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Optimization Model of Transportation Product Selection for Railway Express Freight

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Abstract

Mode selection is a vital part of express freight transportation. The kind of shippers and capacity of each transportation product, which are often neglected, significantly influence mode choices. An optimization method for multiple batches of express freight demands is proposed for the shippers of railway express freight to select the most suitable transportation products to transport, considering the priority of shippers and capacity constraints. Five transport attributes, the most common concerns of express freight shippers, including freight transit time, transport cost, convenience, safety, and reliability, are selected as main indexes. A 0-1 programming model with the capacity constraints of the products is established for the transportation product selection of railway express freight. The model without capacity constraints is obtained by adjusting the original model. Furthermore, a solution algorithm is designed by considering important clients who prioritize choosing transportation products. Moreover, a numerical example is applied to illustrate the feasibility of the proposed model and algorithm. Results show that the proposed method can solve the problem of transportation product selection for rational shippers; however, the method is limited for irrational shippers, who select transportation product randomly. This study can guide railway express freight shippers in selecting the most rational transportation product. The result also presents considerable significance to both shippers and transportation enterprises.

Keywords: Express freight, Railway freight transportation, Transportation product, Classification of clients, 0-1 programming

1. Introduction

The demand volume of express freight increases rapidly with social and economic developments, and many transportation enterprises adopt various methods to improve their competitiveness in express freight market. Railway enterprises also develop diverse transportation products to satisfy shipper demands. In most cases, express freight shippers comprehensively consider several attributes, such as transport time, transport cost, and safety, when selecting the transport mode or transportation product. Recent research on freight mode choice achieved success, however, theoretical research on the selection of transportation products for express freight remain rare. The transport properties of different railway transportation products essentially include a large difference. For instance, the speed and punctuality rate of express freight trains in China are higher than those of ordinary freight trains. Moreover, the priority of shippers should also be considered. In the present study, a transportation product selection model for railway express freight that considers the priority of vital clients is proposed to provide decision reference for both shippers and freight transportation companies.

2. State of the art

In the past 40 years, various attempts have been made to obtain the optimal freight transport mode for shippers. These attempts primarily include three aspects: analysis of shipper preferences for a certain kind of freight, determination of the applicable scope for each transportation mode, and establishment of a universal model for freight mode choice.

Freight mode selection is greatly influenced by the kind of freight and the preferences of shippers. Many researchers discussed the problem for a certain kind of freight and a certain district, and subsequently gained the preference of the shipper for this kind of freight in the district. Gursoy discussed the most suitable choice of transportation mode for textile in Turkey and established a linear model according to four criteria, namely, transport time, safety, cost, and accessibility [1]. Kofteci et al. studied the freight transportation demand of cement firms between two Turkish regions and constructed transportation mode selection model by adopting conjoint analysis method [2]. Danielis et al. investigated the freight transport service preference of shippers and performed experimental simulation by applying adaptive conjoint analysis; their results showed that shippers commonly prefer time, reliability, and safety as service attributes [3]. Based on the Freight Analysis Framework database and the US highway and networks, Shen and Wang established a binary logit model and a regression model, both of which performed well for the transportation mode selection of cereal grains in the United States between truck and rail [4]. Puckett et al. investigated the role of preference and the scale heterogeneity of shippers choosing in freight mode; he further constructed a mixed logit model and found that the frequency of service is the most important factor influencing the willingness of shippers to pay [5]. Brooks et

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al. analyzed freight mode selection at three specific transport corridors in Australia using investigative and experimental methods; their study results showed that shippers are sensitive to cost, transit time, and arrival reliability [6].

The applicable scope for each transportation mode should also be determined. Jiang et al. analyzed the demand characteristics of freight and developed a disaggregate model for freight mode selection; in their research, they gained the dominant distance of each transportation mode [7]. Dunn et al. pointed out that express freight presents a large potential income; thus, transportation enterprises of aviation, road, and railway are competitive in the market of express freight transportation [8]. Lu researched the effect of freight shippers from service attributes of carriers on satisfactory degree by using structural equation model, and proposed that the service related to time exhibits the most influence [9]. Samimi et al. discussed the freight transportation mode of truck and rail in the US through behavioral analysis method; they found that rail shipments are sensitive to shipping cost, and truck shipments are sensitive to shipping time [10, 11]. Feo considered the design of freight transport policy by investigating the preferences in road transport and short sea shipping of Spanish freight forwarders and by constructing the mode selection model between trucking and short sea shipping [12].

