Research on Pallet Scheduling Model with Time Windows and Uncertain Transportation Time

Fuli Zhou, *Member, IAENG*, and Yandong He, *Member, IAENG*

Abstract— **To improve the efficiency of pallet scheduling, an amended pallet sharing service alliance is established for industrial applications. Besides, an interval non-linear integer programming model for pallet scheduling problem concerning time window and uncertain transportation time is formulated to assist to achieve resources deployment, targeted the total cost minimization. The uncertain programming model is converted into a deterministic one by introducing time effect coefficient, resolved by Lingo 11.0 software. The numerical case verifies the validity and effectiveness of the formulated model. Results demonstrate that the proposed model enables to help decision makers to cope with the pallet scheduling problem considering the time window and uncertain transportation time.**

Index Terms—**pallet scheduling model; time window; uncertain transportation time; pallet share service alliance**

I. Introduction

PALLET, as the most important industrial tool to improve operational efficiency of transportation and distribution, is one of the essential elements of modern logistics system. To state of the art, utilization of pallet in China is relatively low due to following two reasons. Firstly, the authoritative pallet sharing service alliance has not been established yet; Secondly, there are few studies focusing on the pallet scheduling problem comparing with other engineering problems such as logistics service provider selection, vehicle routing programming (VRP) and third-party logistics (TPL) etc [1]. In response to these two questions, academic experts and industrial practitioners have put forward some effective suggestions [2, 3]. The establishment of pallet sharing service alliance and the study on scientific pallet scheduling can not only realize the consistent pallet operation and fulfill the maximum potentials of the tray to achieve resource-sharing and cost burden-sharing, but also can greatly reduce the logistics costs, together with the logistics efficiency improvement, which ultimately will assist to achieve a win-win goal [4].

Recently, academic researchers focus on the pallet sharing mechanism exploration, pallet alliance construction and pallet scheduling matters. Chen [5] designed the pallet sharing system based on the transport, storage and distribution operations involved in the pallet processing procedures. In order to improve the logistics efficiency and reduce the total cost of the supply chain, Roy [6] studied the pallets' rental pricing and proposed a simulation model to examine game power of supply and requisition parties through establishing the pallet sharing system in the supply chain. After studying the pallet sharing system, Tiacci [7] proposed a demand forecasting model which can estimate the cost of owning pallets and renting pallets. Xu [8, 9] put forward the establishment of a pallet sharing service chain based on the supply chain management theory and scrutinized the factors that affected the rental price and tenancy of pallets. Ren et al. [10, 11] improved the existing pallet sharing system so that the pallets can be transferred among customers and reduced the empty loading rate of pallets. They also proposed a random scheduling model in some uncertain circumstances, such as under the stochastic or uncertain pallet supply and demand scenarios.

All abovementioned literature only focuses on the segmental study in terms of pallet sharing mechanism or tasks scheduling problem. Thus, it can be observed that there are few studies on this combined topic of pallet sharing mechanism and pallet scheduling problem. Generally speaking, most practitioners and researchers mainly focus on establishing the pallet sharing system just from the perspective of pallets' lessors. In other words, they did not fully devote them into the pallet sharing systems and just took the responsibility of providing pallets. In addition, uncertain factors of pallet scheduling literature mainly focus on the supply/demand uncertainty and inventory capacity uncertainty. Due to the uncontrollable factors, such as terrible weather, traffic jam and other instability, the transportation uncertainty cannot fully meet the customer's punctual requirements in the practical distribution process [12, 13, 14] has become much more common. The transportation time generally is regarded as a typical uncertainty. However, there is little study on the pallet scheduling research in terms of the uncertain transportation time and the time window of pallet demand. It is necessary and urgent to formulate a pallet scheduling model and find a suitable solution at the lowest cost by setting the customer flexible time window.

