Scheme Design of Returnable Transportation Packaging System between Shandong Province and South Korea

Jun Wang¹*, Yimeng Hou¹ and Weishan Wang²

¹Shandong Jiaotong University, Jinan 250357, China
²Shandong Institute for Product Quality Inspection, Jinan 250102, China

*Corresponding author’s e-mail: wangjun@sdjtu.edu.cn

Abstract. The main trade product categories and logistic packaging standard systems were firstly investigated between Shandong province and South Korea. Based on the results, the auto parts were chosen as the target product to design the returnable transportation packaging system. Therefore, the system composed of standardized plastic pallet, nested plastic returnable box and top cover were designed for the light auto parts, while the folding visualized metal mesh box was designed for the heavy auto parts. By simulating the adaptability among different specifications of packaging equipment and the shipping containers, the recycling plastic pallet with size of 1140 mm×980 mm, plastic packaging boxes with size of 480 mm×380 mm were preferred to match 40 ft containers, the plane and space loading efficiencies of which are 94.89% and 87.35%, respectively. While, the metal mesh boxes with 1000 mm×800 mm×760 mm were preferred to match with 20 ft containers, with the plane and space loading efficiencies of 94.89% and 87.35%, respectively.

1. Introduction

Returnable Transportation System (RTS) is a complete system composed of reusable transportation packaging and various kinds of equipment and required service system, which is jointly operated by suppliers, manufacturers, logistic centers and enterprises. In this system, in order to protect products and facilitate storage and transportation, a system composed of reusable containers, materials and auxiliary materials is adopted according to certain technical methods, which is called returnable transportation packaging system (RTPS)³.

With the continuously rapid development of the logistics industry, the use of logistics packaging materials increases, resulting in a large amount of resource consumption and environmental pollution. Additionally, packaging standards are not still unified, seriously affecting the efficiency of logistics transportation and circulation. RTPS can effectively replace the existing traditional logistics packaging materials including cartons, wooden pallets, foam boxes, greatly reduce the amount of disposable packaging and the loss of goods, improve circulation efficiency, and finally realize the recycling and reduction of logistics packaging in domestic and foreign trade. Safe, efficient, environmentally friendly and standardized returnable transportation packaging has become the inevitable trend of domestic and international logistics development. Singh et al.²³ found in the environmental impact analysis of packaging of various materials that plastic packaging has the lowest environmental impact, while paper packaging have the highest environmental impact of all kinds. In addition, they also found that, compared with the one-way logistics system, RTPS has a higher advantage in both accident rate and economic efficiency. Increasing the number of repeated uses and prolonging the life cycle of the
returnable transportation packaging (RTP) will greatly improve its economy and environmental protection. Albrecht[4] analysed the environmental and economic impacts of raw materials, energy consumption and waste generation in the production, circulation and waste of wooden boxes and plastic recycling packaging in the process of fresh food transportation. They found that, compared with wooden boxes, recycling plastic containers have obvious advantages in greenhouse gas emissions, acid rain and other environmental impacts. Because they can be reused for many years, the use cost will be greatly reduced with the number of uses. So, they are more convenient to be widely used.

China has been committed to promoting the application of RTPS. For example, plastic packaging that can be recycled for many times have been used in the transfer and distribution of e-commerce logistics, so as to solve the problem of excessive use of cartons and packaging in e-commerce logistics. The international logistics packaging system is also rapidly transitioning from disposable logistics packaging to intelligent circular logistics packaging. The application proportion of the latter has increased from 11% in 2005 to 60% in 2015. However, for international logistics, due to a long transportation period and inconsistent standards among countries, problems such as repackaging at port often occurred, resulting in decreased efficiency of loading, unloading and handling and increased costs. While, at present, there is no relatively perfect internationally standardized RTPS.

As the largest trading partner of Shandong Province, South Korea is geographically adjacent and has complementary resources. With the expansion of the trade scale between China and South Korea, it is necessary to reduce the logistics cost and create a friendly, efficient and low-cost international logistics environment. Therefore, South Korea is chosen as the destination, and the target products were also selected to design RTP between China and South Korea. Also, the adaptability among each packaging in the system was simulated, so as to establish a more reasonable standardized RTPS suitable for both sides, and provide some references for realizing the harmonized standardization of the international logistics packaging system.

