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Research on Optimization Algorithm of Single-block Train Formation Plan of Technical Station

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Abstract

The optimization of train formation plan is a large-scale combinatorial optimization problem, which is difficult to solve. This paper mainly studies the optimization algorithm of the single-block train formation plan. The corresponding mathematical model is established by consulting relevant literature, and a positive feedback search algorithm based on absolute conditions is proposed. First of all, the wagon flow that meets the absolute conditions directly runs through train flow without making other choices. For the wagon flow that does not meet the absolute conditions, select the target station to reach directly according to the probability. The probability of wagon flow selecting a station is calculated according to the pheromone of the wagon flow at the station. At the same time, a pheromone update strategy with positive feedback mechanism is proposed to make the search process converge. Finally, the feasibility of the algorithm and the necessity of introducing absolute conditions into the algorithm are verified by taking eight technical stations in the linear direction of the road network as examples.

Keywords: Single-block train, Train formation plan, Absolute condition, Positive feedback mechanism.

1 Introduction

The task of the train formation plan (TFP) of the technical station is to organize the wagon flows sent by the technical station into different arrival and different types of trains according to the destination. The optimization purpose of TFP is to reduce wagon-hour consumption, reduce transportation costs, and indirectly reduce greenhouse gas emissions[1]. The optimization of TFP is a large-scale combinatorial optimization problem, which is difficult to solve. According to the different forms of wagon flow organization, the TFP of the technical station includes single-block TFP and multi-block TFP. A single-block train is the most basic organizational form of a freight train. This paper mainly studies the optimization algorithm of single-block TFP. Optimization methods can be classified into three categories according to their properties. The first is the exhaustive method, also known as the absolute calculation method, which is to calculate the total wagon-hours consumption for all TFPs, and the one with the minimum total wagon-hours is the optimal scheme. The algorithm is simple and computationally heavy. When the number of technical stations reaches 9, it is difficult to obtain the optimal solution even using computers. The second is the screening method, whose main feature is to delete some disadvantageous schemes through certain criteria. Thus reducing the search scope and improving the efficiency of the solution. Then compare and analyze the undeleted schemes and select the economic and reasonable scheme. There are many algorithms belonging to this kind of method, among which the tabular method is the most common. The tabular calculation method has the advantages of direct-view, simplicity, and a small calculation workload. In terms of the method idea, the tabular calculation method is not to calculate the wagon-hour consumption of all TFPs, but to use several criteria to determine the definitely favorable train flow and directly eliminate the unreasonable train flow. For the possible favorable train flow, calculate the wagon-hour consumption according to different wagon flow consolidation methods, and then compare and select. These criteria include absolute conditions, necessary conditions, and sufficient conditions. In a small number of technical stations and basically in a straight line direction, the use of tabular calculation can often find the optimal solution quickly and conveniently. However, the tabular method has two essential disadvantages: first, after the initial scheme is formed, the optimal scheme is solved by repeatedly merging the wagon flow to calculate the saved wagon-hour. The whole merger process is blind and there are no definite rules to follow. Second, there is no criterion to determine whether the solution is the optimal solution, and when the number of technical stations is large, it is difficult to ensure that the optimal solution is not missed. The third kind can be collectively called the mathematical programming method, which is to transform the wagon flow organization problem into a kind of mathematical programming problem for modeling and solving. There are integer programming methods and dynamic programming methods in this category. For the third type of optimization method, domestic and foreign scholars have carried out a lot of research and exploration:

