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Research Article

Optimization Model and Algorithm of Empty Pallets Dispatching under the Time-Space Network of Express Shipment

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Relying on the express freight network, the dispatching of empty pallets based on the pallet pool mode is studied to reuse pallets with the minimum transport cost, enhance the pallet utilization rate, reduce the waste of resources, and save the cost of logistics. Considering the influence of transport efficiency for different modes in transportation process, differences of transportation cost, carbon emissions, and transportation timeliness of demand points required, an optimization model is constructed. The objective of the model is to minimize the total cost including transportation cost, inventory cost, lease cost, and loss cost. According to the structural characteristics of the model, genetic algorithm and improved cloud clonal selection operation is used to solve the model. Finally, the validity and rationality of the optimization model are verified by a case study. The result shows that the total dispatching cost of considering time requirement is 1.8 times the cost without considering the time requirement, respectively, both less than the total cost of pallets leasing. Moreover, when there are 3 supply points and 2 demand points and the number of iterations is 100, after the algorithms are run for 30 times, the worst values are 9305 and 8317 for genetic algorithm and the improved cloud clonal selection operation, respectively. Therefore, the efficiency of the improved cloud clonal selection operation is higher than genetic algorithm.

1. Introduction

With the rapid development of logistics technology, express freight transportation service and electronic commerce on a global scale, demand for small-batch, multicategory, and high value-added express freight transportation service grows continually. Traditional mode of load and transportation is replaced by unitized logistics mode gradually. In unitized logistics mode, bulk cargo is loaded as goods unit with integrated packaging apparatuses (refer to devices that assemble goods into a complete, unified volume unit and are structurally convenient for mechanical handling and storage) and fixed by machine. In this mode, the efficiency of cargo handling and transportation can be improved and transportation cost, carbon emission, freight loss, and damage can be reduced. Integrated packaging apparatuses, such as pallets, container cages, and circulation boxes, are widely used in unitized logistics mode for its cheap, efficient, and convenient features.

In the efficiency of pallet loading, Zhou et al. [1] (2013) indicated that integrated packaging apparatuses can make cargo handling more convenient, transportation more efficient, and transportation cost lower. Moreover, several studies have been conducted on usage pattern and benefit analysis of integrated packaging apparatuses. Martins and Dell [2] (2008) presented new bounds, heuristics, and an exact algorithm for the pallet loading problem. Raballand and Carroll [3] (2007) presented options for exporters to mitigate the adverse effects of pallet standards multiplicity. Lau et al. [4] (2009) presented a hybrid approach to solve the profit-based multipallet loading problem. In the management and dispatching of pallet, Doungpattra et al. [5] (2012) developed a computer simulation model based on the empirical case to analyze the flow of pallets from the factory, the subcontractors, and the distribution center and to determine the system performance measures. Ray et al. [6] (2006) established cost variable categories for two pallet load systems and simulation modeling of each pallet system was performed. Elia and Gnoni [7] (2015) analyzed pallet management systems and developed a simulation-based tool to support logistic managers to design effective organizational scenarios for pallet management systems. Roy et al. [8] (2016) analyzed the existing industry strategies for managing pallets. Guaman-Siller et al. [9] (2010) revealed two ways, i.e., according to retailers' level of integration with their suppliers and according to retailers' managerial orientation toward pallets, to classify retailers with qualitative research methodology. Carrano et al. [10] (2014) presented a prescribed approach for estimating the carbon footprint, or greenhouse gas emissions, which arise across all phases of a pallet life cycle, and quantified the impact of contributing materials, processes, and activities in each phase.

One-way transportation and disposable use reduce service efficiency of integrated packaging apparatuses, which also increases transportation cost, wastes vast resources, and is not low-carbon. Therefore, it is necessary to build the integrated packaging apparatuses pool system to share and recycle integrated packaging apparatuses by dispatching them reasonably to improve service efficiency, reduce transportation cost, and resource waste.

