Optimization of Palletized Unit Implants Dispatch Considering Less than Truckload Transportation in Auto Parts Industry

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Abstract. In recent years, the acceleration of economic globalization has played an irreplaceable role in promoting the development of modern logistics industry. Reducing production and operating costs, reducing logistics costs, and increasing enterprise competitiveness have become new challenges of the rapid development for the logistics industry. At the same time, the demand for automobiles has also increased significantly which has strongly driven the development of auto parts industry. A method to optimize palletized unit implants dispatch in auto parts industry which adopts less than truckload (LTL) transportation is proposed in this paper. An optimization model of palletized unit implants dispatch is constructed with the goal to minimize the total transportation cost and the constraints including dispatching demand, dispatching time and so on. And the effectiveness of the model and algorithm is verified by case study. The results show that the dispatch optimization model of shared palletized unit implants considering less than truckload transportation is 7.5% less than full dispatch mode and 146.6% less than full lease mode.

1. Introduction
With the continuous development of global logistics technology and improvement of the demand for the timeliness and safety of cargo transportation, the traditional cargo transportation mode can’t meet the needs and the advantages of unitized cargo transportation are gradually obvious. At the same time, with the maturity of the auto market and increasingly fierce price competition, reducing logistics costs is increasingly noticed by auto parts industry. Sharing of palletized unit implants plays an important role in reducing the production and operation costs of the logistics industry. When the supply and demand of palletized unit implants in auto parts company are unbalanced, it should be considered how to dispatch palletized unit implants to meet needs.

Palletized unit implants include pallets, turnover boxes, etc. There are more studies on pallet sharing systems. In the academic field, developed countries in Europe and the United States have begun research on pallet sharing since the 1960s. At present, the research of pallet sharing mainly focus on benefit analysis, model discussion and information construction, scheduling models and algorithms and so on. Pallet dispatch is the core of the operation management of the pallet sharing system. Ren et al. [1] studied a multiscenario planning model for pallet sharing scheduling considering mixed pallets under extreme uncertain conditions. Zhou et al. [2] studied the dispatching model of the railway pallet sharing system. Zhou et al. [3] studied the pallet sharing dispatch model considering
time constraint. Ren [4] constructed a multimodal transport pallet shared scheduling optimization model and compared the advantages and disadvantages of two different particle swarm algorithms. Doungpattra et al. [5] studied the pallet sharing scheduling method in the pet food industry. Liu [6] studied the optimization of urban logistics network of LTL logistics enterprises. Liu [7] studied the current status of LTL logistics industry and development of smart logistics technology, proposed the volume prediction algorithm based on hybrid dual neural network and constructed a dynamic scheduling model.

The palletized unit implants which carries auto parts is generally a turnover box which has the characteristics of large size, high price, and fixed arrival time. Due to the limited number of palletized unit implants for transportation, less than truckload (LTL) transportation along the way can reduce the waste of transportation costs caused by the low truck loading rate. In this paper, the optimization plan for the dispatch of palletized unit implants in the auto parts industry is studied to reduce dispatch cost. In the process of transportation, LTL transportation will be considered.

2. Materials and Methods

2.1. Problem Description

The key points of palletized unit implants dispatch include supply points and demand points. The transportation of auto parts is unitized by palletized unit implants. After several production cycles, the auto parts manufacturer will lack a certain number of palletized unit implants. Then it is necessary to assign the corresponding surplus points to call back empty palletized unit implants. The auto parts manufacturer is demand point, and the surplus point of palletized unit implants is supply point. LTL transportation along the way is when a truck transport the palletized unit implants from a supply point, it can pick up some palletized unit implants on the other supply points in transportation and will cause transfer cost. Inventory fee is also charged for the remaining palletized unit implants at the supply points after the delivery.

The auto parts industry needs to rationally dispatch palletized unit implants in the lowest cost to meet the needs of the auto parts manufacturer. If the number of palletized unit implants in the system is not enough to meet the needs of demand points or the transportation distance is too long, the demand points can lease some palletized unit implants from leasing hubs. The supply points must deliver palletized unit implants within the time required by the demand points. The transportation process of palletized unit implants is shown in Figure 1.

