_{i\max} - f_{i\min}}{1 - 0.1}$, r_{ij} is the membership degree of factor item i to scheme j in reserve. In $n \times m$ dimensional space, n evaluation values of m schemes constitute a fuzzy evaluation matrix *R*.

4.2 CONFIRMING MEMBERSHIP DEGREE OF QUALITATIVE FACTOR INDEX

As for the confirmation of the membership degree of qualitative factor index, a comprehensive decision method is adapted to make an evaluation, when every factor index value f_{ij} is a qualitative index, the evaluation of the fuzzy matrix *R* can be made by experts. The specific way is that the factor index is to be divided into seven grades (worst, worse, bad, general, good, better, best), and the evaluation value can be get according to the standard shown in Table 1.

TABLE 1 The table of evaluation standard

Remark	Worst	Worse	Bad	General	Good	Better	Best
Evaluation value	0.05	0.20	0.35	0.50	0.65	0.80	0.95

4.3 CONFIRMING THE WEIGHT OF EVERY FACTOR INDEX

It is necessary to confirm the importance degree of every factor to the container transport schemes according to the true environment [12]. And the importance degree, namely, is the corresponding factor weight value of n evaluation factors: $w_1, w_2, \cdots, w_n$. In order to dynamically reflect the different importance degrees of each factor index to each transportation route scheme, the varied weight factors of every factor index $\varepsilon_1, \varepsilon_2, \cdots, \varepsilon_n$ should be given a corresponding value [11]. The weight set with varied weight of each factor, namely $W = ((1+\varepsilon_1)w_1, (1+\varepsilon_2)w_2, \cdots, (1+\varepsilon_n)w_n)^T$, can be gained, which shows the dynamic features of the evaluation factors.

4.4 EDUCING THE OPTIMUM SCHEME

Make a calculation according to Equation (2), and get the result $T_j = \max[N(f^0, R_j)]$. Therefore, scheme b_j is an optimum scheme.

5 Case study

5.1 TRANSPORT MODE INVESTIGATION AND SCHEME ANALYSIS

The land-based transportation section of the containers, sent from the Changsha city and exported via Shanghai Harbor, is chosen as a case of route scheme. The container transport routes between Changsha and Shanghai Harbor are illustrated in Figure 1.

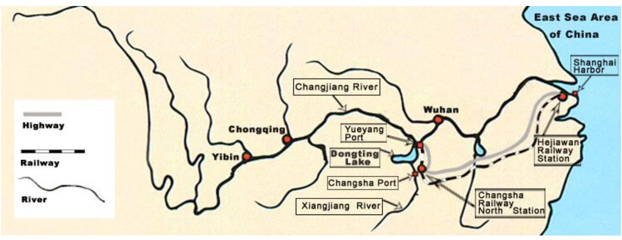

FIGURE 1 Container transport routes between Changsha and Shanghai Harbor in China

Scheme b_1: the railway + highway transport scheme, namely after the exported containers being sent at Changsha North Station, then they are transported to Hejiawan Station of Shanghai by railway, then transshipped on container trucks. Again they are transported to Shanghai Harbor by the short-distance road transport [13].

Scheme b_2: the whole highway transport scheme, namely after exported containers are loaded on container trucks in Changsha and transported to Shanghai Harbor by highway.

Scheme b_3: the whole inland water transport scheme, namely after exported containers are loaded into the ship in Changsha Port and transported through the Xiangjiang River, by way of Tongting Lake and Yueyang, to Changjiang River, then transported to Shanghai Harbor through the Changjiang River.

After Scheme b_1, Scheme b_2 and Scheme b_3 are designed based on the multi-modal freight transport network theory [14], the three schemes in reserve are chosen to be compared with each other. The index values of schemes in reserve have been educed in Table 2.