2. Determination of target products of returnable transportation packaging system

The import and export data of Qingdao Customs in recent five years are investigated to determine the target products of RTPS between Shandong Province and South Korea. The results show that the top four categories of Chinese exports to South Korea are electronic machinery, cutting-edge technology products, agricultural products and auto parts. While the top three categories of South Korean exports to China in terms of quantity are semiconductors, flat panel displays and sensors, and synthetic resins. The categories of import and export products of both sides are similar.

With reference to the successful operation experiences of international RTS, advanced logistics enterprises such as Toyota Motor Parts Co., Ltd., Euro Pool System International and CHEP of the United States have run mature RTS with automobile parts as the leading products. Therefore, the suitable trial product of RTPS between Shandong Province and South Korea is determined to be the auto parts with a high value, which keep a high bilateral trade volume and have a long storage period.

3. Demand analysis of RTPS for automobile parts between Shandong province and South Korea

The pallet and the unitized packaging containers are the key elements of RTPS design. The material, strength, loading rate and adaptability among them are particularly important in the international logistics.

The pallets are most frequently used in China-South Korea trade. Among the pallets, the use of wooden tray is decreasing year by year, because the China-South Korea trade restriction terms is increasing and the re-processing cost is also added as recycled, resulting in the high resource consumption and environmental pressure. Therefore, wooden pallets are mostly used as a disposable packaging in China-South Korea trade, but not suitable for RTPS.

Considering the cost consumption and environmental pressure, the plastic pallets gradually replaced the wooden ones, which are reused in trade. The more times they are used, the lower the single cost of pallets will be, and the more obvious the cost advantage over the disposable pallets. However, in the reuse of plastic pallets, it is necessary to carry out repeated operations on them, which will put forward
higher requirements on the durability and strength of the pallets. So, the strength of the plastic pallets needs to be increased. The plastic pallets are also required clean in repeated use. To prevent the detachment of the pallet from the loading cargo, it could be fixed with lashing items.

In addition, heavy and bulky cargos between China and South Korea are usually packaged and transported by wooden cases, resulting in resource consumption and processing difficulties. While the metal packaging boxes currently in use are characterized by high production price, insufficient use times, heavy quality and high repair and maintenance costs. Therefore, it is necessary to develop and design RTPS with light weight, repeatable use, easy repair and maintenance, and low cost.

To sum up, the target product has been chosen as auto parts between Shandong - South Korea trade. So, the design of RTPS applicable to the international RTS for automobile parts should be considered, including the special box for light and small parts, the packing box for heavy parts and the corresponding special pallets.

4. Comparison of the standardized specifications of transportation packaging between China and South Korea

The design of RTPS should follow the principle of standardization. Therefore, the standardized specifications of logistics packaging between China and South Korea are compared. As shown in Table 1, China's current national standard GB/T 2934-2007[5] requires two standard specifications of pallets, 1200 mm×1000 mm and 1100 mm×1100 mm. While the Korean national standard requires that the sizes of the pallet are 1200 mm×1100 mm and 1100 mm×1100 mm. There is also a size of 1140 mm×980 mm for the general pallet out of the standard. The plane dimensions of the cargo packing modules for each pallet are also listed in Table 1.

| Country | Pallet Size (length×width, mm) | Plane dimensions of packaging modules (length × width, mm) |
|---------|-------------------------------|----------------------------------------------------------|
| South Korea | 1100×1100 | 550×366, 366×275, et al |
|         | 1200×1100 | 600×500, 600×400, et al |
|         | 1140×980  | 480×380, 380×240, et al |
| China   | 1100×1100 | 550×366, 275×366, et al |
|         | 1200×1000 | 600×400, 600×200, et al |
|         | others    | 600×400, 400×300, et al |

Through comparison from Table 1, it is found that the pallets of the same specifications for both countries are 1100 mm×1100 mm, and the same corresponding packaging module is 550 mm×366 mm. Other specifications of 1200 mm×1000 mm, 1140 mm×980 mm pallets are corresponding to the basic packaging module of 600 mm×400 mm, 480 mm×380 mm, respectively.

| Category | 20ft | 40ft | 40ft (HC) |
|----------|------|------|----------|
| internal size (mm) | length 5899 | 12034 | 12034 |
| | width 2348 | 2348 | 2348 |
| | height 2390 | 2695 | 2390 |
| opening size (mm) | width 2336 | 2336 | 2336 |
| | height 2278 | 2583 | 2278 |
| weight (kg) | self weight | 2290 | 4150 | 3890 |
| | max loading | 21710 | 26330 | 26590 |
| | total weight | 24000 | 30480 | 30480 |

Shipping containers are the basis of international trade. The loading efficiency and the matching of shipping containers with pallets and packaging boxes should be considered. The standard specifications
of 20ft, 40ft and 40ft high volume (HC) shipping containers in Korea are listed in Table 2. 20ft and 40ft shipping containers are commonly applied for China's export, and auto parts are usually transported in 40ft shipping containers with an internal size of 12034mm×2348 mm×2390 mm.