The number of research on the establishment of universal model for freight mode selection has been increasing recently. Holguín-Veras concluded that freight mode selection is the outcome of the interations between carriers and shippers to a certain extent and proposed a cooperative game model for freight mode selection [13]. Reis pointed out that the effect of distance in freight mode selection is often neglected, and short-distance multimodal transport presented more potential market opportunities relative to mature medium to long-distance multimodal freight transport market; consequently, he established an agent-based model for short-distance freight transport service to provide references for policy revision of multimodal freight transport [14]. Reis et al. defined the multimodal freight transport and analyzed the advantages and disadvantages of combining rail freight service with road shipping, combining rail with sea transport, and combining rail with air transport; their study shed some light on the multimodal freight mode selection that considered energy use and environmental friendliness [15]. The network structure of each transport mode can affect the result of freight mode choice. Bhattacharya et al. developed a mixed integer programming model for the intermodal transport system considering cost and capacity constraints to design the optimal freight transport network [16].

The literature provides a summary of previous studies. Meixell and Norbis revealed that some important aspects, such as environmental concerns, safety in the whole supply chain, and the role of emerging information technologies, are seldom considered when studying freight mode selection [17]. SteadieSeifi studied the literature on multimodal freight transportation planning from 2005 onwards and analyzed the models and solution methods obtained in the literature [18].

These studies provided useful references for the freight mode selection of shippers. Most present studies establish models by only considering single freight demand and fail to take into account the selection of freight transportation product of the same transportation mode. Transportation products with different attributes also showed considerable differences for the same freight transportation mode, specifically for railway freight transportation. Furthermore, the research on transportation product selection of railway express freight with multiple demands can also guide the design of the railway transportation product system. Thus, studying the problem of transportation product selection for railway express freight presents both theoretical significance and practical value. This paper considers the demands of railway express freight among shippers and proposes an optimization model of transportation product selection for railway express freight. A heuristic solution algorithm is also developed.

The remainder of this paper is organized as follows. Section 3 states the problem of transportation product selection of railway express freight; their optimization model is established, and the solution algorithm is designed as well. In Section 4, a numerical example is provided to verify the effectiveness of the model and algorithm; subsequently, the result analysis and some discussions are given. Section 5 provides the conclusions and the possible areas of further research.

3. Methodology

This study investigates the problem of transportation product selection with multigroups of railway express freight. The problem is not passenger traffic mode and traditional freight mode choices. Based on the transport attribute preferences of each shipper and the transport attribute values of each transportation product, selecting the scheme with the maximum comprehensive preferences among all shippers is the most suitable. Freight transit time, transport cost, convenience, safety, and reliability are adopted as transport attributes in this paper. Railway express freight shippers are often classified as important and ordinary clients; important clients are always given higher priority in choosing railway transportation products. Each railway transportation product of express freight has a capacity limitation; thus, we consider the capacity constraints and the different client priorities in designing the model and algorithm.

3.1 Model Hypothesis

The selection of railway transportation product is a complicated integrated optimization problem, and the following assumptions are made to reduce the difficulty in formulating the model.

(1) Shippers are all rational persons, and they select the transportation product with the maximum transport attribute preferences.

(2) The loading capacity of each car is identical, and the loading ratio of different kinds of freight is the same.

(3) In view of railway express freight exhibiting the characteristic of small batches, we assume that railway express freight demand should not be removed and that the transportation product selection of each batch of express freight demand is consistent.

(4) Important clients are given the highest priority when selecting the transportation product, that is, the demand of important clients should be satisfied first.