Some scholars proposed a mathematical programming model of TFP with fuzzy cost and proposed an efficient hybrid algorithm combining local branch and relaxation-induced neighborhood search methods [2]. In 2011, a bilevel programming model was proposed, and a simulated annealing algorithm was used to solve the model to obtain TFP that meets the remote re-classification rules [3]. Some scholars have established a comprehensive optimization model of TFP using single-block trains and two-block trains, aiming to minimize the total wagon-hours consumption of all yards [4]. Some scholars have established a 0-1 programming multi-objective model and proposed an optimization algorithm based on block coding improved genetic algorithm to optimize TFP [5]. Some research results show that the use of variable criteria in the formulation of TFP can improve its stability, reduce the number of adjustments and reduce the operating costs of implementing the plan [6]. Some scholars have proposed a new method to calculate the plan of forming a through train of a single group within the section of predetermined railway stations [7]. Some scholars have proposed a nonlinear binary programming model and a heuristic solution method based on simulated annealing to solve the mathematical model in order to reduce the total cost of TFP and traffic path optimization [8]. As early as 2009, some scholars used multi-agent methods to study the TFP problem and verified the effectiveness and feasibility of the model through simulation examples [9]. Some scholars also proposed a parallel FP growth mining algorithm with load balancing constraints[10] and new modeling ideas[11], which also provided new ideas for TFP optimization. Some scholars used improved genetic algorithms to design automatic calculation methods for TFP and achieved good results [12]. Some scholars have studied the optimization of TFP of large railway network trains under the condition of elastic capacity [13]. In 2019, some scholars designed an improved solution algorithm for TFP optimization based on Branch-and-Price [14]. Some scholars put forward the collaborative optimization method of single-block TFP and took the Belarusian railway section as an example to check the calculation [15]. Some scholars have proposed a new linear programming model for the TFP problem using a mixed integer programming method and designed an effective heuristic algorithm to solve it [16]. Genetic algorithm has strong global search ability, some scholars have used improved genetic algorithms to solve mechanical operation sequence problems [17], flexible job shop scheduling problems [18], and 3D-container loading problems [19], which also provides a reference for designing optimization algorithms in this paper.

From the above research literature, it can be seen that domestic and foreign scholars optimize TFP from both models and algorithms. The research on the optimization of the model is relatively mature, but the research on the solution algorithm is still insufficient. Therefore, this paper mainly studies the optimization algorithm of TFP.

2 Establish a mathematical model

2.1 Description and assumption of the problem

There are several technical stations on a railway network, and there are many wagon flows from each technical station. A wagon flow can form a train flow alone. However, in general, it is impossible for each wagon flow to form a single train flow. It is necessary to merge some wagon flows to generate a combined train flow. Therefore, a TFP is essentially a combination of all wagon flows in the direction. The wagon flows from the same technical station are combined to form the TFP of the technical station. The TFP of all technical stations in the direction is combined to form the TFP of the direction. The more technical stations in a certain direction, the more TFP in that direction. Now we need to find the best TFP from many TFPs. In order to solve this problem, the following assumptions are made:

(1) The wagon flow between any two technical stations on the road network is known.

(2) The accumulation of wagon-hour required by each wagon flow to operate through train flow (TTF) at the departure station is known.

(3) The district train flow must be run between two adjacent technical stations.

(4) In order to simplify the model, the wagon-hour consumption irrelevant to the change of the scheme is not included in the calculation when calculating the scheme value. No matter what TFP, the district train flow always exists, and their wagon-hour consumption is irrelevant to the scheme change. Therefore, the wagon-hour consumption generated by the district train flow is not calculated when calculating the wagon-hour consumption, but only the wagon-hour consumption of TTF. Therefore, the model built in this paper does not consider the wagon flow between two adjacent technical stations.

(5) It is assumed that the number of shunting lines at each technical station can meet the requirements.

2.2 Parameters and variables

This paper defines the following parameters and variables:

(1)L_{ij} refers to the number of sections between technical station i and technical station j. $L_{ij} = 1$ means only one section is included between station i and station j.

(2)x_{ij} is a 0-1 decision variable. It indicates whether to operate the TTF from station i to station j, $Yes = 1$, $No = 0$. And station i and station j meet the following conditions: $L_{ij} \geq 2$. This inequality indicates that there are at least 2 sections between station i and station j.

(3)x_{ij}^k is a 0-1 decision variable. It indicates whether station k is the first reorganization station of ij wagon flow. $Yes = 1$, $No = 0$. And $L_{ij} \geq 2$, that is, there are at least 2 sections between station i and station j.

(4) S is the collection of technical stations on the road network.

(5) $B(k)$ represents the collection of stations in front of station k.

(6) $A(k)$ represents the collection of stations behind station k.

(7) w_{ij} refers to the fixed wagon flow from station i to station j.

(8)f_{ij} is the state variable. It represents the total wagon flow from station i to station j, and f_{ij} consists of two parts. One part is the fixed wagon flow from station i to station j, namely w_{ij}; the other part of the wagon flow is the wagon flow from the station behind station i to station j, which is sent to station j after the reorganization at station i.