The purpose of this paper is to help industrial managers to deal with the pallet scheduling problem concerning uncertain transportation time. The main contribution of this research is threefold. Firstly, a novel pallet sharing service alliance is constructed by integrating the pallet manufacturers with pallet operators jointly. Secondly, an interval non-linear integer programming model is formulated to minimize the total operational cost of the pallet alliance. Thirdly, the

Fuli Zhou is with the Research Center of Innovation and Industry, School of Economics and Management, Zhengzhou University of Light Industry, Zhengzhou, Henan Province, 450001 China (office phone: +86 0371-86609578; email: deepbreath329@outlook.com)

Yandong He is with the Research Centre on Modern Logistics, Graduate School at Shenzhen, Tsinghua University, Shenzhen, Guangdong Province, 518055 China (email: ydhe602@163.com)

influence coefficient is introduced to deal with the uncertainty, and the sensitivity analysis on coefficient parameter is performed to verify the validity of the proposed model.

The novel pallet sharing alliance is described by introducing the pallet manufacturers into the pallet sharing system, illustrated in Fig. 1. According to the provision of the contract, members of the union can perform their respective duties by integrating decentralized logistics resources, make rapid response to market changes and customer needs, and complete the pallet distribution, recycling and maintenance tasks jointly.

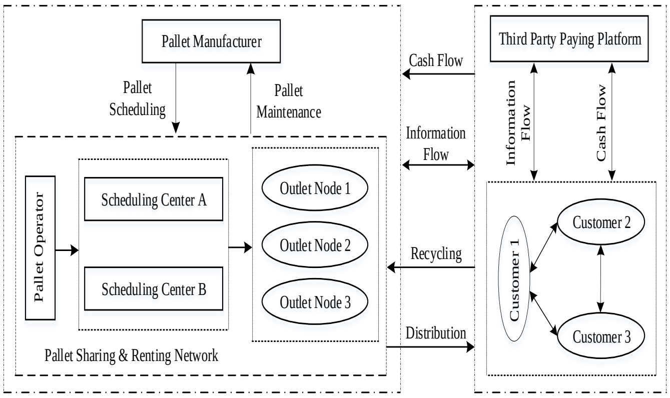

Fig. 1 Pallet sharing service alliance operation mechanism

The reminder of this paper is as follows. Section 2 presents the formulated nonlinear integer programming model. The mathematical model concerning the uncertain transportation time is formulated and resolved as well. A case study is performed by Lingo 11.0 software in Section 3. Finally, we close this paper with some conclusions.

II. Mathematical Model Formulation

The nonlinear integer programming model considering time window and uncertainty of transportation time is established in this section. In order to develop the mathematical model, the basic assumptions are supposed, and the variable parameters in the uncertain programming model are transferred to interval numbers, contributing to problem-solving of the established model [15].

A. *Basic assumptions*

According to previous studies and practical scenarios, there following assumptions need to be highlighted:

(1) The pallet sharing service alliance consists of pallet manufacturers and pallet providers. The former one is responsible for pallet supplying and maintenance of damaged ones, while the later one concentrates on construction of pallet distribution center, layout of the rental outlets, and the daily pallet rental work.

(2) The pallet manufacturer is responsible for the construction and maintenance of the regional pallet scheduling center, and decides according to the requirements of pallet operators.

(3) The transportation times of pallets show a very high uncertainty, which can be described as interval numbers.

(4) The following variables can be estimated and known in advance, such as amounts of supply and demand volume, transportation ability of the supplying outlet, time window of the order, and cost per unit of the transportation and inventory operation etc.

The proposed model caters to the specific pallet scheduling scenario that has uncertain transportation time in a certain period.

B. *Variables and notations*

The variables and notations occurred in the proposed mathematical model are summarized as follows.