The volumes of freight transported with integrated packaging apparatuses are unbalanced in different areas, which usually leads to unbalanced distribution of integrated packaging apparatuses. It is necessary to dispatch integrated packaging apparatuses to balance the demand in different areas and reduce resource waste [11]. Few studies have focused on the optimization of dispatching integrated packaging apparatuses. Ren and Zhang [12–14] and Ren et al. [15] introduced the pallet pool system and an improved system was proposed. Besides, stochastic factors in the process of pallet allocation were analyzed and a stochastic programming model was presented. Wu et al. [16] (2016) developed a deterministic model and a multiscenario model to optimally allocate pallets in the certain and uncertain situation, respectively. Tornese et al. [17] (2018) developed an analytical model to quantify the effects of repair facility location and pallet service conditions on a pallet pooling system's economic and environmental performance and developed a simulation model to investigate two common operational policies, cross-docking and take-back, and to quantify the impact of pallet handling and loading conditions and customer network structures on several key performance indicators. In order to frame and model the environmental issues and impacts associated with the management of pallets throughout the entire life cycle, Mazeika-Bilbao et al. [18] (2011) used the space-time network to express physical flow of pallets, manufacture, and end of life. However, the abovementioned researches only optimize delivery and collection of pallets in a small area while transportation mode, demand for different kinds of integrated packaging apparatuses, and time constraint are neglected.

Contrary to transporting pallets with special trains which results in high transportation cost, this paper proposes an optimization model to dispatch pallets between service centers based on express freight transportation network. Express freight transportation network optimization has been studied [19]. The differences between railway transportation and highway transportation in freight rates, transportation distance, carbon emission, and damage rate of goods are considered. The objective is to minimize total dispatching cost and time constraint for pallet demand points is considered. An improved cloud clonal selection operation is presented to solve the model and obtain the scheme of dispatching with minimal cost.

The structure of the remainder of this paper is as follows: in the second section, the problem that needs to be solved is described and a pallet dispatching model is developed. The topic of the third section is to describe the solution method. Then, in the fourth section, a computational example is described. The paper is concluded in the fifth section.

2. Problem Formulation

2.1. Problem Description. Express freight transportation time-space network can describe the process of transportation and operation of different transportation modes directly. In this paper, the pallet dispatching network based on highway and railway is considered. For railway transportation, the service network is optimized based on the given wagon flow reorganization plan and marshaling plan, while highway transportation is based on the existing transportation mode and frequency.

The decision period is divided into several units to describe the time factors of the dispatching system. In this paper, the decision period is 1 week and one unit is 24 hours, and then the time-space network is shown in Figure 1 and "A," "B," "C," and "D" are freight terminals. After the decision period, a super node (a virtual node) is set for each terminal to make it the end point of the transportation arcs which cannot reach the terminal, i.e., Node 8 in Figure 1. The smaller the gap between the super node and the transportation deadline of the demand points is, the smaller the punishment will be.

The purpose of pallet dispatching is to transport pallets from supply points to demand points with minimal dispatching cost and in reasonable time [20]. If the dispatching cost is higher than leasing cost, pallets should be leased out to the demand points out of the pallet pool system instead of being transported between the supply points and demand points. Moreover, the carbon emission volumes of different transportation modes are different. Therefore, the impact of transportation on environment is considered and carbon emission cost is considered as one term of optimization objective. Furthermore, warehouse cost and damage rate of goods can also influence the dispatching scheme.

2.2. Assumptions. Throughout this paper, the following assumptions are made in our model formulation.

Assumption 1. The demand is deterministic and can always be satisfied by dispatching or leasing.

Assumption 2. Each route starts from supply points and ends with demand points. Departure frequencies or marshaling plans of different transportation modes are fixed in the decision period.

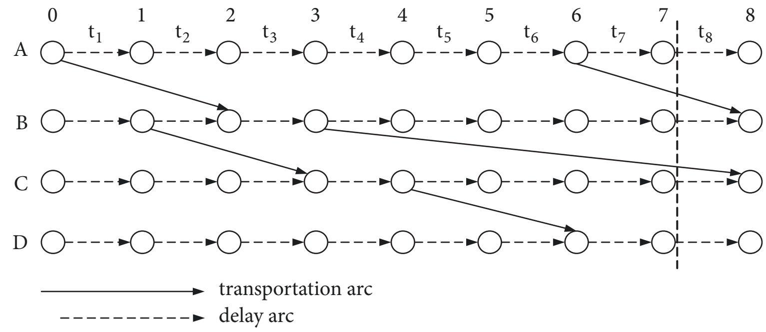

FIGURE 1: The time-space network of physical network for empty pallet dispatching.

Assumption 3. The type of pallet is divided by weight; the same type of pallets with different materials can be regarded as the same pallets.

Assumption 4. The demand time for pallets is not related to the type of pallet.

Assumption 5. Costs cannot change in the decision period.

Assumption 6. During transportation, pallets are considered as goods.