3.2 Notation and definition

Suppose that M is the batches of express freight demands, N is the kind of railway freight transportation products, and

K is the transport attributes. The following notations are defined to formulate the proposed model.

x_{ij} : 0–1 decision-making variable; when transportation product j is selected to transport express freight demand i, the value of x_{ij} is 1, otherwise 0, where i = 1, 2, ..., M, j = 1, 2, ..., N.

y_{kj} : Standardized value of transport attribute k of transportation product j, where j = 1, 2, ..., N, k = 1, 2, ..., K.

w_{ik}: Weight of express freight demand i to transport attribute k, which is the shippers' preference degree of demand i to transport attribute k, where $w_{ik} \in [0,1]$ and $\sum_{k=1}^{K} w_{ik} = 1$. In this paper, five transport attributes are considered; when k = 1, 2, 3, 4, and 5, and the attributes are expressed as freight transit time, transport cost, convenience, safety, and reliability, respectively.

q_i : Volume of express freight demand i.

n_j : Carrying capacity of railway freight transportation product j.

T_j : Freight transport time by railway freight transportation product j.

P_j : Transport cost of railway freight transportation product j.

C_j : Transport convenience of railway freight transportation product j.

S_j : Safety of railway freight transportation product j.

R_j : Reliability of railway freight transportation product j.

3.3 Model formation

3.3.1 Objective function

The maximum comprehensive preference of shippers to transport attributes should be realized while considering various factors from the aspects of shippers, and the following formula is established as the objective function.

$$Max \quad z = \sum_{i=1}^{M} \sum_{j=1}^{N} \sum_{k=1}^{K} q_i w_{ik} y_{kj} x_{ij} \tag{1}$$

3.3.2 Constraint conditions

Three constraints, namely, distinct constraint, capacity constraint, and value range of parameters, are considered. First, only one kind of transportation product can be selected by a batch of freight demand in a transport process; thus, we obtain the following equality.

$$\sum_{j=1}^{N} x_{ij} = 1 \tag{2}$$

Second, the overall volume of express freight demand selecting one railway transportation product cannot exceed the carrying capacity of this product; consequently, the following inequality is obtained.

$$\sum_{i=1}^{M} q_i x_{ij} \le n_j \tag{3}$$

Finally, the value range of parameters should be satisfied. x_{ij} is a 0–1 decision-making variable, and other parameters are all nonnegative real numbers; thus, we obtain Eqs. (4) and (5).

$$x_{ij} \in \{0,1\} \tag{4}$$

$$y_{kj}, w_{ik}, q_i, n_j \ge 0 \tag{5}$$

3.4 Model analysis

The integrated expression of the model, which is denoted by Model 1, is obtained according to Eqs. (1) – (5).

Model 1:

$$\max \quad z = \sum_{i=1}^{M} \sum_{j=1}^{N} \sum_{k=1}^{K} q_i w_{ik} y_{kj} x_{ij}$$

$$s.t. \begin{cases} \sum_{j=1}^{N} x_{ij} = 1 \\ \sum_{i=1}^{M} q_i x_{ij} \le n_j \\ x_{ij} \in \{0,1\} \\ y_{kj}, w_{ik}, q_i, n_j \ge 0 \end{cases}$$

Model 1 represents the transportation product selection of multiple demands with capacity constraint. When the numbers of railway freight transportation products, the railway express freight demands, or the considered transport attributes of shippers change, the suitable model is obtained by adjusting relative parameters; consequently, the model presents good extensibility. The transportation product selection model for the multiple demands without capacity constraint is obtained if the capacity constraint is not considered; this model is denoted as Model 2.

Model 2:

$$\max \quad z = \sum_{i=1}^{M} \sum_{j=1}^{N} \sum_{k=1}^{K} q_i w_{ik} y_{kj} x_{ij}$$

$$s.t. \begin{cases} \sum_{j=1}^{N} x_{ij} = 1 \\ x_{ij} \in \{0,1\} \\ y_{kj}, w_{ik}, q_i \ge 0 \end{cases}$$

Analysis of the shipper demands using Model 2 can guide railway freight transportation enterprise in designing and optimizing the transportation product system of railway express freight.