(9)C_k represents the effective sorting capacity of station k.

(10) T_{ij} refers to the accumulation wagon-hour required for gathering a train flow from station i to station j.

(11) t_k represents the time saving of wagon flow through station k without reorganization.

(12) H_{ij} refers to the collection of technical stations between station i and station j.

2.3 Establishment of model

In 2006, some scholars established the optimization model of the single-block TFP of the technology station [5]. This paper makes some improvements on the basis of this model. The model establishment process in this paper is as follows:

The principle of wagon flow organization in the technical station requires that the same wagon flow should not be separated. According to this principle, when two or more wagon flows are merged into a shorter train flow and driven to a closer technical station, the same wagon flow cannot be merged with different wagon flows, and included in several different train flows. Therefore, the following constraints must be met for any wagon flow in TFP from station i to station j, see equation (1).

$$\sum_{k \in H_{ij}} x_{ij}^{k} + x_{ij} = 1 \quad \forall i, j \in S \tag{1}$$

If station k is the first reorganization station of f_{ij}, and $L_{ik} \geq 2$, the following constraints need to be met, see equation (2). The expression of equation (2) means that if $x_{ij}^{k} = 1$, that is, f_{ij} chooses to reorganize at station k, then the shorter f_{ik} must run TTF instead of reorganizing halfway from station i to station k, that is, $x_{ik} = 1$. When $x_{ij}^{k} = 0$, it means that f_{ij} is not reorganized at station k. At this time, f_{ik} can run TTF or reorganize halfway from i to k.

$$x_{ik} \geq x_{ij}^{k} \quad \forall i, k, j \in S, L_{ik} \geq 2 \tag{2}$$

When the long-haul wagon flow is combined with the short-haul wagon flow, the long-haul wagon flow has to be reorganized at the terminal of the short-haul wagon flow. At this time, the long-haul wagon flow is combined with the wagon flow with the same destination sent by the terminal. This is another principle of wagon flow organization, called the continuous merging principle of wagon flow. According to this principle, the following constraints are established. See equation (3).

$$f_{ij} = w_{ij} + \sum_{y \in A(i)} f_{yj} x_{yj}^{i} \quad \forall i, j \in S \text{ And } L_{ij} \geq 2 \tag{3}$$

The sorting capacity of each technical station is certain, so the total sorting wagons of each technical station in the midway cannot exceed the effective sorting capacity of each technical station. Therefore, the following constraints need to be met. See equation (4).

$$\sum_{i \in A(k)} \sum_{j \in B(k)} f_{ij} x_{ij}^{k} \leq C_k \tag{4}$$

See equation (5) for the mathematical model aiming at minimizing the total wagon-hours consumption of the road network.

$$\min F_H = \sum_{i \in S} \sum_{j \in S} T_{ij} x_{ij} + \sum_{k \in S} t_k \left(\sum_{i \in A(k)} \sum_{j \in B(k)} f_{ij} x_{ij}^{k} \right) \tag{5}$$

3 Solving strategy

Combining the advantages and disadvantages of various algorithms and the characteristics of TFP, this paper proposes a positive feedback search algorithm based on absolute conditions. The idea of the algorithm can be described as follows: TTF is performed on the wagon flow that meets the absolute conditions of the table calculation method. For the wagon flow that does not meet the absolute condition, select the target station to reach directly according to the probability. The probability of wagon flow selecting a station is calculated according to the pheromone of the wagon flow at the station. The size of the pheromone of each wagon flow at a certain station needs to be updated after completing an iteration. The update strategy is that only the best TFP in this iteration can update the pheromone. It should be emphasized that the pheromone concentrations of different wagon flows at the same station are independent of each other and cannot be accumulated. The solution process of the algorithm includes four parts: expression of the solution, selection strategy, optimization strategy, and pheromone update strategy. This paper takes a certain direction of the line with n technical stations as an example to describe the algorithm and its solution process in detail. The line layout is shown in Figure 1.

