Research on design methodology for railway freight service combination plans to meet diverse demands

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Abstract

Purpose – Facing the diverse needs of large-scale customers, based on available railway service resources and service capabilities, this paper aims to research the design method of railway freight service portfolio, select optimal service solutions and provide customers with comprehensive and customized freight services.

Design/methodology/approach – Based on the characteristics of railway freight services throughout the entire process, the service system is decomposed into independent units of service functions, and a railway freight service combination model is constructed with the goal of minimizing response time, service cost and service time. A model solving algorithm based on adaptive genetic algorithm is proposed.

Findings – Using the computational model, an empirical analysis was conducted on the entire process freight service plan for starch sold from Xi'an to Chengdu as an example. The results showed that the proposed optimization model and algorithm can effectively guide the design of freight plans and provide technical support for real-time response to customers' diversified entire process freight service needs.

Originality/value – With the continuous optimization and upgrading of railway freight source structure, customer demands are becoming increasingly diverse and personalized. Studying and designing a reasonable railway freight service plan throughout the entire process is of great significance for timely response to customer needs, improving service efficiency and reducing design costs.

Keywords Diverse demands, Service pattern, Service quality, Continuous clustering

Paper type Research paper

1. Introduction

The transition in China's economy, from rapid growth to high-quality development, has resulted in frequent changes in the structure of freight demands. As a consequence, the logistics demands for energy-intensive industries, such as social bulk commodities, have slowed down, while the transport demands for e-commerce, consumer goods and cross-border logistics have experienced rapid growth. Freight demands are gradually shifting from the previous model of "large-volume transport in few varieties and at low frequencies" to "small-volume transport in multiple varieties and high frequencies". This shift necessitates the provision of quality services that prioritize higher speeds, punctuality, economical efficiency and a wider variety. To meet the logistics demands of enterprise customers and enhance the quality of railway freight services, an imperative step is the organic integration of railway freight services with modern logistics services, which aims to broaden the service scope and offer customers comprehensive and customized freight services. Facing the diverse freight demands of customers, railway freight services need to be upgraded to door-to-door

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services, which requires changes in the following two aspects. First, the service chain needs to be extended towards both ends of the "door-to-door" process to satisfy customer needs with enriched service options and cover the door-to-door freight service. The second is operation coordination among various service units, including transport, warehousing, packaging, processing, sorting, delivery and other service functions, which should be supported by efficient and integrated freight service combination plans, ensuring balanced and synchronized control over cost, time and quality. With the increasing railway development empowered by digital, networked and intelligent technologies in China, to cater to the vast array of diversified and personalized demands of customers, an Internet-based deployment of numerous traditional and independent railway freight service resources, which leverages the 95306 network freight service platform, enables real-time dynamic, efficient and intelligent combinations of freight service resources through web service composition and allows for the design of service plans ensuring prompt response, thereby paving a new path toward upgrading railway freight services to a door-to-door pattern.

Given the multitude of freight requests and the wealth of available freight service resources on the 95306 platform, new requirements have arisen concerning the design method and efficiency of railway freight service plans intended to address diverse demands. Among the research literature available, Zhang Fei *et al.* have developed a logistics-oriented web service composition model and introduced an improved NSGA-II algorithm for solving, for which the effectiveness has been demonstrated (Zhang & Zhang, 2018). Tang Li *et al.* have constructed an objective model incorporating minimal factors such as service time, cost and carbon emissions by introducing the concept of modular design (Tang & Ling, 2019). The proposed method has been verified through a case study. Shi Xiupeng has proposed that railway freight should prioritize the development of an e-commerce freight service pattern, and has designed a service plan in line with this pattern (Shi, 2012). Chen Dengke has raised the concept of a "one-stop" service pattern for railway freight, using the freight services provided by China Railway Shanghai Group Co., Ltd. as an example (Chen, 2015). Nevertheless, the dearth of research concerning the theories and methods pertaining to the formulation of freight service plans has resulted in inadequate support for the intelligent design of such plans.