Models 1 and 2 are both 0–1 linear programming problem. The scale of these models is relevant to the number of express freight demands and railway freight transportation product. For Model 1, the number of decision-making variable is MN, and the number of constraint conditions is $MN + M + N$. For Model 2, the number of decision-making variable is MN, and the number of constraint conditions is $MN + M$. Proven solving methods, such as the branch and bound algorithm, cutting plane method, and implicit enumeration method, can be used for these models if the scale is not large. However, Model 1 cannot be easily solved in this paper using the traditional exact method for the different priorities of shippers when choosing transportation products; therefore, we design a fractional step algorithm. When the prioritized important clients are not considered, the solution can be calculated using the Lingo software. Moreover, Model 2 does not consider capacity constraint; hence, the priority of shippers when selecting transportation product cannot influence the transportation product selection result. The solution algorithm for Model 1 is relatively simple, and we introduce the algorithm for Model 2.

3.5 Algorithm Design

3.5.1 Determination of standardized values of transport attributes

The problem involves several transport attributes with different dimensions, and the standardized value of each transport attribute y_{kj} should be determined first. The y_{kj} parameter can be expressed by the ratio of k transport attribute value of transportation prodcut j and the sum of k transport attribute value of the N transportation product. The objective function is to obtain the maximum value; consequently, the values of transport time and cost, which are negatively correlated with the selection probability of transportation product, can be processed to ensure the positive corresponding coefficient of the model. The reciprocal values of these transport attributes in this paper are used to calculate y_{kj}. When only freight transit time, transport cost, convenience, safety, and reliability are used as key factors, and when k = 1, 2, 3, 4, and 5, the transport attributes are expressed as freight transit time, transport cost, convenience, safety, and reliability, respectively. Subsequently, y_{1j} and y_{2j} can be expressed as Eqs. (6) and (7), respectively.

$$y_{1j} = \frac{1/T_j}{\sum_{n=1}^{N}(1/T_n)} \tag{6}$$

$$y_{2j} = \frac{1/P_j}{\sum_{n=1}^{N}(1/P_n)} \tag{7}$$

Transport convenience, safety, and reliability are different from the first two attributes. Other conditions being the same, when these three attribute values are high, the selection probability of the railway freight transportation product is also high. Therefore, the corresponding y_{kj} value can be directly calculated using relevant attribute value. The obtained expressions of y_{3j}, y_{4j}, and y_{5j} are as follows.

$$y_{3j} = \frac{C_j}{\sum_{n=1}^{N} C_n} \tag{8}$$

$$y_{4j} = \frac{S_j}{\sum_{n=1}^{N} S_n} \tag{9}$$

$$y_{5j} = \frac{R_j}{\sum_{n=1}^{N} R_n} \tag{10}$$

3.5.2 Solution steps

We classify express freight transport demands according to the two parts according to the kinds of shippers first to describe the solution steps. The first part is the demand of important clients, which supposes the M_1 batches; the other part is the demand of ordinary clients, which supposes the M_2 batches; thus, $M_1 + M_2 = M$. The solution steps are as follows.

Step1: Determine the index values of each transportation product, which includes transport time, service frequency, punctuality rate, satisfied rate of consigning, accident rate, and transport cost.

Step2: Obtain the values of T_j, C_j, S_j, R_j, and P_j by substituting the above index values into corresponding transport property expressions.

Step3: Calculate y_{kj} according to Eqs. (6–10) and transport attribute values; the values of y_{kj} are denoted by matrix Y.

Step 4: Determine the value of w_{ik} by analyzing the investigation result of shipper preference. The w_{ik} values of important and ordinary clients are relatively expressed by the matrices W_1 and W_2, respectively.

Step 5: According to the data of matrices Y and W_1, as well as the column vector $Q = \{q_i\}$, where i = 1, 2, ..., M_1, solve the optimal solution of the initial model adopting Lingo software. Consequently, the transportation product selection result of important clients can be obtained.