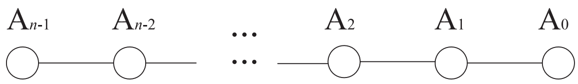

Figure 1: Schematic diagram of line layout

3.1 Expression of solution

In the direction from A_{n-1} to A_0, A_{n-1} is the first departure station, and the length of $f_{(n-1)0}$ in A_{n-1} station is the longest. $f_{(n-1)0}$ can choose to reorganize at any station from A_{n-2} to A_1, or directly reach station A_0. Therefore, the option of $f_{(n-1)0}$ can be expressed as: $x^{n-2}_{(n-1)0}$, $x^{n-3}_{(n-1)0}$, $\dots$, $x^{1}_{(n-1)0}$, $x_{(n-1)0}$. Similarly, the option of $f_{(n-1)1}$ can be expressed as: $x^{n-2}_{(n-1)1}$, $x^{n-3}_{(n-1)1}$, $\dots$, $x^{2}_{(n-1)1}$, $x_{(n-1)1}$. All the options of wagon flow are concatenated and separated by "|" in the middle, which is the expressive form of the solution. The rules of series connection are as follows: in the direction of A_{n-1} to A_0, the series connection is in the order of A_{n-1} to A_0; in the same station, it is connected in series according to the principle of long-haul wagon flow first and then short-haul wagon flow. The expression form of the solution is:

$|x^{n-2}_{(n-1)0}, x^{n-3}_{(n-1)0}, \dots, x^{1}_{(n-1)0}, x_{(n-1)0}|\ x^{n-2}_{(n-1)1}, x^{n-3}_{(n-1)1}, \dots, x^{2}_{(n-1)1}, x_{(n-1)1}|\dots|x^{n-3}_{(n-2)0}, x^{n-4}_{(n-2)0}, \dots, x^{1}_{(n-2)0}, x_{(n-2)0}|\dots|x^{1}_{20}, x_{20}|$

3.2 Selection strategy

In essence, the solution is to select the direct destination stations in a certain order for each wagon flow under constraint conditions. Take $f_{(n-1)0}$ as an example, $f_{(n-1)0}$ can select any station from A_{n-2} to A_0, including A_{n-2} and A_0. If station A_0 is selected, it means that $f_{(n-1)0}$ runs TTF; if station A_{n-4} is selected, it means that $f_{(n-1)0}$ is reorganized at station A_{n-4}. According to the principle of continuous merging, that is, the constraint of equation (3), each wagon flow has only one chance to choose. When $f_{(n-1)0}$ chooses to reorganize at station A_{n-4}, $f_{(n-1)0}$ runs the train flow from A_{n-1} to A_{n-4}, and then $f_{(n-1)0}$ and $w_{(n-4)0}$ merge into a wagon flow at station A_{n-4}, that is, $f_{(n-4)0}$. As for how to transport $f_{(n-4)0}$ to station A_0 in the future, $f_{(n-4)0}$ will choose. According to the principle that the same wagon flow does not break up, that is, the constraint of equation (1), the value of the station selected by wagon flow is 1, and the value of other stations is equal to 0. For example, when $f_{(n-1)0}$ is reorganized at station A_3, $x^{3}_{(n-1)0} = 1$, and the values of other stations are 0. According to the constraint of equation (2), when $f_{(n-1)0}$ chooses to reorganize at station A_{n-4}, $f_{(n-1)(n-4)}$ can only choose to operate TTF, that is, $x_{(n-1)(n-4)} = 1$. About the order of wagon flow selection. In the direction from A_{n-1} to A_0, the wagon flow of station A_{n-1} first selects the direct destination station, and then the wagon flow of A_{n-2} station selects the direct destination station, and so on. On the contrary, in the direction from A_0 to A_{n-1}, the wagon flow of station A_0 will first select the direct destination station. In the wagon flow of the same station, the long-haul wagon flow first selects the direct destination station, and then the short-haul wagon flow selects the direct destination station. After all wagon flows have selected, a TFP will be formed. Finally, it is checked whether TFP meets the constraint of equation (4). The scheme that does not meet the constraint of equation (4) is directly discarded.