Drawing from existing research outcomes and taking into account the diverse demands of customers, this paper introduces a model of railway freight service combination plans, aimed at minimizing response times, service costs, service times and other relevant factors, leveraging separate units of service functions derived from a division of the door-to-door railway freight service system. Additionally, a model solution algorithm is proposed, based on an adaptive genetic algorithm. An empirical analysis was conducted on door-to-door railway freight service plans for transportation from a starch factory in Xi'an to Chengdu. The results demonstrate that the proposed optimized model and algorithm are practical for guiding the design of freight plans in a reasonable and effective manner. Furthermore, they are suitable for application as technical support in promptly responding to diverse customer demands for door-to-door freight services.

2. Overview of railway freight service combination

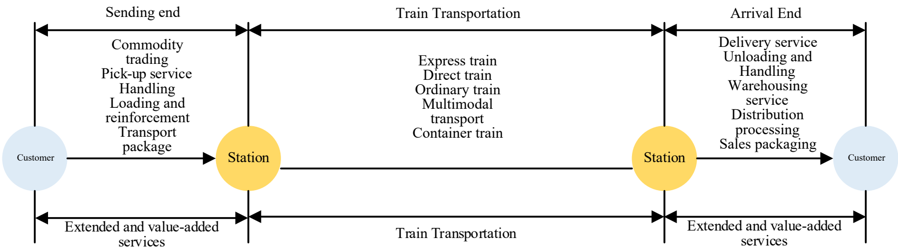
Modern railway freight services incorporate logistics elements by placing product transportation as the central focus and extending the service chain, to facilitate the shift from "station-to-station" transport to "door-to-door" services. Furthermore, the "door-to-door" service chain offers a range of value-added logistics services to deliver door-to-door freight services to customers. The activities of door-to-door railway freight transport services can be categorized into three modules. As shown in Figure 1, the first module focuses on offering fundamental transport services that revolve around railway block trains. The second module involves expanded services such as warehousing, delivery, loading and unloading. The third module encompasses an organic integration with financial, commercial and consulting services to deliver value-added services, including distribution processing, loading reinforcement and commodity trading.

2.1 Service combination process

Oriented to the diversified and personalized demands of customers and relying on railway service resources, numerous elements are effectively combined from a series of sets such as railway service providers, transport capacity resources, service options and service values according to specific rules or methods to generate freight service combination plans that integrate transport services, extended services and value-added services. During the stage of generating a railway freight service combination plan, a search and matching procedure is performed across multiple sets of service resources based on each freight request. This process, as illustrated in Figure 2, leads to the identification of candidate sets of freight services. Feasible service combination plans are then derived from these candidate service sets, utilizing a quality assessment model. Finally, the optimal plan is selected from these feasible plans.

2.2 Service assignments

A freight service assignment corresponds to a specific service combination. The process of addressing the freight demands from each customer request at the 95306 platform is referred to as a freight service assignment.



Source(s): The author's own work

Figure 1. Railway freight service process oriented to diverse demands

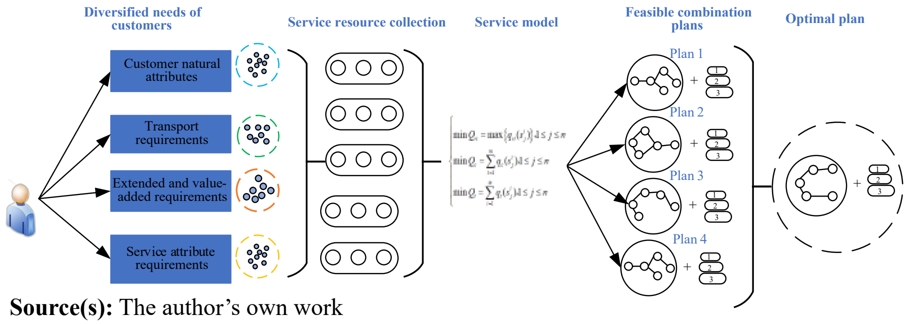


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Figure 2. Railway freight service combination process oriented to diverse demands

2.3 Service functions

Each freight service function is intended to meet a category of customer demands, including transport, distribution, loading and unloading and warehousing. The set of service functions is expressed as $S = (S_1, S_2, \ldots, S_n)$.