TABLE 2 The index values of schemes in reserve

	Scheme b_1	**Scheme** b_2	**Scheme** b_3
Transportation costs	￥3100 RMB /TEU	￥8300 RMB/TEU	￥2500 RMB /TEU
Transportation time	4 days	3 days	7 days
Transportation security	Better	Between “better” and “good”	Good
Transportation reliability	Worst	Best	Better

5.2 CALCULATING THE MEMBERSHIP DEGREE OF EVERY FACTOR INDEX

According to Table 2, the two indexes of “transportation costs” and “transportation time” are quantitative and minus indexes, so their membership degrees are calculated according to the Equation (3). The two indexes of “transportation security” and “transportation reliability” are qualitative indexes, so their membership degrees are calculated with corresponding assessed values of fuzzy comments, then the fuzzy matrix R is got:

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \\ r_{41} & r_{42} & r_{43} \end{bmatrix} = \begin{bmatrix} 0.91 & 0.10 & 1 \\ 0.78 & 1 & 0.10 \\ 0.80 & 0.7 & 0.65 \\ 0.20 & 0.95 & 0.80 \end{bmatrix}.$$

According to the Equation (1), the index standard value vector of an ideal scheme is $f^0 = (1, 1, 0.80, 0.95)$.

5.3 CONFIRMING THE WEIGHT OF EVERY FACTOR INDEX

With Delphi method, through the consultation investigation of two experts engaged in the Third Party Logistics, four experts engaged in international freight agency business and four experts engaged in transporttation for imports and exports enterprises, and they are invited to evaluate every index weight. The result that the constant weight values w_1, w_2, w_3, w_4 of the 4 factor indexes of transportation costs, transportation time, transporttation security and transportation reliability are 0.41, 0.22, 0.11, 0.26 respectively after the data of assigning the weight are collected and processed. After introducing varied weight factor, the weight value is:

$$W = ((1+\varepsilon_1)w_1, (1+\varepsilon_2)w_2, (1+\varepsilon_3)w_3, (1+\varepsilon_4)w_4)^T = \\ (0.41(1+\varepsilon_1), 0.22(1+\varepsilon_2), 0.11(1+\varepsilon_3), 0.26(1+\varepsilon_4)).$$

5.4 CALCULATING THE HAMMING CLOSING DEGREE TO GET AN OPTIMUM SCHEME

Calculate Hamming closing degree of every scheme with Equation (2), the result is got as following:

$$b_1: N(f^0, R_1) = 1 - \sum_{i=1}^{n} W_i (f_i^0 - r_{i1}) = 0.720 - 0.037\varepsilon_1 - 0.048\varepsilon_2 - 0.195\varepsilon_4 ,$$

$$b_2: N(f^0, R_2) = 1 - \sum_{i=1}^{n} W_i (f_i^0 - r_{i2}) = 0.620 - 0.369\varepsilon_2 - 0.011\varepsilon_3 ,$$

$$b_3: N(f^0, R_3) = 1 - \sum_{i=1}^{n} W_i (f_i^0 - r_{i3}) = 0.746 - 0.198\varepsilon_2 - 0.017\varepsilon_3 - 0.039\varepsilon_4 .$$

When the weight of every factor index is constant weight and varied weigh factors are not considered, namely if $\varepsilon_i = 0 (i = 1,2,3,4)$, then:

$$T_j = \max[N(f^0, R_j)] = \max[0.720,\ 0.620,\ 0.746] = 0.746 .$$

Thereby, scheme b_3 is the optimum scheme. If varied factors are evaluated, there are differences to some extent in the gained result of the scheme compositor.

6 Conclusions

The major contribution of this paper lies in the development of a comprehensive methodology for the planning of transport modes between inland terminals and seaports. According to the multi-object fuzzy mathematics decision-making theory and the centralized and evacuated transportation features of the containers, a fuzzy decision model of container transport modes between inland terminals and seaports is constructed, which is under the restriction of multiple qualitative and quantitative decision factors and based on varied weight factors. The introduction of varied weight, which can reflect dynamically importance degrees of related decision factors, adapts the decision model to the dynamic changes of the decision factors. This study raises several important issues that warrant further research. Evaluation and refinement of the model using additional field studies may prove beneficial, and its applicability may be expanded to other similar decision problems. Further, the intelligent software based on the methodology may also be developed.

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