3.3 Optimization strategy

In order to improve the efficiency of the solution, when each wagon flow selects the direct destination station, the wagon flow that meets the absolute conditions of the table calculation method directly selects to run the TTF. By this way, the number of solutions can be reduced, so as to narrow the search scope and improve the efficiency of the solution. Absolute conditions can be expressed in equation (6). In equation (6), f_{ij} represents the size of wagon flow, t_k represents the time saved by TTF at station k, and K represents the collection of technical stations between i and j. f_{ij} in this paper consists of two parts, one is the fixed wagon flow from station i to station j; The other part of the wagon flow is the wagon flow from the station behind station i to station j, which is sent to station j after the reorganization at station i.

$$f_{ij} \cdot \min \{t_k \mid k \in K\} \geq T_{ij} \tag{6}$$

The wagon flow that meets the absolute conditions directly runs the TTF, and the wagon flow that does not meet the absolute conditions selects the direct destination station according to the probability. First, define the set $visit_k$, which represents the collection of all technical stations in the direction of i to j except for the station i. Define the variable p_{ij}^k, which means the probability that f_{ij} selects station k, where $k \in visit_k$. The expression of p_{ij}^k is shown in equation (7). In equation (7), τ_{ij}^k represents the pheromone concentration of f_{ij} at station k, where $k \in visit_k$. The higher the pheromone concentration of f_{ij} in a station, the greater the probability of being selected, but it does not mean that the one with the highest probability must be selected. In the actual selection process, the roulette wheel selection is used to select the target station.

$$p_{ij}^k = \frac{\tau_{ij}^k}{\sum_{\mu \in visit_k} \tau_{ij}^\mu} \tag{7}$$

3.4 Pheromone update strategy

First of all, it should be emphasized that only the pheromones generated by the same wagon flow at the same station can be accumulated, while the pheromones generated by different wagon flows at the same station are independent of each other and cannot be accumulated. When updating the pheromone concentration of one wagon flow at station k, the pheromone concentration of other wagon flows at station k remains unchanged. For example: $\tau_{61}^3 = 2$, indicating that the pheromone concentration of f_{61} at station A_3 is equal to 2; $\tau_{51}^3 = 3$, indicating that the pheromone concentration of f_{51} at station A_3 is 3. The pheromone concentrations of the above two wagon flows at station A_3 are independent of each other and do not affect each other. Pheromone update strategy: In one iteration, several TFPs are obtained, but only the best TFP in this iteration can update the pheromone. See equation (8) for the pheromone update strategy. In equation (8), $k \in visit_k$, δ indicates pheromone increment; $\tau_{ij}^k(n)$ represents the pheromone concentration of f_{ij} at station k in the nth iteration; $y_{ij}^k(n, optimal)$ indicates whether f_{ij} selects station k in the optimal TFP of the nth iteration. $Yes = 1$, $No = 0$. The pheromone update strategy is essentially a positive feedback mechanism, which increases the pheromone concentration of the target station selected by each wagon flow in the optimal scheme obtained in each iteration, so as to increase the probability of being selected in subsequent iterations.

$$\tau_{ij}^k(n+1) = \begin{cases} \tau_{ij}^k(n) + \delta, y_{ij}^k(n, \ optimal \ ) = 1 \\ \tau_{ij}^k(n), \quad \text{otherwise} \end{cases} \tag{8}$$

The initial pheromone concentration of each wagon flow at each station is set as $\tau_{ij}^k(1)$, its value is shown in equation (9). Equation (9) means that in the first iteration, the pheromone concentration of any wagon flow at any station is equal to c. In order to avoid falling into the local optimal solution as much as possible, a threshold is set for the pheromone. When the pheromone concentration of a wagon flow at a station reaches the threshold, the pheromone of the wagon flow at the station will not be updated. See equation (10) for pheromone constraints. Equation (10) means that in the nth iteration, the pheromone concentration of any wagon flow at station k cannot exceed Q.

$$\tau_{ij}^{k}(1) = c \tag{9}$$

$$\tau_{ij}^{k}(n) \leq Q \tag{10}$$

4 Example analysis

4.1 Basic data

Taking 8 technical stations in a straight line as an example, the optimization model of single-block TFP for technical stations and the positive feedback search algorithm based on absolute conditions are checked. The station layout is shown in Figure 2.