2.4 Candidate service resources

The service resources corresponding to each service function are referred to as candidate freight services. For example, the loading and unloading service function module corresponds to a range of loading and unloading resources such as forklifts, cranes, gantry cranes and truck cranes, which are expressed as $S_i = (s_{i1}, s_{i2}, \ldots, s_{im})$.

2.5 Service combination plan

A function S_i is selected from several freight service functions according to specific customer demands, a service resource s_{ij} is selected under each function and an initial service combination plan C_i is generated by permutation and combination.

2.6 Performance evaluation of service combination plan

The performance of freight service combination plans is determined by the attributes of quality evaluation indicators. The generated service combinations are evaluated from the aspects including service cost, service time and service response level (Guo & Wang, 2012; Liu, Song, & Xue, 2013). This evaluation not only relates to the execution quality of individual freight service assignments but also takes into account the combination structure of door-to-door service assignments, which can be incorporated as an objective function of the model.

3. Construction of objective model

The railway freight service combination can be approached as a multi-objective optimization problem.

3.1 Objective model

The set of railway freight service functions is expressed as $S = (S_1, S_2, \ldots, S_n)$, among which each function S_i includes m candidate service resources $S_i = (s_{i1}, s_{i2}, \ldots, s_{im})$ and each candidate service s_{ij} is a specific service assignment. Aiming to minimize response time Q_{rt}, service cost Q_c and service time Q_t, the model to freight service combination plans is developed as follows:

$$\begin{cases} minQ_{rt} = \sum_{i=1}^{m} b_{ij} q_{rt}(s_{ij}), \ 1 \leq j \leq n \\ minQ_c = \sum_{i=1}^{m} b_{ij} q_c(s_{ij}), \ 1 \leq j \leq n \\ minQ_t = \sum_{i=1}^{m} b_{ij} q_t(s_{ij}), \ 1 \leq j \leq n \end{cases} \tag{1}$$

where, $\boldsymbol{b_{ij}}$, as a binary decision variable, represents the service resource selection identifier. $\boldsymbol{b_{ij}} = \mathbf{1}$ indicates that the service resource $\boldsymbol{s_{ij}}$ is selected, while $\boldsymbol{b_{ij}} = \mathbf{0}$ indicates that the service resource $\boldsymbol{s_{ij}}$ is not selected.

3.2 Constraint conditions

Railway freight service combination is composed of service process combination and service function combination. Therefore, the logical structure constraints and quality evaluation constraints of a combination are the focuses of service selection.

3.2.1 Logical structure constraints. A freight service combination plan is composed of multiple sub-service resources by certain rules or methods, and each sub-task corresponds to a group of candidate service sets with the same freight service function but different service values. Generally, the combination plan involves different freight service logic, mainly including sequence, parallelism, selectivity and cyclicity.

Sequence: In the sequential combined freight-service workflow, service functions are executed in sequence, for example, in door-to-door freight services, the pick-up service, loading and unloading service, train service and delivery service are arranged in sequential order.

Selectivity: In the selective combined service, there are multiple selection branches, and the task of each branch is selectively executed with 0-1 decision variables. For example, in trunk transportation, product services from different trains can be selected.

Parallelism: In the parallel combined freight service workflow, there are many parallel branches and the tasks of parallel branches are simultaneously executed, for example, the tasks of financial service module can be executed in parallel with those of the transport module.