Step 6: Remove the product selection result of important clients to obtain a new model. Solve the new model using the Lingo software according to the data of matrix Y, matrix W_2, and column vector $Q = \{q_i\}$, where $i = M_1 + 1$, $M_2 + 2$, ..., M. Moreover, the transportation product selection results of ordinary clients are obtained.

Step7: The final solution can be combined with the results of steps 5 and 6, and the results can be obtained.

The algorithm can both ensure that the demands of important clients are satisfied first, and decrease the solving time when the size of the problem is large.

4. Result Analysis and Discussion

Transportation products for railway express freight, namely, special express scheduled freight train, express scheduled freight train, and ordinary scheduled freight train, are available between a city pair. The carrying capacity and transport attribute values of these three products are shown in Table 1.

Table 1. Carrying capacity and transport attribute values of each transportation product

Transportation product	Transport capacity (10^3kg)	Transport attribute values				
		Time (10^3s)	Cost (\$·kg^{-1})	Convenience	Safety	Reliability
Special express scheduled freight train	600	1901	0.175	0.96	0.99	0.99
Express scheduled freight train	800	2592	0.12	0.95	0.98	0.96
Ordinary scheduled freight train	1200	3456	0.09	0.88	0.95	0.90

Table 2. Express freight demand and their preference to each transport attribute

Demand	Kind of client	Demand volume (10^3kg)	Preference of each transport attribute				
			Time	Cost	Convenience	Safety	Reliability
1	Ordinary client	28	0.23	0.16	0.19	0.20	0.22
2	Ordinary client	40	0.17	0.23	0.20	0.15	0.25
3	Important client	110	0.32	0.10	0.20	0.12	0.26
4	Important client	95	0.20	0.26	0.18	0.15	0.19
5	Ordinary client	5	0.27	0.12	0.20	0.16	0.25
6	Ordinary client	35	0.31	0.11	0.21	0.15	0.22
7	Ordinary client	22	0.22	0.19	0.23	0.21	0.15
8	Important client	250	0.31	0.12	0.20	0.11	0.26
9	Ordinary client	45	0.35	0.08	0.24	0.12	0.21
10	Important client	150	0.33	0.05	0.25	0.10	0.27
11	Ordinary client	25	0.21	0.18	0.24	0.16	0.21
12	Ordinary client	6	0.25	0.16	0.19	0.20	0.20
13	Important client	135	0.30	0.10	0.23	0.13	0.24
14	Ordinary client	26	0.26	0.13	0.20	0.19	0.22
15	Ordinary client	43	0.16	0.28	0.21	0.11	0.25
16	Ordinary client	36	0.25	0.15	0.25	0.14	0.21
17	Ordinary client	24	0.20	0.11	0.26	0.20	0.23
18	Important client	325	0.22	0.27	0.17	0.14	0.20
19	Important client	98	0.30	0.06	0.21	0.15	0.28
20	Important client	160	0.23	0.16	0.20	0.19	0.22
21	Ordinary client	41	0.24	0.17	0.22	0.16	0.21
22	Ordinary client	30	0.22	0.14	0.27	0.17	0.20
23	Ordinary client	16	0.18	0.25	0.23	0.16	0.18
24	Ordinary client	20	0.22	0.20	0.19	0.23	0.16
25	Important client	227	0.21	0.22	0.19	0.17	0.21
26	Important client	138	0.20	0.26	0.17	0.22	0.15
27	Ordinary client	32	0.34	0.07	0.20	0.21	0.18
28	Important client	185	0.22	0.14	0.26	0.21	0.17
29	Ordinary client	35	0.25	0.15	0.19	0.18	0.23
30	Ordinary client	42	0.20	0.28	0.18	0.13	0.21

A total of 30 batches of railway express freight transportation demands are obtained between the city pair, and the client types, demand volumes, and preferences of each transport attribute are shown in Table 2. In both tables, we provide the parameter values that suit the calculation of the model to simplify the problem expression; these values are equivalent to the parameter values obtained from Step 2, and the example can be calculated from Step 3.