![Figure 1. The transportation process of palletized unit implants.](image)
2.2. Notation

$I$ is the set of supply points, and $i,k \in I$. $J$ is the set of supply points, and $j \in J$. $W_i$ is inventory cost of supply point $i$. $R$ is lease cost. $B_i$ is transfer cost of supply point $i$. $C$ is unit transportation cost. $L$ is maximum load per unit truck. $S_i$ is inventory at the supply point $i$ before dispatch. $jD$ is demand volume at demand point. $Z_{ij}$ and $Z_{ik}$ are transportation time from supply point $i$ to demand point $j$ and supply point $k$, and $i \neq k$. $\alpha_j$ and $\beta_j$ are acceptable earliest arrival time and latest arrival time at the demand point $j$. $g_{ij}$ and $g_{ik}$ are the number of palletized unit implants dispatched from supply point $i$ to demand point $j$ and supply point $k$, and $i \neq k$. $h_j$ is the number of palletized unit implants leased at demand point $j$. $q_i$ is inventory quantity at supply point $i$. $p_{ij}$ and $p_{ik}$ are the number of trucks to transport palletized unit implants from supply point $i$ to demand point $j$ and supply point $k$, and $i \neq k$. $t_{ij}$ and $t_{ik}$ are initial dispatch time of palletized unit implants from supply point $i$ to demand point $j$ and supply point $k$, and $i \neq k$.

2.3. Model Formulation

2.3.1. Objective Function.

Min $V = C \times \left( \sum_{i \in I} \sum_{j \in J} p_{ij} \times Z_{ij} + \sum_{i \in I} \sum_{k \in I, k \neq i} p_{ik} \times Z_{ik} \right) + \sum_{i \in I} W_i \times q_i$

$$+ \sum_{i \in I} \sum_{j \in J} B_i \times g_{ij} + \sum_{j \in J} R \times h_j$$

(1)

The goal of the model is to minimize the total cost of palletized unit implants dispatch, considering transportation costs, inventory costs, transfer costs, and lease costs.

2.3.2. Constraints.

This model contains 10 constrains, including supply constraint, demand constraint, inventory constraint, truck constraints and time constraints.

$$\sum_{j \in J} g_{ij} + \sum_{k \in I, k \neq i} g_{ik} \leq S_i + \sum_{k \in I, k \neq i} g_{ki} \quad (i \in I, k \neq i)$$

(2)

$$\sum_{j \in J} g_{ij} + h_j = D_j \quad (j \in J)$$

(3)

$$q_i = S_i - \sum_{j \in J} g_{ij} - \sum_{k \in I} g_{ik} + \sum_{k \in I, k \neq i} g_{ki} \quad (i \in I, k \neq i)$$

(4)

$$g_{ij} \leq L \times p_{ij} \quad (i \in I, j \in J)$$

(5)

$$g_{ij} > L \times (p_{ij} - 1) \quad (i \in I, j \in J)$$

(6)

$$g_{ik} \leq L \times p_{ik} \quad (i \in I, k \in I, k \neq i)$$

(7)

$$g_{ik} > L \times (p_{ik} - 1) \quad (i \in I, k \in I, k \neq i)$$

(8)

$$(t_j + Z_{ij} - \alpha_j) \times g_{ij} \geq 0 \quad (i \in I, j \in J)$$

(9)

$$(t_j + Z_{ij} - \beta_j) \times g_{ij} \leq 0 \quad (i \in I, j \in J)$$

(10)
\[
\left[ t_{kj} - (t_{ik} + Z_{ik}) \right] \times g_{ik} \geq 0 \quad (i \in I, k \in I, j \in J, k \neq i) \tag{11}
\]

Constraint (2) is supply constraint. The palletized unit implants which supply point \(i\) can provide are consisted of two parts: the original inventory and transfer palletized unit implants at supply point \(i\). The palletized unit implants exported by supply point \(i\) are also composed of two parts, which are palletized unit implants transported to demand points and to other supply points. It indicates that the number of palletized unit implants dispatched by the supply point should not exceed the number can be provided. Constraint (3) is demand constraint which indicates the number of palletized unit implants transported from supply points to demand point \(j\) and the leased quantity can meet the demand. Constraint (4) is inventory constraint. Constraints (5), (6), (7) and (8) are truck constraints. The quantity of palletized unit implants on each transport path must be less than or equal to the number of transport trucks multiplied by the load of per unit truck, and it is guaranteed that one less truck cannot load all the palletized unit implants on this path. During the transfer process of the supply point, the number of trucks also meet the constraints. Constraints (9), (10) and (11) are time constraints. If there are palletized unit implants dispatch between supply point \(i\) and demand point \(j\), the time to reach demand point \(j\) should be between the earliest arrival time and the latest arrival time. Constraint (11) means if supply point \(k\) is used as a transit point to receive palletized unit implants from other supply points and integrate them for delivery, the arrival time from the other supply points to supply point \(k\) is required to be earlier than departure time.