Table 1 Variables and notations in the model

Var.	Notations
X_{ij}	Number of Pallets from the Supplier Outlet *i* (including Operations Center) to the Customer *j*
C_{ij}	Transportation Cost Per Unit from the Supplier Outlet *i* to the Customer *j*
C_i	Inventory Cost Per Unit for Supplier Outlet *i*
C_{ij}^e	Waiting Cost Per Unit when the Supplier *i* at the Customer *j*
C_{ij}^p	Punishment Cost Per Unit from the Supplier Outlet *i* to the Customer *j* when there is a Delay
T_{ij}	Transportation Time from the Supplier Outlet *i* to Customer *j*
D_j	Demand Amount for the Customer *j*
$[E_j, L_j]$	Time Window Requirement of the Customer *j*
ST_i	Inventory of the Supplier Outlet *i*
S_i	Supply Amount by the Pallet Supplier Outlet *i*
ST_i^0	Maximum Inventory of the Pallet Supplier Outlet *i*
TR_i	Transportation Ability of the Pallet Supplier Outlet *i*
ΔT_{ij}^e	Waiting Time of the Supplier Outlet *i* for Customer
ΔT_{ij}^p	Delay Time of the Supplier Outlet *i* for Customer *j*

C. *Nonlinear integer programming model formulation*

The pallet scheduling process by pallet sharing service alliance is described as a nonlinear integer programming model as follows, when as for the precise transportation time.

$$Min \;\; TC = \sum_{i=0}^{m}\sum_{j=1}^{n} C_{ij}X_{ij} + \sum_{i=0}^{m}\sum_{j=1}^{n} \Delta T_{ij}^{e} C_{ij}^{e} P_{ij} + \sum_{i=0}^{m} C_i ST_i + \sum_{i=0}^{m}\sum_{j=1}^{n} \Delta T_{ij}^{p} C_{ij}^{p} P_{ij} \tag{1}$$

s.t.

$$\sum_{i=0}^{m} X_{ij} = D_j \tag{2}$$

$$\sum_{j=1}^{n} X_{ij} \le S_i \tag{3}$$

$$ST_i \le ST_i^0 \tag{4}$$

$$ST_i = S_i - \sum_{j=1}^{n} X_{ij} \tag{5}$$

$$\sum_{j=1}^{n} X_{ij} \le TR_i \tag{6}$$

$$\Delta T_{ij}^{e} = \begin{cases} 0, & T_{ij} \ge E_j \\ E_j - T_{ij}, & otherwise \end{cases} \tag{7}$$

$$\Delta T_{ij}^{p} = \begin{cases} 0, & T_{ij} \le L_j \\ T_{ij} - L_j, & otherwise \end{cases} \quad (8)$$

$$P_{ij} = \begin{cases} 1, & X_{ij} > 0 \\ 0, & X_{ij} = 0 \end{cases} \quad (9)$$

$$C_{ij}, C_i, C_j^e, C_j^p, E_j, L_j, T_{ij} \ge 0 \quad (10)$$

$$X_{ij}, S_i, ST_i, ST_i^0, T_i, D_j \in N \cup \{0\} \quad (11)$$

$$i = 0, 1, \cdots m;\ j = 1,\ 2,\ \cdots n \quad (12)$$

The Eq. (1) shows the objective function, which is the minimum total cost of pallet scheduling, which consists of transportation cost, inventory cost, waiting cost and punishment cost item. The Eq. (2) is the demand constraint, and the supplement constraint is as Eq. (3) illustrates. The inventory constraints are described by Eq. (4) ~ (5). The Eq. (6) reflects the transportation ability. The waiting time and delay time constraints are formulated as Eq. (7) ~ (8) shows. The other parameter values are constrained by Eq. (9) ~ (12).

D. The mathematical programming model with uncertain transportation time

The abovementioned pallet scheduling nonlinear integer programming model is constructed under the condition of certain transportation time. However, due to the influence of external factors such as traffic jam and terrible weather in practice, the transportation time variable shows high uncertainty. The traditional programming model cannot cater to the practical scenarios, which motivates our research on uncertain programming model based on dynamic discrepant transportation time.