3. Objectives and Constraints

3.1. Objectives. Mathematically, the objective functions are as follows:

$$\min C = \sum_{o\in O}\sum_{d\in D}\sum_{p\in P}\sum_{a\in A}\sum_{v\in V}\gamma_{od}^{p}\delta_{od}^{pa}\left[\left(c_a+\beta_a c_0\right)g^v+\rho^a c^v\right]x_{od}^{pv} + \sum_{o\in O}\sum_{v\in V}q_o^v c_o^v + \sum_{d\in D}\sum_{d\in D}r_d^v c_d^v \tag{1}$$

$$\min T' = \max\left(t_{od}^{pv}-l_d^v,0\right)+\max\left(e_d^v-t_{od}^{pv},0\right). \tag{2}$$

Equation (1) minimizes the total cost including transportation cost, warehouse cost, and leasing cost. O represents the set of supply points, $o \in O$. The set of demand points is denoted by D, $d \in D$. P denotes the set of transportation routes with each route $p \in P$. The set of directed arcs is defined as $A = A_r \cup A_h$, where A_r is the set of transportation arcs and A_h is the set of delay arcs at the points, $a \in A$. Transportation arcs with two transportation modes are split into two arcs. The set of pallet types is denoted by V, $v \in V$. The binary variable γ_{od}^{p} is introduced, and it equals 1 if and only if pallets are transported from o to d via route p. A binary variable δ_{od}^{pa} is used, having value 1 if and only if route p is chosen to transport pallets and arc a is in the route. For each arc $a \in A$, an arc cost is defined as c_a. If $a \in A_r$, c_a is transportation cost of arc a. If $a \in A_h$, c_a is delay cost at the point, i.e., reloading cost or waiting cost. Carbon emission of cargo per unit mass is defined as β_a. c_0 represents unit carbon emission cost. g^v is used to represent mass of a pallet of type v. c^v is used to represent unit damage cost of a pallet of type v. ρ^a is used to represent the damage rate of pallets on arc a. Decision variables x_{od}^{pv} model the number of pallets of type v transported from supply point o to demand point d via route p. Each demand point d is associated with leasing price of pallets of type v which is denoted by c_d^v and the number of pallets of type v to be leased which is defined as r_d^v. Analogously, for each supply point $o \in O$, unit warehouse cost of pallets of type v is defined as c_o^v and the number of pallets of type v in the supply point is defined as q_o^v, $q_o^v = s_o^v - \sum_{d\in D}\sum_{p\in P}x_{od}^{pv}, \forall o \in O, v \in V$.

Equation (2) indicates that total transportation time should satisfy the demand, which means that T' should be minimized. The set of unit periods is denoted by T, $t \in T$. For each demand point d, the expected earliest duration e_d^v is defined and the latest duration is defined as l_d^v. t_{od}^{pv} is defined as the actual transportation duration from supply point o to demand point d via route p and $t_{od}^{pv} = T_{od} = n \cdot t$.

3.2. Constraints. Three types of constraints encountered in a real pallet dispatching problem are considered in the model.

(i) Supply constraint is as follows:

$$s_o^v \geq \sum_{d\in D}\sum_{p\in P}x_{od}^{pv}, \quad \forall o \in O,\ v \in V, \tag{3}$$

where s_o^v represents the number of pallets of type v which can be supplied by supply point o, while $\sum_{d\in D}\sum_{p\in P}x_{od}^{pv}$ represents the total number of pallets of type v supplied by supply point o. Hence, $\sum_{d\in D}\sum_{p\in P}x_{od}^{pv}$ cannot be bigger than s_o^v.

(ii) Demand constraint is as follows:

$$\sum_{o\in O}\sum_{p\in P}\sum_{a\in A}x_{od}^{pv}\left(1-\rho^a\right)+r_d^v \geq d_d^v, \quad \forall d \in D,\ v \in V, \tag{4}$$

where d_d^v represents the number of pallets of type v needed by demand point d. $\sum_{o\in O}\sum_{p\in P}\sum_{a\in A}x_{od}^{pv}(1-\rho^a)$ represents the total number of undamaged pallets of type v transported to demand point d via route p. The sum of the total number of undamaged pallets of type v and r_d^v, i.e., the number of pallets of type v leased by demand point d, cannot be smaller than d_d^v.