Cyclicity: In the cyclic combined service workflow, a task is cyclically executed for k times before proceeding with other tasks. Cycle structure can be regarded as a sequential structure that is executed for multiple times. Therefore, it is not studied herein.

When the c service function is the start and the d service function is of sequential or parallel structure, each service function is bound with specific service resources, Formula (2) represents the constraints of sequential and parallel structures. When the e service function is the start and the f service function is of selective structure, only one service function is allowed to be bound with specific services, Formula (3) represents the constraints of selective structure.

$$s.t$$

$$\sum_{i=1}^{J} b_{ij} = 1, i = c, c+1, \ldots, c+d \tag{2}$$

$$\sum\nolimits_{i=e}^{e+f} \sum_{i=1}^{J} b_{ij} = 1, \tag{3}$$

3.2.2 Quality evaluation constraints of combination plan. In practical freight services, customer's expectation arising from their diverse demands for door-to-door freight services becomes the evaluation constraints of service combination plan, which mainly includes treatment time, service time and cost constraints.

(1) Treatment time constraint

The response time Q_{rt} of completing all service assignments in the freight service combination shall not exceed the customer's expected maximum time, for example, the response time for each service is six hours at maximum. In this case, the constraint is:

$$\sum_{i=1}^{m} q_{rt}(s_{ij}) \leq Q_{rt}^{max} \tag{4}$$

(2) Service time constraint

The total time Q_t of completing all service tasks in the freight service combination shall not exceed the customer's expected maximum time, for example, the given door-to-door freight service time is 72 hours at maximum. In this case, the constraint is:

$$\sum_{i=1}^{m} q_t(s_{ij}) \leq Q_t^{max} \tag{5}$$

(3) Cost constraint

The total expenditure Q_c of completing all service tasks in the freight service combination shall not exceed the customer's maximum budget expenditure, for example, the given door-to-door freight service cost is at most RMB 20,000. In this case, the constraint formula is:

$$\sum_{i=1}^{m} q_c(s_{ij}) \leq Q_c^{max} \tag{6}$$

(4) Selection constraint

Selection identifier constraint of service resources means that only one service resource is selected in the set of selected service function resources, and no service resource can be selected under the service function that is not selected. In this case, the constraint formula is as follows:

$$\sum_{i=1}^{m} b_{ij} = b_j \tag{7}$$

The final constraint condition is:

$$s.t \quad \begin{cases} \sum_{i=1}^{m} b_{ij} q_{rt}(s_{ij}) \leq Q_{rt}^{max} \\ \sum_{i=1}^{m} b_{ij} q_c(s_{ij}) \leq Q_c^{max} \\ \sum_{i=1}^{m} b_{ij} q_t(s_{ij}) \leq Q_t^{max} \\ \sum_{i=1}^{m} b_{ij} = b_j \end{cases} \tag{8}$$

where, $q_{rt}(x_{ij})$, $q_c(x_{ij})$, $q_t(x_{ij})$ represent the treatment time, service cost and service time of a single service item, respectively. Q_{rt}^{max}, Q_c^{max}, Q_t^{max} represent the maximum treatment time, the maximum service cost and the maximum service time of the full services, respectively.

4. Adaptive genetic algorithm

For the multi-objective service combination problem, commonly used particle swarm algorithms, ant colony algorithms, genetic algorithms, etc. (Huang, Wang, & Xie, 2011; Fan, Jiang & Fang, 2010; İsmail & Koç, 2015; Wang, Liu, & Zhu, 2008; Xia, Cheng, & Chen, 2012), there are often easy to fall into the local optimization and other problems, in this paper, an adaptive genetic algorithm is used to solve the target model.

4.1 Algorithm optimization idea

Existing literature for genetic algorithm improvement has more research (Xu & Chen, 2019; Xiong, Feng, & Chen, 2012; Cha & Yang, 2013; Zhang & Wu, 2012), to meet the extensive and diverse demands of freight transport by railways, with the expansion of search space, challenges are created under a certain population size, such as reduced search efficiency, premature convergence, and local optimization.