To the state of art, there are three methods to deal with the uncertain programming problem consisting of stochastic programming method, fuzzy programming, and interval programming technique [16, 17]. As for the first two approaches, it is prerequisite that decision makers need to know much about probability distribution functions and membership functions of the decision variables. It is usually very difficult to obtain the crisp distribution information of these variables, while it is much easier to get the confidence interval [18]. The interval programming is that the uncertain parameters in objective functions or constraints are described as interval numbers.

As the uncertain variable T_{ij}, we approximately estimate the transportation time based on the traffic condition, weather condition and historical data. The best/worst transportation scenario is regarded as $\underline{T}_{ij} / \overline{T}_{ij}$, and then the uncertain transportation time variable is $T_{ij} \in \psi = [\underline{T}_{ij}, \overline{T}_{ij}]$. Due to existing of the interval numbers in constraints (7) and (8), the above formulated model can be regarded as an interval nonlinear integer programming model, and it is of great difficulty to resolve. According to the literature [19, 20], the uncertain programming model is transferred to a normal one.

As for the $T_{ij} \in \psi$, the time influence coefficient α, and the specific calculation is illustrated in Eq. (13).

$$\alpha = \frac{T_{ij} - \underline{T}_{ij}}{\overline{T}_{ij} - \underline{T}_{ij}}, \alpha \in [0,1] \quad (13)$$

The coefficient α reflects the influence of the uncertain factors such as traffic condition and weather condition. Specifically, when α=0 ($T_{ij} = \underline{T}_{ij}$), it means the transportation time is the shortest under the best transportation condition. When α =1 ($T_{ij} = \overline{T}_{ij}$), the transportation time becomes longer with worse transportation condition. Then the Eq. (13) is transferred to the following Eq. (14).

$$T_{ij} = \alpha \overline{T}_{ij} + (1-\alpha) \underline{T}_{ij} \quad (14)$$

Therefore, constraints (7) and (8) in the above-mentioned programming model becomes the following constraints in Eq. (15) – (16).

$$\Delta T_{ij}^{e} = \begin{cases} 0, & \alpha \overline{T}_{ij} + (1-\alpha) \underline{T}_{ij} \ge E_j \\ E_j - [\alpha \overline{T}_{ij} + (1-\alpha) \underline{T}_{ij}], & otherwise \end{cases} \quad (15)$$

$$\Delta T_{ij}^{p} = \begin{cases} 0, & \alpha \overline{T}_{ij} + (1-\alpha) \underline{T}_{ij} \le L_j \\ [\alpha \overline{T}_{ij} + (1-\alpha) \underline{T}_{ij}] - L_j, & otherwise \end{cases} \quad (16)$$

Then, the interval nonlinear integer programming model becomes the normal and certain one.

III. Case Study

Suppose there is a pallet sharing service alliance as an operation center (*i*=0) consisting of three supplier outlets (*i*=1, 2, 3). There are three customer demands (*j*=1, 2, 3).

Table 2 Variable setting

Variables	Practical Setting
S_i	$S = [300, 300, 200, 250]$
TR_i	$TR = [200, 300, 250, 250]$
ST_i^0	$ST^0 = [500, 400, 250, 350]$
D_j	$D = [350, 250, 330]$
C_i	$C = [1, 3, 4, 2]$
C_{ij}^e	$C^e = [20, 15, 15]$
C_{ij}^p	$C^p = [30, 35, 50]$
$[E_j, L_j]$	$[E_j, L_j] = \{[10,15],[18,28],[17,25]\}$

A. Parameter setting

As we all know, the transportation time is greatly affected by the external factors, such as traffic jam and bad weather conditions [21, 22]. The normal transportation time from the supplier outlet to the customer demand place is denoted as T_{ij}^N. Suppose $T_{ij} \in (0.8T_{ij}^N, 1.3T_{ij}^N)$, which means the minimum transportation time between two places under the most positive scenario is regarded as $\underline{T}_{ij}$=$0.8T_{ij}^N$, and the maximum transportation time under most negative scenario is $\overline{T}_{ij}$=$1.3T_{ij}^N$. The other parameter values are as Table 2~4 illustrated.