(iii) Arc capacity constraint is as follows:

$$w_a \geq \sum_{o\in O}\sum_{d\in D}\sum_{p\in P}\sum_{v\in V}\delta_{od}^{pa}x_{od}^{pv}, \quad \forall a \in A, \tag{5}$$

where w_a represents the capacity of arc a. If $a \in A_r$, w_a represents the maximal transportation capacity of the arc; however, when $a \in A_h$, w_a represents the capacity of points, such as handling capacity and warehouse capacity. The number of pallets transported through arc a in each period cannot exceed w_a.

3.3. Model Processing. Let function $f(t_{od}^{pv})$ denote the penalty cost for pallets of type v that cannot be transported to demand point d on time:

$$f\left(t_{od}^{pv}\right) = \max M_2^v\left(t_{od}^{pv} - l_d^v, 0\right) + \max M_1^v\left(e_d^v - t_{od}^{pv}, 0\right), \quad (6)$$

where M_1^v represents the penalty coefficient for pallets arriving in advance. If early arrival is forbidden, M_1^v is ∞. M_2^v is used to represent the penalty coefficient for pallets arriving late. When arriving late is not allowed, M_2^v is ∞. Extra cost caused by pallets not arriving on time is defined as C_e which should be minimized and calculated by the following:

$$C_e = \sum_{o\in O}\sum_{d\in D}\sum_{p\in P}\sum_{v\in V} f\left(t_{od}^{pv}\right) x_{od}^{pv} \quad (7)$$

Therefore, the objective function to minimize total cost can be defined as follows:

$$\begin{aligned}\min C' &= \sum_{o\in O}\sum_{d\in D}\sum_{p\in P}\sum_{a\in A}\sum_{v\in V} \gamma_{od}^{p}\delta_{od}^{pa}\left[\left(c_a + \beta_a c_0\right) g^v + \rho^a c^v\right] x_{od}^{pv} \\ &+ \sum_{o\in O}\sum_{v\in V} q_o^v c_o^v + \sum_{d\in D}\sum_{v\in V} r_d^v c_d^v \\ &+ \sum_{o\in O}\sum_{d\in D}\sum_{p\in P}\sum_{v\in V} f\left(t_{od}^{pv}\right) x_{od}^{pv}.\end{aligned} \quad (8)$$

4. Solution Method

In 1959, clonal selection theory was proposed by Burnet. Clonal selection operation simulates the microevolutionary process in immune system. High-frequency variation is introduced to keep the diversity of the population and multipeaks searching [21, 22]. Clonal selection operation is introduced by Huang in detail [23].

In cloud clonal selection operation, stochastic and stabilized cloud model is used to optimize immunity operation in traditional clonal selection operation, which means that crossover and mutation are executed by cloud generator. Cloud model is proposed by Li to perform the uncertain transformation from qualitative concept to quantitative description or otherwise [24]. As the methodology to implement cloud model, cloud generator is the tool to connect quality with quantity and make mapping between qualitative and quantitative concepts. The most common cloud generators include forward cloud generator, backward cloud generator, X condition cloud generator, and Y condition cloud generator [25]. In this paper, Y condition cloud generator is used to perform crossover operator. For Y condition cloud generator, three digital characteristics, i.e., E, E_1, and H, and cloud generator with subject degree $y = y_0$ are given. E indicates the center-of-gravity position of cloud drops in number field, reflecting the coordinate of qualitative concept in number field. E_1 is the uncertainty measurement of qualitative concept reflecting the number field range which can be accepted by the linguistic value and the probability that those points can represent this linguistic value. H is degree of dispersion of E_1 reflecting the cohesion of certainty of the notion that each numeric represents the linguistic value. Moreover, H also reflects condensation degree of cloud drops [26, 27]. As the basis of the uncertain inference based on cloud model, Y condition cloud generator consists of two main stages:

(1) Generate normal random number E_1' with expectance E_1 and standard deviation H.

(2) Obtain cloud drops according to $Q_c = E \pm \sqrt{-2\ln(\mu)E_1'}$, where μ represents certainty degree.

Improved cloud clonal selection operation can generate different digital characteristics to control algorithm parameters according to affinities in different stage. At the beginning of the algorithm, the digital characteristics are bigger to update the population with a high probability. The digital characteristics are smaller to preserve excellent individuals and quicken constringency in the later period of the optimization. The algorithm can keep the diversity of the population and guarantee powerful ability of both global search and local search. Binary coding method is adopted for antibody of which the length is the number of routes which can be chosen between supply points and demand points. If one route is chosen, the corresponding gene will be 1. Initial antibodies are generated randomly. The algorithm flowchart is presented in Figure 2.