The individual selection in a genetic algorithm works by elite optimization strategy, which optimizes two populations at the same time, including the primary population C and the external population E. Among them, E comprises elites, and the parents are obtained from C and E, respectively, to generate offspring. The most suitable freight service combination plan (i.e. the elite) is selected according to the fitness function. The selected elite with best fitness is not used for genetic manipulation but for the replacement of the most unsuitable combination plan produced from the current generation through genetic manipulation. Through the elite optimization strategy, the best combination plan of parents is passed on to the next generation, while the worst combination plan is directly eliminated, effectively ensuring the quality of genetic combined scheme.

4.2 Genetic manipulation

(1) Chromosome coding

The service combination plan should select service resources for each service function, so the coding of this plan includes two parts: service function coding and service resource coding. The certificate coding plan of this paper is adopted to develop a bilayer coding system.

In genetic manipulation, each chromosome represents a service combination plan C_i, which directly reflects the combination structure of each freight service function. Therefore, the first layer of chromosomes is composed of n service functions and objective functions, covering $n+3$ gene loci. The first n gene loci represents the selected service function, which is expressed as an integer, and the last three gene loci represents the objective function value. The coding system of the first layer of chromosomes is as follows:

S_1	S_2	……	S_{n-1}	S_n	Q_{rt}	Q_c	Q_t

The first n gene loci of the second layer of chromosomes represents a service resource for storing a binary code ID. The relationship between the combined service plans can be intuitively reflected by relationship matrix. The elements on the leading diagonal of the relationship matrix represent the gene locus of the genetic algorithm chromosome, and the off-diagonal elements represent the relationship between the combined services. The chromosome coding is shown in the following figure.

As shown in Figure 3, the diagonal elements $S_{ij}= 1$ indicate that the service resource is selected by the service combination plan, and $S_{ij}= 0$ indicates that the service resource is not selected by the service combination plan. The off-diagonal element S_{ij} represents the service resource relationship locus, and $S_{ij}= 1$ indicates that the service function i is adjacent to and directly in front of the service function j. Chromosome coding is realized by arranging the elements on the leading diagonal of matrix. The initial population (i.e. population) for genetic algorithm is actually the codes selected from service combinations, and the elements on the diagonals of matrix are the objects of various genetic manipulations.

(2) Chromosome initialization

Determine the freight service functions and control structure that meet diverse demands, and select any freight services that meet local optimal constraints from the candidate resources corresponding to each service function to generate the initial population P_0.

(3) Elite strategy

First, the parents are obtained from the current population and the elite population, respectively, and the top k elites are selected from the offspring of each generation into the external population. When the number of individuals in the external population reaches the limit value of 100, the new individuals need to be ranked and selected before entry and those who rank behind 100 will be eliminated and enter into the current population. If the number of current population exceeds 100, ranking and selection should be applied likewise.

4.3 Genetic algorithm steps

In the course of solving railway freight service combination plan model with adaptive genetic algorithm, the following optimized search steps should be used.

Step1: Set initial parameters, including population size N, penalty intensity coefficient α_1, α_2, crossover probability p_c, mutation probability p_m and genetic algebra T.

Step2: Set a decimal code for the chromosome of each freight service combination plan, and a plan C_i is expressed in a string with the corresponding code of service functions. According to the population size and individual ranking, N service combination plan individuals are randomly generated to form the initial population.

Step3: Individual evaluation. Decode the individual C_i to find the target value of each individual in the population, and judge whether the individual C_i meets the constraint conditions of the target model.

Step4: Elite strategy.

Step4.1: Find out the individual $max(c_t^i)$ with the best fitness and the individual $min(c_t^i)$ with the worst fitness in the current population;

Step4.2: If the fitness of the best individual in the current population is better than that of the best individual ever recorded, the best individual in the current population should be taken as the new best individual;

Step4.3: Replace the worst individual in the current population with the best individual ever recorded.