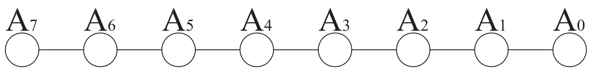

Figure 2: Layout of station

The data of wagon flow between stations are shown in Table 1. This paper takes the direction A_7 to A_0 as an example, so only the data of wagon flow in the direction A_7 to A_0 are given in the table. The mathematical model proposed in this paper only considers the wagon flow with $L_{ij} \geq 2$, so the wagon flow irrelevant to the calculation is not listed in the table.

Table 1: Wagon flow data

	A_5	A_4	A_3	A_2	A_1	A_0
A_7	60	70	100	60	80	100
A_6	-	180	90	130	80	120
A_5	-	-	60	100	120	60
A_4	-	-	-	100	90	80
A_3	-	-	-	-	70	90
A_2	-	-	-	-	-	80

This case assumes that the accumulation wagon-hour of each wagon flow in the same station is the same. See Table 2 for specific data. The data of time-saving without reorganization of each technical station and the effective sorting capacity of each intermediate technical station are also listed in Table 2. In Table 2, T_i represents accumulation wagon-hour, unit: wagon-hour; t_k represents the time saved by TTF at station k, unit: hour. C_k means effective sorting capacity. The values of relevant parameters in the positive feedback search algorithm based on absolute conditions proposed in this paper are shown in Table 3. In Table 3, *Maxiter* represents the maximum number of iterations. There are 1000 cycles in each iteration.

Table 2: Relevant data of each technical station

	A_7	A_6	A_5	A_4	A_3	A_2	A_1
T_i	600	500	550	500	500	500	-
t_k	-	2	3	2	2.5	3	2
C_k	-	300	340	380	360	300	280

Table 3: Value of relevant parameters of the algorithm

Maxiter	Q	$\tau_{ij}^{k}(1)$	δ
300	10	1	0.1

4.2 Calculation results

Through repeated calculations, the global optimal solution is 5930 wagon-hours. See Figure 3 for the optimal solution search process in a calculation process. In Figure 3, the abscissa is the number of iterations and the ordinate is wagon-hour. It can be seen from Figure 3 that the target value gradually decreases with the number of iterations, and the minimum value is found in the 81st iteration.

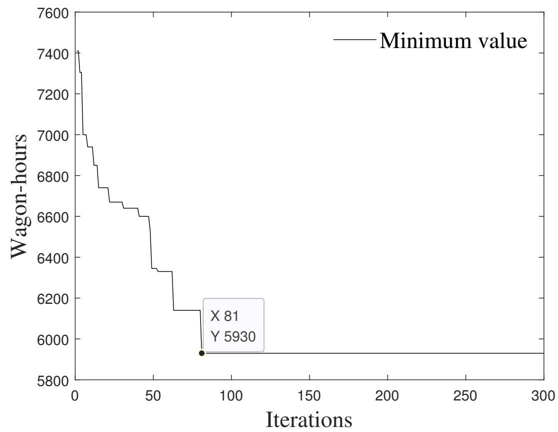

Figure 3: Search process diagram of the optimal solution

The optimal TFP is shown in Figure 4. It can be seen from Figure 4 that there are 6 TTFs running in the direction from A_7 to A_0. Take station A_7 for example, there is only TTF from station A_7 to station A_3 in station A7. The train flow is composed of three wagon flows, w_{73}, w_{70} and w_{72}. w_{70} and w_{72} need to be reorganized at station A_3, so the wagon-hour of midway reorganization will be generated; the terminal of w_{73} is station A_3, so w_{73} will not generate a reorganization wagon-hour at station A_3. In order to distinguish these two situations, add brackets to the wagon flow that needs to be reorganized after arriving at the station to make a difference. In addition, the wagon flow between two adjacent technical stations is not shown in Figure 4.