4.1. Clone. Clone population $\boldsymbol{A}$ to obtain population $\boldsymbol{A}'$ is as follows:

$$\boldsymbol{A}' = \left(a_1', a_2', \cdots, a_m'\right)^T, \quad (9)$$

where $a_i' = \boldsymbol{I}_i \times a_i$, $i = 1, 2, \cdots, \text{m}$, and $\boldsymbol{I}_i$ is a q_i-dimensional row vector with all elements 1, which is called q_i-clone for antibody a_i. Clone scale for a_i should be adjusted based on the affinities of a_i to antigens and the similarities between a_i and other antibodies. The clone scale is calculated according to the following formulation:

$$q_i = \left\lfloor n_c \frac{f\left(a_i\right)}{\sum_{j=1}^{m} f\left(a_j\right)} \varphi_i \right\rfloor, \quad i = 1, 2, \cdots, \text{m}, \quad (10)$$

where $\lfloor\bullet\rfloor$ is a function to round up the input to an integer. n_c indicates a fixed value related to clone scale and $n_c > m$. $f(a_i)$ represents the affinity of a_i to antigens. φ_i is the similarity of a_i to other antibodies and its value can be obtained by the following:

$$\varphi_i = \min\left[\exp\left(\left\|a_i - a_j\right\|\right)\right], \quad i \neq j;\ i, j = 1, 2, \cdots, \text{m}, \quad (11)$$

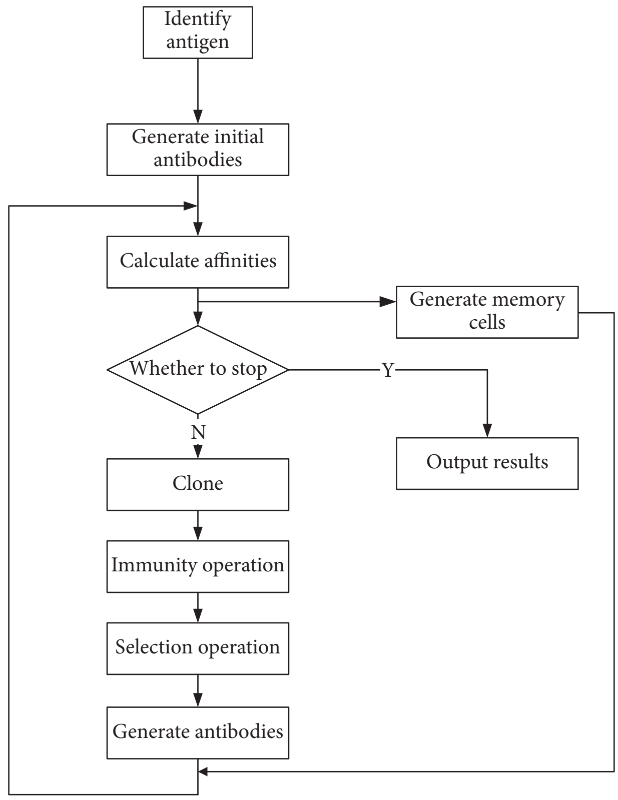

Figure 2: Flowchart of cloud clonal selection operation.

where $\|\cdot\|$ indicates Euclidean distance after unitization processing; therefore, $0 \le \|\cdot\| \le 1$. Obviously, the smaller the antibodies are, the more similar they will be and the stronger the inhibition will be, and, hence, the smaller φ_i will be.

4.2. Immunity Operation. Immunity operation consists of two stages, i.e., crossover and mutation. Cloud model is used to update antibodies for its randomness and stability [28].

4.2.1. Crossover. Antibody a_i' can be crossed with antibody a_j' as follows.

Step 1. Certainty degree μ is obtained according to the following:

$$\mu = \mu_{\max} - \frac{f_{\max} - f\left(a_i'\right)}{f_{\max} - f_{\min}}\left(\mu_{\max} - \mu_{\min}\right). \quad (12)$$

Step 2. Expectance E is generated by the following:

$$E = \frac{f\left(a_i'\right)}{f\left(a_i'\right) + f\left(a_j'\right)} a_i' + \frac{f\left(a_j'\right)}{f\left(a_j'\right) + f\left(a_j'\right)} a_j'. \quad (13)$$

Step 3. Entropy E_1 is generated by the following:

$$E_1 = \frac{\text{Search range of variables}}{k_1}. \quad (14)$$

Step 4. Hyperentropy H is generated by the following:

$$H = \frac{E_1}{k_2}. \quad (15)$$

Step 5. Child antibodies x_1 and x_2 are generated by Y condition cloud generator.