Step5: Selection operation.

$$\begin{vmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{vmatrix}$$

Figure 3.
Chromosome coding

$\sum_{i=1}^{N} F(c_t^i)$ *Step5.1*: Calculate the sum of the fitness of all individuals in the population;

Step5.2: Calculate the relative fitness $p(c_t^i) = F(c_t^i)/\sum_{i=1}^{N} F(c_t^i)$ of each individual, and rank these individuals from small to large by fitness; where, $p(c_t^i)$ represents the probability of individual i to be selected and $F(c_t^i)$ is the fitness value of an individual.

Step5.3: Sequentially generate a uniformly distributed random number r in the interval [0,1], if $r \le p(c_t^1)$, select the first individual; if $p(c_t^{i-1}) < r \le p(c_t^i)$, select the i individual. Repeat this step for N times to generate the next population.

Step*6*: Crossover operation.

Step*6.1*: Generate .N evenly distributed random numbers $r_1, \ldots, r_i, \ldots r_N$ in the interval [0,1] in turn, if $r_i < p_c$, repeat this step using the individual c_t^i as the parent for crossover operation to form a parent population for crossover operation;

Step*6.2*: Randomly select two from those parents and also a crossover point, and exchange some chromosomes between the two set crossover points with crossover probability .P_c. Keep the daughter chromosome, and remove the parent chromosome from the parent chromosome population for crossover operation. Repeat this step until all the parent chromosomes are crossed.

Step*7*: Mutation operation. Generate N evenly distributed random numbers $r_1, \ldots, r_i \ldots, r_N$, in the interval [0,1] in turn, if $r_i < p_m$, perform mutation operation on the individual c_t^i.

Step*8*: Judge whether t is less than the genetic algebra T, if Yes, go to Step9, if No, go back to *Step*2

Step*9*: Stop the calculation, and the individual in the population who maximizes the objective function is taken as the optimal solution for output.

5. Case Study

5.1 Case description

A starch company in Shaanxi has five corn starch production lines. It has an annual processing and transformation capacity of one million tons of corn, producing 700,000 tons of corn starch as well as 260,000 tons of by-products such as corn oil, corn protein powder, corn germ meal and corn bran. The company's delivery is made from Huxian Station, which is approximately 6 km away from the company. After the goods arrive at Chengdu North Railway Station, the average distance from Chengdu North Railway Station to each distribution point is about 25 km. The railway distance from Huxian Station to Xi'an West Railway Station is 42 km, and the railway distance from Xi'an West Railway Station to Chengdu North Railway Station is 842 km. For pallet traffic, the pallet can carry 1 ton of goods, while the freight volume for covered goods wagon is 60 tons/wagon and for 40-foot containers is 27 tons/container. The specific freight service requirements of the company are shown in Table 1.

Based on the aforementioned freight demands of corporate customers, the transport, extended and value-added freight service resource set available at the corresponding station sections of China Railway Xi'an Group Co., Ltd. and China Railway Chengdu Group Co., Ltd. are presented in Table 2

Taking into account the available freight service resources at the corresponding station sections of China Railway Xi'an Group Co., Ltd. and China Railway Chengdu Group Co.,

Classification of customer requirements	Specific service requirements	Description of requirements
Customer attributes	Region	Xi'an, Shaanxi Province
	Delivery destination	Chengdu, Sichuan Province
	Single-batch freight volume	1,800 tons
Goods category	Food	Be kept away from moisture
Basic transport requirements	Transport requirements	No specific limitations on train schedules; bagged packaging should be intact and in good condition
Extended service	Pick-up service	The enterprise has no private siding, so short-distance transportation by trucks is required to the loading point of railways
	Handling	No specific requirements for handling method
	Delivery service	Delivery in batches according to sales volume
	Warehousing service	Due to limited space at the distributor's site, five-day warehousing service for some goods is required
	Loading reinforcement	Loading reinforcement materials as well as containerized equipment are required
Value-added service	Sales packaging	Repackaging is required as different distributors need different specifications and quantities of goods
Service attributes	Service time	Except for warehousing services, the door-to-door service time is expected to not exceed 144h
	Service cost	Except for the warehousing service cost, the door-to-door service cost is expected to not exceed RMB 800,000
	Service response time	The average response time for each service function will not exceed 6h