Table 3 c_{ij} parameter setting

i	j=1	2	3
0	3	5	4
1	2	3	2
2	1	4	2
3	3	2	3

Table 4 T_{ij}^N parameter setting

i	j=1	2	3
0	16	27	30
1	11	19	18
2	10	25	30
3	12	12	20

B. Results

The model is resolved by LINGO 11.0 software with total 506 iterations. The optimal objective function value is obtained within one second, and the variation of the minimum total cost of pallet scheduling outcome is changing with fluctuation of parameter α. The specific variation of the objective function value is illustrated in Figure 2.

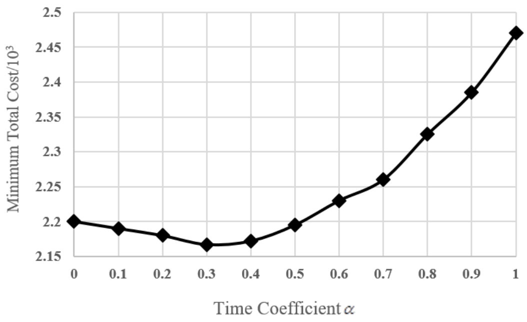

Fig. 2 Relationship between optimal objective value and α

As we can see from the Fig. 2, the optimal total cost of pallet scheduling is influenced by the time parameter α. When α∊ (0, 0.3], the total cost shows the negative correlation with the parameter α. If α∊ (0.3, 1], the parameter has positive influence on the objective function.

C. Sensitivity analysis

In order to verify and validate the proposed nonlinear programming model, there are three solutions have been generated under the help of LINGO11.0 software. The three pallet scheduling solutions are illustrated in Table 5, and the optimal total cost of every solution shows the discrepant variation with changing parameter α (Fig. 3).

Table 5 The three pallet scheduling solutions

	Solution 1			Solution 2			Solution 3		
i	j=1	2	3	1	2	3	1	2	3
0	180	0	0	150	30	0	180	0	0
1	0	0	300	0	0	300	0	0	300
2	170	0	30	200	0	0	170	30	0
3	0	250	0	0	220	30	0	220	30

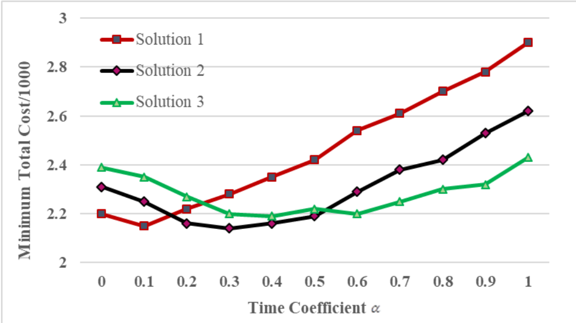

Fig. 3 Relationship between total costs and α

We can obtain the following conclusions based on Table 5 and Fig. 3.

(1) The optimal objective value is influenced by the coefficient α, and there are three scheduling solutions with the variation of the parameter α.

(2) The generated three scheduling solutions is all affected by the parameter α, and the optimal objective value shows the fluctuation tendency with increasing of α. For solution 1, when α∊ (0, 0.1], the total cost decreases with increasing of the parameter. Whileα∊ (0.1, 1], the total scheduling cost increases with the increasing of the coefficient. For solution 2, when α∊ (0, 0.3], the optimal cost declines. While α∊ (0.3, 1], the optimal cost increases with the increasing of the coefficient. For solution 3, when α∊ (0, 0.4], the optimal cost decreases. While α∊ (0.4, 1], the objective cost shows a soaring tendency with the increasing of α.