Step 6. Compare the affinities of x_1 and x_2 and replace a_i' with the child antibody of which the affinity is bigger.

After crossover, population $\boldsymbol{A}'$ is updated to

$$\boldsymbol{A}'' = \left(a_1'', a_2'', \cdots, a_m''\right)^T. \quad (16)$$

4.2.2. Mutation. For antibody a_i'', mutation can be executed as follows.

Step 1. Set E to the original antibody.

Step 2. E_1 is generated according to the following:

$$E_1 = \frac{\text{Search range of variables}}{k_3}. \quad (17)$$

Step 3. H is generated by the following:

$$H = \frac{E_1}{k_4}, \quad (18)$$

where $k_1 \sim k_4$ are control coefficients.

Step 4. Cloud drop (x, μ) is generated with basic cloud generator. Then, random number T_e is generated and the antibody is updated if $\mu > T_e$.

After mutation, population $\boldsymbol{A}''$ is updated to

$$\boldsymbol{A}''' = \left(a_1''', a_2''', \cdots, a_m'''\right)^T. \quad (19)$$

4.2.3. Clone Selection Operation. Clone selection operation is to select excellent individuals from offspring obtained by antibodies' clone operation to form a new population [29]. In clone selection operation, parents and offspring are mixed and then individuals with the biggest affinities are selected as the next population to avoid algorithm degradation.

5. Computational Example

One pallet pool system includes 3 supply points (o_1, o_2, and o_3), 2 demand points (d_1 and d_2), and 5 transfer points ($n_1 \sim n_5$). There are 3 commonly used types of pallets (v_1, v_2, and v_3) and the masses of the 3 types of pallets are 20kg, 18kg, and 15kg, respectively. Relevant data were obtained via questionnaires and interviews. The supplies and demands are shown in Table 1. The transport prices and carbon emissions are presented in Table 2. The departure frequencies and routes are presented in Figure 3. Decision period is 1 week and unit period is 24h.

The data of carbon emission are obtained according to the revision of the German Railway 2008 annual environmental report on CO_2 emission statistics.

Table 1: Parameters of supply and demand.

Pallets type	Leasing price ($)	Supply point	Storage cost in decision period ($/t)	Supply	Demand point	Demand	Transport time requirement (d)	
							The shortest time	The longest time
v_1	1.2	o_1	0.29	5 020	d_1	1 046	5	7
		o_2	0.28	3 200				
		o_3	0.22	2 480	d_2	3 089	4	7
v_2	1	o_1	0.29	3 610	d_1	743	5	6
		o_2	0.28	4 900				
		o_3	0.22	1 210	d_2	1 615	4	6
v_3	1.3	o_1	0.29	2 600	d_1	1 615	5	7
		o_2	0.28	4 260				
		o_3	0.22	1 100	d_2	862	4	7

Table 2: Related parameters of two transport modes.

Transportation mode	Highway	Railway
Transport prices per kilometer ($/t)	0.07	0.01
Carbon emissions per kilometer (kg/t)	0.0796	0.028

In this paper, the penalty coefficient of additional cost caused by early arrival of pallets is unit warehouse cost, while the penalty of additional cost caused by delay of pallets is unit pallet leasing cost. The damage rate of pallets is defined as ρ^a which is 0.4% if pallets are transported in highway and 0.3% if pallets are transported in railway and 0.5% when pallets are transferred. The transport cost of the arcs of which the end points are the super node is ∞. Reloading cost is $3.2 per ton.

The other correlative parameters are c_1=6, c_2=10, c_3=6, c_4=10, μ_{max}=0.9, and μ_{min}=0.2 and the number of iterations is 100. Both improved cloud clonal selection operation and genetic algorithm are implemented in MATLAB to solve the problem, respectively.

The improved cloud clonal selection operation and genetic algorithm are repeated 30 times [30]. The dispatching schemes with and without consideration of time limit are obtained, which are shown in Scheme 1 (see Table 3) and Scheme 2 (see Table 4 and Figure 4), respectively. For Scheme 2, the efficiency of the two algorithms is presented in Table 5 and Figure 5. It can be observed that the two algorithms can obtain the same result as ILOG CPLEX. However, when the size of the problem is too large, it is too long for ILOG CPLEX to obtain the optimal solution.