3. Case Study

3.1. Case Design

In order to verify the effectiveness and accuracy of the model and algorithm, the case study is designed. The data of case is provided by an auto parts company. There are 4 supply points of palletized unit implants in the palletized unit implants dispatch system, namely \(o_1\), \(o_2\), \(o_3\) and \(o_4\), and two demand points namely \(d_1\) and \(d_2\). The supply quantity, inventory cost, and transfer cost of supply points are shown in Table 1. The demand quantity, lease cost, the earliest arrival time and the latest arrival time of demand points are shown in Table 2. The maximum load of palletized unit implants for each transport truck is 70, and the daily transportation cost of per transport truck is 200 yuan.

| Supply point | \(o_1\) | \(o_2\) | \(o_3\) | \(o_4\) |
|--------------|--------|--------|--------|--------|
| supply quantity | 165    | 161    | 177    | 179    |
| inventory cost (¥) | 5.6    | 2.8    | 4.8    | 4.6    |
| transfer cost (¥) | 0.4    | 0.3    | 0.5    | 0.5    |

| Demand point | \(d_1\) | \(d_2\) |
|--------------|--------|--------|
| demand quantity | 363    | 338    |
| lease cost (¥) | 25     | 25     |
| the earliest arrival time (d) | 4      | 2      |
| the latest arrival time (d) | 8      | 6      |

The transportation time from supply point to other points are shown in Table 3.

| Transportation time (d) | \(o_1\) | \(o_2\) | \(o_3\) | \(o_4\) | \(d_1\) | \(d_2\) |
|------------------------|--------|--------|--------|--------|--------|--------|
| \(o_1\)                | —      | 3      | 5      | 3      | 2      | 2      |
| \(o_2\)                | 3      | —      | 2      | 3      | 5      | 2      |
| \(o_3\)                | 5      | 2      | —      | 4      | 7      | 3      |
| \(o_4\)                | 3      | 3      | 4      | —      | 5      | 2      |
3.2. Results and Discussion

ILOG Cplex Optimization Studio is used to calculate this problem. Optimal dispatching plan for palletized unit implants is shown in Table 4.

| Demand points | Transporting path | Number of dispatched | Number of leases | Total cost (¥) |
|---------------|-------------------|----------------------|-----------------|---------------|
| d₁            | o₁→d₁             | 165                  |                 |               |
|               | o₁→o₁→d₁          | 39                   | 19              |               |
|               | o₄→d₁             | 140                  |                 |               |
|               | o₂→d₂             | 161                  |                 | 7101.7        |
|               | o₃→o₂→d₂          | 37                   | 0               |               |
|               | o₃→d₂             | 140                  |                 |               |

The result shows that 39 palletized unit implants are transported from supply point o₁ to supply point d₁, 204 palletized unit implants are transported from supply point o₁ to demand point d₁ after assembly, and 140 palletized unit implants are transported from supply point o₄ to d₁. 37 palletized unit implants are transported from supply point o₃ to supply point o₂, and 140 palletized unit implants are transported from supply point o₁ to demand point d₂. Then, 198 palletized unit implants are transported from supply point o₂ to demand point d₂. For the demand point d₁, the total transportation volume is 344, and 19 palletized unit implants need to be leased. For the demand point d₂, the total transportation volume is 337, and there is no need to lease palletized unit implants. The total transportation cost is 7101.7 yuan.

In order to prove the validity of the model proposed in this paper, the cost of full dispatch mode which is originally adopted by the auto parts company and full lease mode are calculated. The full dispatch mode is that all palletized unit implants in supply points are transported to demand points without considering LTL transportation. The full lease mode is to meet the demand by leasing. The result shows that the total transportation cost of full dispatch mode is 7,675 yuan and full lease mode is 17525 yuan. The total cost of the transportation under LTL transportation mode is 7.5% less than full dispatch mode and 146.6% less than full lease mode.

4. Conclusions

An optimization model for palletized unit implants dispatch considering LTL transportation in auto parts industry is proposed in this paper. Finally, an example is studied with the data from an auto parts company to verify the feasibility of model. The study found that: the calculation example shows that the dispatch cost of palletized unit implants with considering LTL transportation is 7.5% less than full dispatch mode and 146.6% less than full lease mode.

Auto parts industry should consider the way of LTL transportation to recycle palletized unit implants, which can reduce logistics costs and improve logistics efficiency. The premise of considering LTL transportation for auto parts industry is to build an information platform to update the number and demand of palletized unit implants in time, so that auto parts industry can optimize the palletized unit implants dispatch comprehensively. This research is a part of building an intelligent transportation system for auto parts industry.

Several future directions are proposed based on this study: firstly, it is possible to further subdivide time window of palletized unit implants demand, so that the data is more practical and can better reflect the advantages of LTL transportation; secondly, the loading and unloading capacity of supply points and demand points, the capacity of transportation path and the damage of the palletized unit implants during transportation in the optimization model can be considered.

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