The proposed method is adopted to solve this example. Table 2 shows that the express freight demands belonging to important and ordinary clients are 11 and 19 batches, respectively. First, the serial number of the demands is reordered according to the kind of shippers, that is, 1–11 belong to important clients, and 12–30 belong to ordinary clients. Afterward, the selection results of important clients can be obtained by solving the following model, where $x_{ij} \in \{0,1\}$, $y_{kj}, w_{ik}, q_i, n_j \geq 0$.

Model 3:

$$\max \quad z_1 = \sum_{i=1}^{11} \sum_{j=1}^{3} \sum_{k=1}^{5} q_i w_{ik} y_{kj} x_{ij}$$

$$s.t. \begin{cases} \sum_{j=1}^{3} x_{ij} = 1 \\ \sum_{i=1}^{11} q_i x_{i1} \leq 600 \\ \sum_{i=1}^{11} q_i x_{i2} \leq 800 \\ \sum_{i=1}^{11} q_i x_{i3} \leq 1200 \end{cases}$$

Model 3 is determined using the proposed algorithm, and the function value is $z_1 = 633.091$. The demands 8, 20, and 28 select special express scheduled freight train, whereas the demands 3, 10, 13, 19, and 25 select express scheduled freight train; the demands 4, 18, and 26 choose ordinary scheduled freight train; these observations correspond to the data presented in Table 2.

According to the selection results of important clients, the transportation product selection problem of ordinary clients can be converted into the solution of Model 4, where $x_{ij} \in \{0,1\}$, $y_{kj}, w_{ik}, q_i, n_j \geq 0$.

Model 4:

$$\max \quad z_2 = \sum_{i=12}^{30} \sum_{j=1}^{3} \sum_{k=1}^{5} q_i w_{ik} y_{kj} x_{ij}$$

$$s.t. \begin{cases} \sum_{j=1}^{3} x_{ij} = 1 \\ \sum_{i=12}^{30} q_i x_{i1} \leq 5 \\ \sum_{i=12}^{30} q_i x_{i2} \leq 80 \\ \sum_{i=12}^{30} q_i x_{i3} \leq 642 \end{cases}$$

Model 4 is calculated to obtain the function value z_2 = 179.1123. The sum of the function values is 812.2033. The solutions of Models 3 and 4 are combined, and the transportation product selection results of railway express freight are presented in Table 3.

The selection results of freight transportation product without considering the priority of important clients are also figured out using the Lingo software. The function value z = 813.2406 is obtained; this value is higher than the sum of the two function values when important clients are given priority in the selection of transportation products. The results are shown in Table 4.

Table 3. Results of transportation product selection when important clients have priority

Demand	Selection of transportation product	Demand	Selection of transportation product	Demand	Selection of transportation product
1	Ordinary scheduled freight train	11	Ordinary scheduled freight train	21	Ordinary scheduled freight train
2	Ordinary scheduled freight train	12	Ordinary scheduled freight train	22	Ordinary scheduled freight train
3	Express scheduled freight train	13	Express scheduled freight train	23	Ordinary scheduled freight train
4	Ordinary scheduled freight train	14	Ordinary scheduled freight train	24	Ordinary scheduled freight train
5	Special express scheduled freight train	15	Ordinary scheduled freight train	25	Express scheduled freight train
6	Express scheduled freight train	16	Ordinary scheduled freight train	26	Ordinary scheduled freight train
7	Ordinary scheduled freight train	17	Ordinary scheduled freight train	27	Ordinary scheduled freight train
8	Special express scheduled freight train	18	Ordinary scheduled freight train	28	Special express scheduled freight train
9	Express scheduled freight train	19	Express scheduled freight train	29	Ordinary scheduled freight train
10	Express scheduled freight train	20	Special express scheduled freight train	30	Ordinary scheduled freight train

Table 4. Results of transportation product selection when important clients have no priority