All demand points can be satisfied by dispatching without considering time limit and the total dispatching cost is $3821. If time limit is considered, some routes will change. For example, the route between o_1 and d_1 will change from a_1-a_2-a_3-a_4-a_5 to a_6-a_4-a_5. New routes will be generated because some demand points are satisfied by leasing instead of dispatching. Total penalty cost will increase to $6988; it is more than 1.8 times the cost of ignoring time requirements, because leasing cost is higher than dispatching cost and time penalty cost is considered. If all demand points are satisfied by leasing, total leasing cost will be $10499; this is more than 1.5 times the result of optimization. Therefore, dispatching pallets within time limit can improve the use ratio of pallets and reduce leasing cost. This can effectively reduce the cost of enterprises and improve economic benefits.

In addition, the two algorithms have almost the same accuracy and can both obtain the optimal solution. Improved cloud clonal selection operation performance is better than genetic algorithm in terms of run time, the number of iterations, and convergence effect. As shown in Table 5, the shortest run times of genetic algorithm and improved cloud clonal selection operation are 103s and 25s, respectively. Hence, the better solution can be obtained by improved cloud clonal selection operation. Figure 5 illustrates the convergence process of the two algorithms.

6. Concluding Remarks

The main contributions and future work can be summarized as follows.

(1) The pallet dispatching problem is analyzed based on time-space network and reasonable routes to dispatch pallets are selected without changing the departure plans.

(2) Related factors which influence pallet dispatching are analyzed and a model with correlative constraints and objective that is to minimize dispatching cost is proposed. Improved cloud clonal selection operation and genetic algorithm are adopted to solve the model. Finally, a computational example is used to verify the feasibility of the model and the efficiency of the algorithm and provide the basis for solving large-scale problems.

(3) Based on existing express service, generating pallets dispatching scheme by optimization is practical and can illustrate the benefit of pallets dispatching. The computational example shows that the model and algorithm have good practical value in the optimization of pallet dispatching. From the calculation results, it is not difficult to find that the pallet dispatching optimization has obvious economic and social benefits.

(4) The model and algorithm are also applicable to the dispatching of similar packaging apparatuses. Therefore, this paper can provide theoretical guidance for dispatching integrated packaging apparatuses.

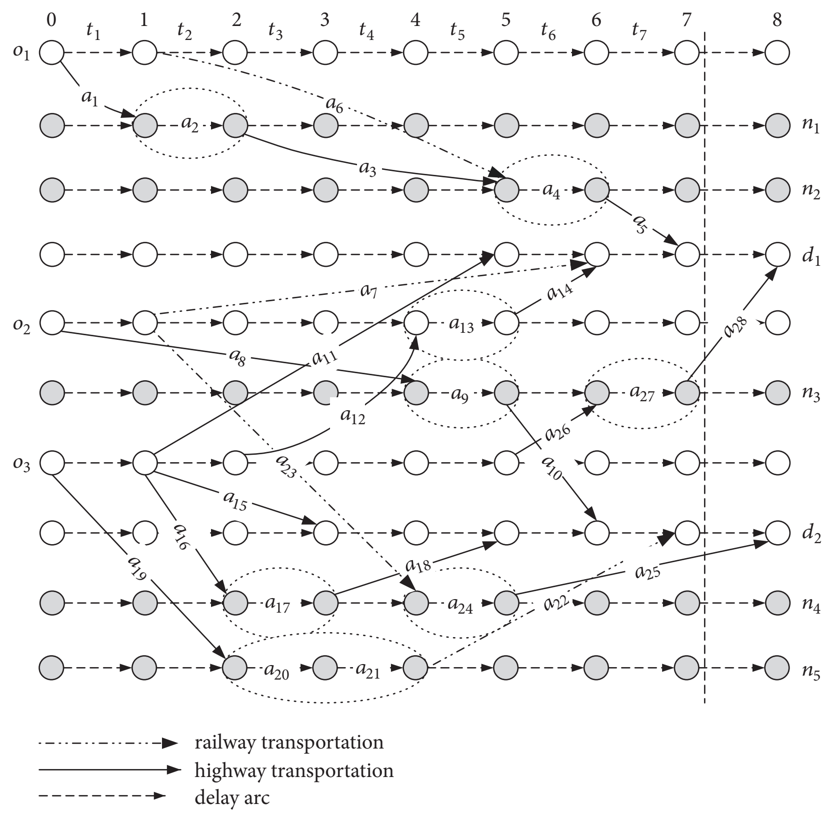

Figure 3: The initial time-space network of transportation.