Source(s): The author's own work

Table 1.
Customer service requirements of the starch company

Service classification	Resource description	Service resource options
Transport services	Optionality of train types	Express train, ordinary train and container train
Extended service	Optionality of pick-up plans	Plan 1: short-distance transportation by container trucks to Xi'an West Railway Station Plan 2: short-distance transportation by container trucks to Huxian Station, followed by railway transfer to Xi'an West Railway Station for consolidation
	Specificity of delivery plans	Delivery in batches
	Optionality of handling tools	Fast operation of fork-lift trucks, and normal speed operation of fork-lift trucks
	Optionality of warehouses	Flat warehouses and three-dimensional warehouses
Value-added service	Optionality of loading reinforcement materials	Flexible freight containers and pallets

Source(s): The author's own work

Table 2.
Information of candidate service resources

Ltd., for railway loading and unloading operations, four fork-lift trucks can be deployed to work in pairs, transporting 0.9 tons of goods by relay forklifting, ensuring that the goods do not touch the ground before being loaded into covered goods wagons or containers. For loading operations, two sets of reach stackers can be deployed. For railway transport products, there are options available including container trains and ordinary covered goods wagon trains. Regarding warehousing, CR-Chengdu provides options of flat warehouses and three-dimensional warehouses at the destination station. As for loading reinforcement materials, based on the starch packaging specifications, there are two options available: flexible freight containers and pallets. In addition, there are two options for transporting goods from the starch factory to the station. The first option is to transport goods by container trucks in a short distance to Xi'an West Railway Station, and the second option is to transport goods by container trucks in a short distance to Huxian Station, and then transfer them by railway to Xi'an West Railway Station for consolidation. Relatively optimal solutions for railway freight service plans is shown in Table 3.

5.2 Solution results

By combining the actual data of the case, an adaptive genetic algorithm is applied to solve the built service combination optimization model. The relevant parameter settings are as follows: three objective functions, 87 decision variables, a population size of 20, 100 iterations, a crossover probability of 0.9 and a mutation probability of 0.1.

After conducting the solution computations, three relatively optimal solutions for railway freight service plans are obtained, thereby excluding other feasible combination plans. Plan 1 has the shortest service time and the shortest response time, with a door-to-door service time of only 56.6 h. However, it has the highest cost. Plan 2 has the lowest cost, with a door-to-door service cost of nearly RMB 540,000, but it has the longest door-to-door service time and the longest response time. Plan 3 is a compromise plan, with the service cost, service time and response time falling in the middle range. For the three plans, in addition to the above three indicators, other factors such as customer satisfaction, freight damage and shortage rate, punctuality rate, service resource reliability, service accessibility and resource conservation level are considered and fuzzy comprehensive assessment method is adopted during evaluation and selection of the plans. After the calculation, Plan 3 is identified as the optimal railway freight service combination plan with a door-to-door service time of 94.7 hours and a service price of RMB 558,671 and total response time 34 hours. The specific implementation process of the freight service is shown in Table 4.

6. Conclusion

Relying on the 95306 network freight service platform, China's railway freight transportation sector has been providing freight services to the greatest extent. To cater to the vast array of diversified and personalized demands of customers, new requirements have arisen concerning the design method and efficiency of railway freight service plans. The research on the design methods of railway freight service combination plans aims to promptly respond to customer needs and provide technical support for the design of railway freight service plans. Based on a division of the service system into separate units of service functions depending on characteristics of the door-to-door railway freight service model, this paper presents a model, that utilizes these units to create railway freight service combination plans with minimized response times, service costs, service times and other relevant factors, and proposes a model solution algorithm based on an adaptive genetic algorithm. It can achieve rapid generation of door-to-door freight service plans, which effectively addresses the issue of low efficiency in manual configuration. Through comprehensive evaluation of indicators such as the response time, service cost and service time for the freight service plans, the overall efficiency and benefit of the plan are optimized.