5. Design and adaptability simulation of RTPS for auto parts between Shandong Province and South Korea

5.1. Simulation of the loading efficiency and adaptability between loading units of pallets and shipping containers

In order to maximize the loading efficiency of shipping containers, 40ft containers commonly used in automobile parts were taken to investigate the loading efficiency and their adaptability with three types of pallets of 1100 mm×1100 mm, 1200 mm×1000 mm, 1140 mm×980 mm and the corresponding basic module packing boxes. In the process of simulation and calculation, the height for different standard basic module packaging boxes is adopted as 200 mm. To maintain the pallets loaded with goods stable, a top cover is designed with the thickness of 200 mm. The loading simulation schematics of three types of pallets are shown in Figure 1-3, respectively, and the data results are summarized in Table 3.

See from Table 3, when pallets of 1100mm×1100mm with the correspondingly basic loading unit module of 550 mm×366 mm×200 mm are matched with 40ft shipping containers (12034 mm×2348 mm×2390 mm), each pallet can load 6 units of goods in each layer shown in Figure 1a and the container can load 20 units of such pallets in each layer. In order to ensure the size adaptability and stability of each pallet, the loading height of each pallet is set as 1000 mm, that is, 5 layers of goods, and each pallet can carry 30 units of goods, as shown in Figure 1b. For each pallet loaded with unit module cargo, the plane size of the cargo is 1098 mm×1100 mm. Comparing with the size of the pallet, both plane and space loading rate of pallets can reach 99.82%. For the shipping container, compared with its internal height of 2390 mm, the loading height can reach 2000 mm + 200 mm (the thickness of top cover) = 2200 mm, that is, 2 layers of unit pallets loaded with cargo, totaling 40 units, as shown in Figure 1c. So, the plane and space loading rate of shipping containers is calculated as 85.65% and 78.84%, respectively.
By the same way, the conclusion can be gotten as following. When pallets of 1200 mm×1000 mm with the correspondingly basic loading unit module of 600 mm×400 mm×200 mm is matched with 40ft shipping containers, each pallet can load 5 units of goods in each layer (shown in Figure 2a), with a total of 5 layers. Then each pallet can carry 25 units of goods (shown in Figure 2b), and the plane and space cargo loading rates of pallets can reach 100%. For a 40ft shipping container, the most suitable number of pallet units with this specification on the plane should be 20, with a total loading capacity of 40 (as shown in Figure 2c). The plane and space loading rates are calculated as 84.94% and 78.19%, respectively.

When pallets of 1140 mm×980 mm with the correspondingly basic loading unit module of 480 mm×380 mm×200 mm is matched with 40ft shipping containers, each pallet can load 6 units of goods per layer (shown in Figure 3a), with a total of 5 layers. Then each pallet can carry 30 units of goods (shown in Figure 3b), and both plane and space cargo loading rates of pallets are 97.96%. For a 40ft shipping container, it can load 24 units of this specification on the plane, with a total loading capacity of 48 (shown in Figure 3c). The plane and space loading efficiencies are calculated as 94.89% and 87.35%, respectively.

According to the comparison of the above results, for 40ft container, from the perspective of loading efficiency, 1140 mm×980 mm pallets should be selected first, followed by 1200 mm×1000 mm pallets. However, the loading efficiency of 1100 mm×1100 mm pallets in 40ft shipping container is poor.