(3) Among the three scheduling solutions, the best alternative is selected based on the variation of the coefficient α. When α∊ (0, 0.1], we can choose the solution 1 with the minimum scheduling cost. When α∊ [0.2, 0.5], the solution 2 shows its absolute advantage. When α∊ (0.6, 1], the solution 3 becomes the optimal one.

Table 6 Parameter setting for computation complexity test

Variables Setting	
$[S_4, S_5]=[200{,}180]$	$[TR_4, TR_5]=[240, 200]$
$[D_4, D_5]=[200{,}150]$	$C_{ij}^e=[15{,}18]$
$[ST_4^0, ST_5^0]=[250{,}200]$	$[E_j, L_j]=\{[12{,}17],[15{,}22]\}$
$[C_4, C_5]=[2{,}2]$	$C_{ij}^p=[25{,}30]$

Table 7 c_{ij} parameter setting (5*5)

i	j=1	2	3	4	5
0	3	5	4	2	2
1	2	3	2	2	2
2	1	4	2	2	3
3	3	2	3	3	2
4	3	2	3	2	2
5	1	2	2	3	2

In order to test the complexity of the computation, this paper investigates the computation efficiency of the proposed model in the following three scenarios (5*5, 10*10, and 20*20). Due to the limitation of the paper, the experimental data is illustrated in 5*5 scenarios. The other parameter values are as Table 6~8 illustrated.

Table 8 T_{ij}^{N} parameter setting (5*5)

i	*j*				
	1	2	3	4	5
0	16	27	30	18	23
1	11	19	18	19	22
2	10	25	30	19	18
3	12	12	20	17	21
4	15	16	25	22	22
5	9	30	20	21	30

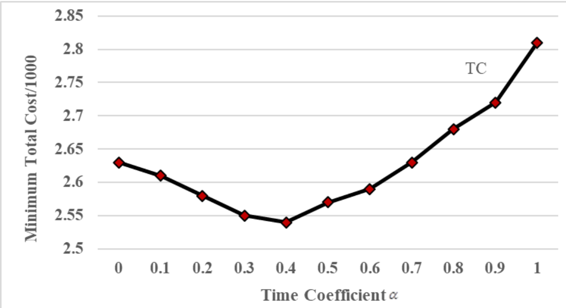

Fig. 4 Relationship between optimal objective value and α

The proposed model is resolved by LINGO 11.0 under the established parameters. The variation of the optimal objective value with coefficient α is as Fig. 4 shows after 280 iterations within 1 second. As we can see from Fig. 4, with the increasing of coefficient α, the optimal objective value shows the similar tendency with the former experimental scenario.

D. Efficiency analysis in differenet scales

To verify the efficiency of best solution generation, the comparison analysis in different proble scales is conducted. There are four experiment scenarios are addressed in this study, and the parameter setting in each problem scale is found in Table 9.

Table 9 Results in 3 experimental scenarios

Problem Scale	Computation Time	Solution
3*3	<1s	Global Solution
5*5	<1s	Global Solution
10*10	9s	Global Solution
20*20	624s	Local Solution

From the Table 9, the nonlinear programming model is computed by LINGO software. With the increasing of problem scale, the computation time shows an increasing tendency. For the small-scale problem, we can obtain the global optimal objective value. However, when the problem scale is 20*20, we just can obtain the local optimal objective value instead of the global one.

According to the above-mentioned analysis, the optimal objective values in different experimental scenarios are affected by the time coefficient α. The specific value of the coefficient is determined by the transportation condition. The decision maker of the pallet sharing service alliance could select the optimal solution by the coefficient and proposed programming model.

IV. Conclusions

In view of the fact that the pallet scheduling with uncertain time window and uncertain transport time is closer to reality, an interval nonlinear integer programming model for pallet scheduling is formulated considering the time window and uncertain transport time, resolved by defining the time influence coefficient. The results demonstrate that the optimal value of the model is affected by the time influence coefficient α. The optimal solution of the model is affected, as well as optimal scheduling solution. With the increase of α, the optimal value of the model shows the trend of decreasing first and then increasing.