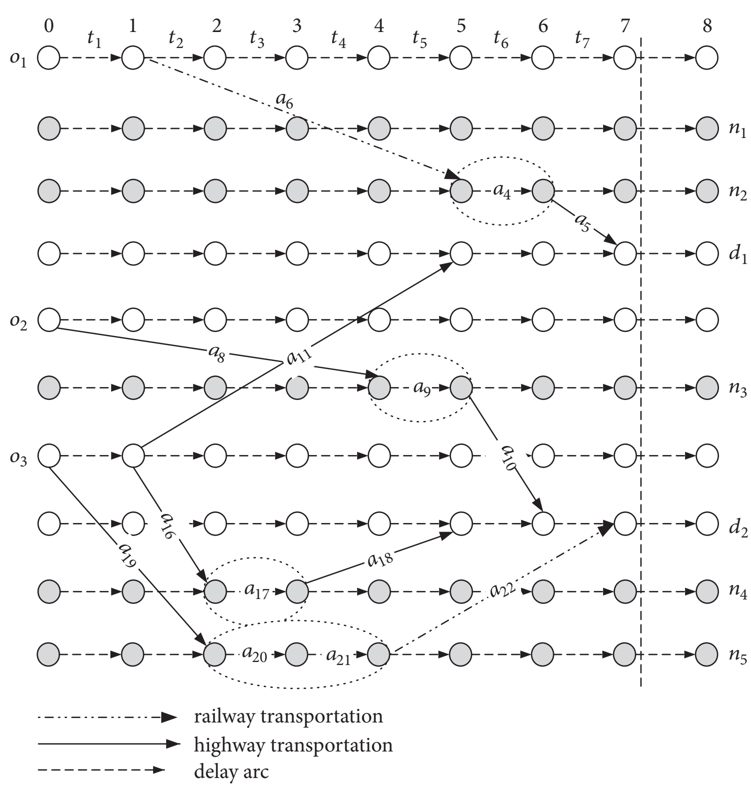

Figure 4: The optimized time-space network of the empty pallet dispatching.

Table 3: Dispatching scheme 1.

Demand point	Transport route	Dispatching amount	Leasing amount	Objective ($)
d_1	o_1-d_1: a_1-a_2-a_3-a_4-a_5	1004, 722, 520	0	3821
	o_2-d_1: a_7	46, 23, 1100		
	o_3-d_1: no dispatching	0, 0, 0		
d_2	o_1-d_2: no dispatching	0, 0, 0	0	
	o_2-d_2: a_8-a_9-a_{10}	863, 950, 287		
	o_3-d_2: a_{15}; a_{16}-a_{17}-a_{18}; a_{19}-a_{20}-a_{21}-a_{22}	2237, 670, 578		

Table 4: Dispatching scheme 2.

Demand point	Transport route	Dispatching amount	Leasing amount	Objective ($)
d_1	o_1-d_1: a_6-a_4-a_5	1050, 0, 866	0	6988
	o_2-d_1: no dispatching	0, 0, 0		
	o_3-d_1: a_{11}	0, 746, 756		
d_2	o_1-d_2: no dispatching	0, 0, 0	1956	
	o_2-d_2: a_8-a_9-a_{10}	1066, 505, 529		
	o_3-d_2: a_{16}-a_{17}-a_{18}; a_{19}-a_{20}-a_{21}-a_{22}	826, 360, 336		

Table 5: Comparison of optimization results for two methods.

Algorithms	Running time (s)	Best iteration number	Average iteration number	Best value	Worst value
ICCSO	25	14	32	6988	8317
GA	103	24	56	6988	9305

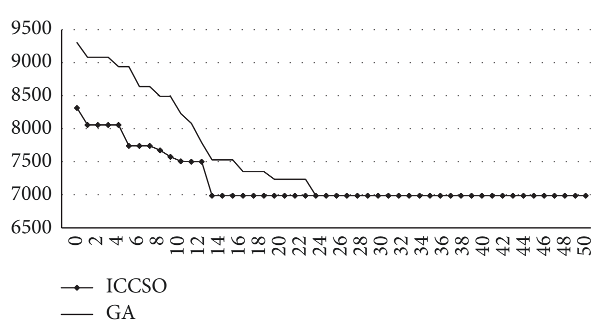

Figure 5: Convergence effect of two algorithms.

(5) In the process of dispatching pallet, there are many uncertainties factors, such as demand uncertainty and damage rate uncertainty, which should be studied in the future.

(6) In addition, the sensitivity analysis of model parameters and the application of the model in more large-scale data need to be further studied.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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