Demand	Selection of transportation product	Demand	Selection of transportation product	Demand	Selection of transportation product
1	Express scheduled freight train	11	Ordinary scheduled freight train	21	Ordinary scheduled freight train
2	Express scheduled freight train	12	Express scheduled freight train	22	Ordinary scheduled freight train
3	Special express scheduled freight train	13	Special express scheduled freight train	23	Ordinary scheduled freight train
4	Ordinary scheduled freight train	14	Special express scheduled freight train	24	Ordinary scheduled freight train
5	Express scheduled freight train	15	Ordinary scheduled freight train	25	Ordinary scheduled freight train
6	Special express scheduled freight train	16	Express scheduled freight train	26	Ordinary scheduled freight train
7	Express scheduled freight train	17	Ordinary scheduled freight train	27	Express scheduled freight train
8	Express scheduled freight train	18	Ordinary express scheduled freight train	28	Express scheduled freight train
9	Special express scheduled freight train	19	Special express scheduled freight train	29	Express scheduled freight train
10	Special express scheduled freight train	20	Express scheduled freight train	30	Ordinary scheduled freight train

Furthermore, the solution of Model 2 is calculated using the Lingo software. The objective function value is 842.265, and the selection results without considering the capacity constraint are obtained. The obtained results correspond to the data in Table 2: demand 2 selects the express scheduled freight train; demands 4, 15, 18, 26, and 30 select ordinary scheduled freight train; and the other demands choose special express scheduled freight train. Figure 1 shows the selection volume of each railway express freight transportation product under the three conditions.

The demands selecting the special express scheduled freight train and express scheduled freight train are both equal to or approximately equal to the capacities of these two transportation products considering capacity constraints. When the capacity constraints of transportation products are not considered, 72% of the demands select special express scheduled freight train, and the demands selecting the two other transportation products decrease sharply. The results show that some shippers do not select the freight transportation product with their maximum preferences because of capacity constraints, and the product structure and service attributes of some products are not reasonable. Consequently, other rational product systems and service attributes can be developed according to the preference of shippers to better satisfy the diverse demands of shippers.

The proposed method can satisfy the demand of selecting the most rational transportation product for shippers of railway express freight; however, the method is unsuitable when shippers randomly select the transportation product. Furthermore, the mechanism that deals with the investigation and experimental data correctly and rapidly should be considered in future research.

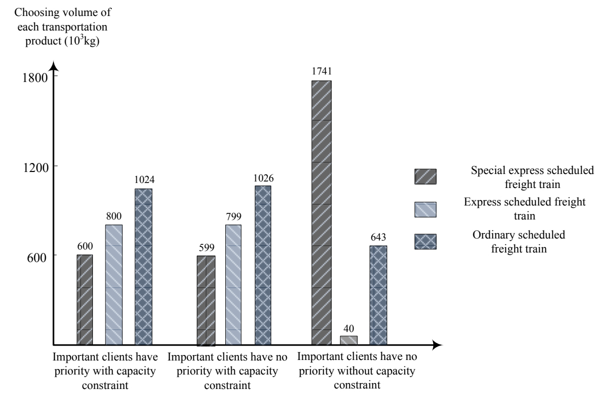

Fig.1. Comparison of the selection volume of each express freight transportation product

5. Conclusions

An optimization method for multiple batches of express freight demands was established based on a 0–1 programming to explore the selection of railway transportation product for express freight considering the priority of different kinds of shippers and the capacity constraints. The following conclusions were obtained.

(1) The proposed method can solve the problem of transportation product selection considering the priority of different kinds of shippers and the capacity constraints, as well as the problems without capacity constraint and those of single demand; therefore, the proposed method shows extensive applications.
(2) In the actual railway freight transportation process, the capacity of each kind of transportation product for express freight is often limited. Some shippers do not select their maximum preferences for freight transportation products because of capacity constraints, that is, the selection of these shippers is passive.
(3) When the capacity constraints of transportation products are not considered, the selection results reflect the demand completely; consequently, the proposed method can provide decision-making basis for railway enterprises to develop freight transportation products and to create transport service policies.

This study is significant to shippers and freight enterprises. Furthermore, the proposed method is limited for irrational shippers, who select transportation products randomly. Data can also be considerably large when investigating shippers; thus, we will further research how to deal with these data correctly and easily to enhance the practicability of the proposed method.

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