A. Theoretical and practical implications

This research serves both theoretical and practical implications to pallet scheduling problem. It contributes to the theoretical knowledge by formulating a pallet scheduling model with time windows and uncertain transportation time, and provides practical implications for industrial managers. Firstly, a novel modified pallet sharing service alliance is established and the operation mechanism is addressed in this research. Secondly, a non-linear integer programming model is formulated to resolve the pallet scheduling process targeting the total operation cost. In addition, the time influence coefficient is introduced to deal with the uncertainty of the transportation time variable, and the Lingo 11.0 is employed to obtain the solution. Finally, the numerical case presented illustrates the effectiveness and validity of the proposed model. This study provides guidance for industrial managers to perform pallet scheduling, also assists engineers to reduce the total operation cost by the proposed programming model.

B. Limitations and future research opportunities

This research carries some limitations. The programming model formulated is based on some assumptions, and other practical pallet sharing mechanism and programming models can also be developed in different industrial scenarios. With the assistance of the highlighted mechanism of pallet sharing service alliance and the proposed framework, there exist research opportunities. In the follow-up study, uncertainties of supply and demand in the tray scheduling can be taken into consideration, contributing to making the model closer to the actual situation. Besides, other cost segments can be extended from a more systematic viewpoint. Finally, the heuristic algorithm and excellent search strategy can be integrated and developed to solve more complex scheduling models, also to improve the efficiency of the formulated programming model.

Acknowledgment

We would like to thank anonymous referees for their remarkable comments and enormous endeavor on the paper improvement. This research is supported by the following programs: the Think-tank Program of Henan Science & Technology (Grant no. HNKJZK-2020-41C); the Scientific Research Starting Fund for Doctors from Zhengzhou University of Light Industry [grant no. 2018BSJJ071]; the Soft Science Research Project from Henan Science and Technology Department [grant no. 192400410016]; the

National Social Science Fund [grant number 18BJY066]; and Major Application Research Program of Philosophy and Social Science in Henan Higher Education Institutions [grant number 2019-YYZD-18].

References

[1] Sun Yang, Teng Lin, Yin Shoulin, and Li Hang, “A New Wolf Colony Search Algorithm based on Search Strategy for Solving Travelling Salesman Problem,” International Journal of Computational Science and Engineering, vol. 18, no. 1, pp 1-11, 2019.

[2] Ren Jianwei, Chen Chunhua, Xu Hao, and Zhao Qingqing, “An optimization model for the operations of a pallet pool with both radio-frequency identification–tagged pallets and non-tagged pallets,” Advances in Mechanical Engineering, vol. 10, no. 1, pp 1-13, 2018.

[3] Zhou Lin, Lin Yun, Wang Xu, and Zhou Fuli, "Model and algorithm for bilevel multisized terminal location- routing problem for the last mile delivery," International Transactions in Operational Research, vol. 26, no. 1, pp 131-156, 2019.

[4] Zhou Fuli, Lim Ming Kim, He Yandong, Lin Yun and Chen Shan, “End-of-life (ELV) Recycling Management: Improving Performance using an ISM Approach,” Journal of Cleaner Production, vol. 228, pp 231-243, 2019.

[5] Chen Chunhua, Ren Jianwei, and Yunga A., "Review of pallet pooling studies," Logistics & Sustainable Transport, vol. 10, no. 1, pp 1-10, 2019.

[6] Roy Debjit, Andres L. Carrano, Jennifer A. Pazour, and Akash Gupta, "Cost-effective pallet management strategies," Transportation Research Part E: Logistics and Transportation Review, vol. 93, pp 358-371, 2016.

[7] Tiacci Lorenzo, and Stefano Saetta, "An approach to evaluate the impact of interaction between demand forecasting method and stock control policy on the inventory system performances," International Journal of Production Economics, vol. 118, no. 1, pp 63-71, 2009.