Table 3.
Relatively optimal solutions for railway freight service plans

S/N		Departure end			Loading and handling	Train transportation		Unloading and handling	Arrival end			Value-added service		Total
		Truck loading	Truck pick-up	Truck unloading		Transfer	Type of trains		Truck loading	Truck delivery	Truck unloading	Warehousing	Loading reinforcement	
Plan 1	Mode selection	Fast operation	Normal speed pick-up	Fast operation	Fast operation	Truck transfer	Container train	Fast operation	Fast operation	Normal speed delivery	Fast operation	Three-dimensional warehouse	Pallet	Total
	Service time	8.7	1	8.7	12	0.5	12	12	8.7	1.5	8.7	–	–	73.8
	Service cost	15,057	36,000	15,057	59,295	67,000	2,95,557	59,295	15,057	41,239	15,057	55,800	27,000	7,01,414
	Response time	4	0	4	2	0	4	2	4	0	4	–	–	24
Plan 2	Mode selection	Normal speed operation	Normal speed pick-up	Normal speed operation	Normal speed operation	Railway transfer	Ordinary train	Normal speed operation	Normal speed operation	Normal speed delivery	Normal speed operation	Three-dimensional warehouse	Pallet	Total
	Service time	15.5	1	15.5	19	5	28.4	19	15.5	1.5	15.5	–	–	135.9
	Service cost	12,443	36,000	12,443	14,416	41,798	2,56,224	14,416	12,443	41,239	12,443	55,800	27,000	5,36,665
	Response time	6	0	6	4	8	6	4	6	0	6	–	–	46
Plan 3	Mode selection	Fast operation	Normal speed pick-up	Fast operation	Fast operation	Railway transfer	Normal speed train	Fast operation	Fast operation	Normal speed delivery	Fast operation	Three-dimensional warehouse	Pallet	Total
	Service time	8.7	1	8.7	12/	5	28.4	12	8.7	1.5	8.7	–	–	94.7
	Service cost	15,057	36,000	15,057	20,191	41,798	2,56,224	20,191	15,057	41,239	15,057	55,800	27,000	5,58,671
	Response time	4	0	4	2	8	6	2	4	0	4	–	–	34

Source(s): The author's own work

S/N	Service activities	Service resource options used	Service time (H)	Service cost (RMB)	Response time (H)
1	Truck loading at the departure end	Rapid unloading of container trucks	8.7	15,057	4
2	Truck Pick-up	Short-distance transportation by container trucks to Huxian Station	1	36,000	0
3	Truck unloading at the departure end	Rapid unloading of container trucks	8.7	15,057	4
4	Railway loading	Quick relay loading by four fork-lift trucks	12	20,191	2
5	Railway transfer	Railway transfer to Xi'an West Railway Station for consolidation	5	41,798	8
6	Train Transportation	Ordinary covered goods wagon train	28.4	2,56224	6
7	Railway unloading	Quick relay unloading by four fork-lift trucks	12	20,191	2
8	Truck loading	Rapid unloading of container trucks	8.7	15,057	4
9	Truck delivery	Short-distance delivery by container trucks	1.5	41,239	0
10	Truck unloading	Rapid unloading of container trucks	8.7	15,057	4
11	Warehousing	Three-dimensional warehouse (warehouse-in/out fees, and storage fees)	–	55,800	–
12	Loading reinforcement materials	Pallet	–	27,000	–
Total			94.7	5,58,671	34

Source(s): The author's own work

Table 4. Optimal implementation process of railway freight service plan

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