### Table 3. Simulation results of adaptability between three pallet loading units and 40ft containers

| Loading unit (mm) | length×width×height | loading units/layer | layer(s) | Total loading units | Plane loading rate, % | Space loading rate, % |
|-------------------|----------------------|---------------------|---------|---------------------|-----------------------|-----------------------|
| Pallet with size of 1100 mm ×1100 mm | 1100×1098×1000 | 6 | 5 | 30 | 99.82 | 99.82 |
| Shipping container loading pallets | 11000×2200×2200 | 20 | 2 | 40 | 85.65 | 78.84 |
| Pallet with size of 1200 mm ×1000 mm | 1200×1000×1000 | 5 | 5 | 25 | 100 | 100 |
| Shipping container loading pallets | 12000×2000×2200 | 20 | 2 | 40 | 84.94 | 78.19 |
| Pallet with size of 1140 mm ×980 mm | 1140×960×1000 | 6 | 5 | 30 | 97.96 | 97.96 |
| Shipping container loading pallets | 11760×2280×2200 | 24 | 2 | 48 | 94.89 | 87.35 |

### 5.2. Simulation of the adaptability and loading efficiency between the metal mesh box and shipping container

Metal packaging is often used to load heavy auto parts. Due to the weight limitation of shipping containers, in this study, the metal mesh boxes and 20ft shipping containers (5899 mm×2348 mm×2390 mm) is considered to be combined for import and export.
The designed metal mesh box is set as 1000 mm×800 mm×760 mm with a visual folding structure. The results of simulation of the adaptability and loading efficiency with 20ft shipping container were shown in Figure 4 and Table 4. It can be seen from Table 4 that the plane and space loading efficiency of 20ft shipping container with the designed metal mesh box are 80.86% and 51.43%, respectively, which are not very good and need to be further optimized and improved.

| length×width×height (mm) | loading Units/layer | layers | total loading units | plane loading rate, % | space loading rate, % |
|--------------------------|--------------------|--------|---------------------|----------------------|----------------------|
| Shipping container loading (1000×800×760mm) | 1100×1098×1000 | 6 | 5 | 30 | 99.82 | 99.82 |

5.3. Confirmation of returnable transportation packaging system
According to the above simulation results, the final parameters of RTPS for auto parts between Shandong Province and South Korea are as follows.

**Pallets** Considering the loading efficiency of pallets and shipping containers, the pallet of 1140 mm×980 mm will be preferred, followed by the pallet of 1200 mm×1000 mm. The self-weight is 7.5 kg with a loading weight is 700 Kg, and the material is recycled plastic (100%).

**Metal mesh box** With a mesh design, not sealed around, easy to judge the loading goods, the visibility of the metal box is strong. In addition, a ¼ folding design is adopted to reduce the whole logistic costs and improve logistics efficiency. The size is set as 1000 mm×800 mm×760 mm. The self-weight is 66 Kg with a loading weight of 1000 Kg and capacity of 388 L. The structure is shown in Figure 5.

**Returnable plastic box** Considering the recycling performance, a returnable plastic box was designed. The size can be set as 480 mm×380 mm×200 mm or 480 mm×380 mm×150 mm to better fit the preferred pallet (1140 mm×980 mm). The structure is designed as nested type, which can greatly reduce the cost of recovery, as shown in Figure 6.

In summary, the target products in Shandong-South Korea logistic system were chosen as auto parts. The light and small auto parts are designed to be packed by the combination of 40ft shipping container, the plastic pallet and returnable plastic box. While the heavy and large auto parts are packed by the combination of 20ft shipping container and metal mesh boxes. The integrated sketch can be seen in Figure 7 and 8.
6. Conclusion
The main logistics category between Shandong Province and South Korea -- auto parts is selected as the target product. Based on the standard system of logistics packaging of both sides, a standardized returnable transportation packaging system suitable for auto parts is designed and adapted. The simulation results show that the plane loading efficiencies of 40ft containers with 1100 mm×1100 mm, 1200 mm×1000 mm and 1140 mm×980 mm pallets are 85.65%, 84.94% and 94.89%, respectively. While the space loading efficiencies were 78.84%, 78.19% and 87.35%, respectively. Therefore, the packaging system of 1140 mm×980 mm recycling plastic pallet, 480 mm×380 mm nested plastic packing box and 40ft container were integrated to transport light auto parts. And a visual folding metal mesh box of 1000 mm×800 mm×760 mm and 20ft shipping container are matched to transport heavy auto parts. The design of nested packing boxes and folding visual metal boxes can greatly save space, reduce the recovery cost, and increase the number of cycles and life. The integrated design of the overall standardized RTPS is beneficial to the efficiency of the international logistics and provides some reference for the coordination and unification of the international logistics packaging system.

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