[8] Xu Qi. “Logistics Pallets Pooling Service Supply Chain System and the Optimal Management,” China Business and Market, vol. 24, no. 186, pp 22-25, 2010.

[9] Xu Qi. “Collaborated Optimal Pricing Strategy of Pallets Pooling Supply Chain System,” China Business and Market, vol. 25, no. 202, pp 54-59, 2011.

[10] Ren Jianwen, and Zhang Xueyan, “Pallet Recovery Stochastic Programming Model of Pallet Pool System,” Control and Decision, vol. 25, no. 8, pp 1211-1214, 2010.

[11] Ren Jianwen, and Zhang Xueyan, “Two Stage Stochastic Chance Constrained Programming Model of Pallet Pool System Dispatch,” Control and Decision, vol. 26, no. 9, pp 1353-1357, 2011.

[12] He Zhuqing, and Sun Linyan, “Model and Algorithm of Vehicle Routing Problem under Dynamic Traffic,” Journal of Traffic and Transportation Engineering, vol. 7, no. 1, pp 111-115, 2007.

[13] Abel Garcia-Najera, and John A. Bullinaria, “An Improved Multi-objective Evolutionary Algorithm for the Vehicle Routing Problem with Time Windows,” Computers & Operations Research, vol. 38, no. 1, pp 287-300, 2011.

[14] Tong Wuning, Xiao Song, and Li Hongbin. “Fault-Tolerant Scheduling Algorithm with Re-allocation for Divisible Loads on Homogeneous Distributed System,” International Journal of Computer Science, vol. 45, no. 3, pp 450-457, 2018.

[15] Zhou Fuli, Wang Xu, Goh Mark, Zhou Lin, and He Yandong, “Supplier Portfolio of Key Outsourcing Parts Selection using a Two-stage Decision Making Framework for Chinese Domestic Auto-maker,” Computers & Industrial Engineering, vol. 128, pp 559-575, 2019.

[16] Wafa Elloum, Driss Mehdi, and Mohamed Chaabane, “Robust Controlled Positive Delayed Systems with Interval Parameter Uncertainties: A Delay Uniform Decomposition Approach,” International Journal of Applied Mathematics and Computer Science, vol. 28, no. 3, pp 441-450, 2018.

[17] Huang Junsheng, Huang Huanping, Guang Xiaoping, Li Rong, and Zhu Jianshu, “Bi-level Programming Model to Solve Facility Configuration and Layout Problems in Railway Stations,” Engineering Letters, vol. 26, no. 3, pp 364-371, 2018.

[18] Sang Shengju, “Pricing and Green Level Decisions with a Risk Averse Retailer in an Uncertain Green Supply Chain,” IAENG International Journal of Applied Mathematics, vol. 48, no. 3, pp 251-257, 2018.

[19] Zhou Fuli, He Yandong, and Zhou Lin, “Last Mile Delivery With Stochastic Travel Times Considering Dual Services,” IEEE Access, vol. 7, pp 159013-159021, 2019.

[20] Jiang Zheng, Dai Liankui, and Wu Tiejun, “Deterministic Interpretation of Interval Nonlinear Programming and Its Hierarchical Optimization Solutions,” System Engineering Theory and Practice, vol. 25, no. 1, pp 110-116, 2005.

[21] He Yandong, Zhou Fuli, Qi Mingyao and Wang Xu, “Joint Distribution: Service Paradigm, Key Technologies and Its Application in the Context of Chinese Express Industry,” International Journal of Logistics Research and Applications, pp 1-17, 2019.

[22] Zhou Fuli, Wang Xu, He Yandong, and Goh Mark, “Production Lot-sizing Decision-Making considering Bottle-neck Drift in Multi-stage Manufacturing System,” Advances in Production Engineering & Management, vol. 12, no. 3, pp 213-220, 2018.