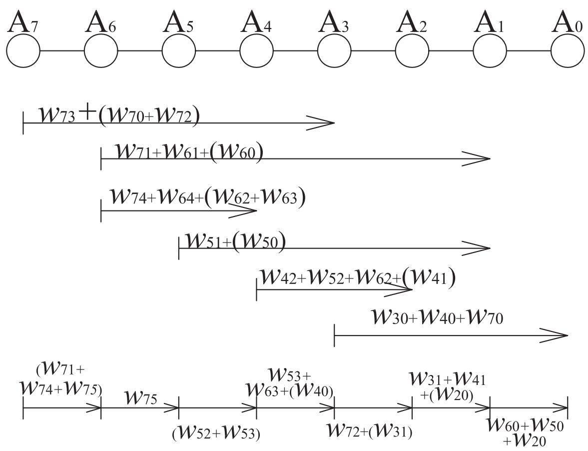

Figure 4: Optimal TFP

The number of reorganizations at each station is shown in Table 4. It can be seen from Table 4 that the number of reorganizations of each intermediate technical station is less than the effective sorting capacity of the station. However, the number of reorganizations in A_5 is 0, and the number of reorganizations in A_4 has reached the maximum, which also reflects a problem: the utilization of sorting capacity in each station is not balanced. If you want the utilization rate of the sorting capacity of each station to be balanced, you can set corresponding constraints, which will not be discussed here.

Table 4: Number of reorganizations at each station

Staton	A_6	A_5	A_4	A_3	A_2	A_1
Quantity	210	0	380	240	160	260

4.3 Comparative experiment

Finally, in order to test whether the absolute conditions introduced in this algorithm are more conducive to searching for the optimal solution. In this paper, we do the following comparative experiments: other parameters remain unchanged, remove the absolute conditions, and only use positive feedback to search. After five repeated experiments, the experimental results are shown in Table 5. In Table 5, N represents the number of iterations when the optimal solution is obtained for the first time.

Table 5: Results of comparative experiments

	1	2	3	4	5
N	192	102	182	150	150
Optimal solution	6360	5930	6330	6357	6295

It can be seen from Table 5 that only the optimal solution of the second experiment is 5930 wagon-hours, and the optimal solution of the other four times is greater than 5930 wagon-hours. This shows that only using positive feedback to search cannot obtain a stable optimal solution. The reason for this is that after removing the absolute condition, the search process completely depends on the pheromone concentration, which makes it easier to fall into the local optimal solution. Therefore, the absolute conditions introduced in this algorithm are conducive to obtaining stable optimal solutions. The search process of the fifth experiment is shown in Figure 5.

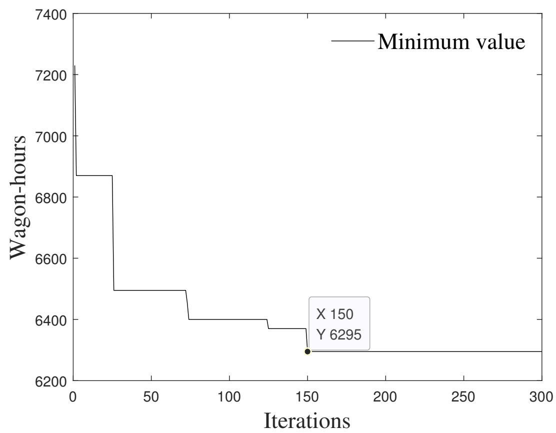

Figure 5: The optimal solution search process diagram of the 5th experiment

5 Conclusion

The optimization of TFP is a large-scale combinatorial optimization problem, which is difficult to solve. This paper mainly studies the optimization algorithm of single-block TFP. The corresponding mathematical model is established, and a positive feedback search algorithm based on absolute conditions is proposed. First of all, the wagon flow that meets the absolute conditions is directly run to the TTF, so as to narrow the search scope and improve the efficiency of the solution; for the wagon flow that does not meet the absolute conditions, select the target station according to the probability. The probability of wagon flow selecting a station is calculated according to the pheromone of the wagon flow at the station. At the same time, a pheromone update strategy with a positive feedback mechanism is proposed to make the search process converge. It should be emphasized that the pheromone concentrations of different wagon flow at the same station are independent of each other and do not affect each other. Finally, the feasibility of the algorithm and the necessity of introducing absolute conditions are verified by taking 8 technical stations in the straight line direction as examples. The calculation results show that the algorithm proposed in this paper can optimize TFP very well, and the absolute conditions introduced are more conducive to obtaining stable optimal solutions. The innovation of this paper is that the positive feedback search algorithm based on absolute conditions is efficient and widely used. The inadequacy of this paper is that the different values of the relevant parameters in the algorithm will have a certain impact on the convergence speed and solution results of the algorithm. This paper has not done in-depth research on the values of each parameter, and further research will be carried out in the next step.

Conflict of interest

The authors declare no conflict of interest.

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