

A Study on Supporting the Choice Between Purchased Pallet and Rental Pallet Using a Comparison Model

Kaung Kyaw

Supervisor : Kurokawa Hisayuki Professor

1. Introduction

1.1. Background of Study

Pallets are essential tools in today's logistics, and is a potential solution for standardization, supporting modal shift and manpower efficiency, as defined in Comprehensive Distribution Policy Principles 2021-2025 by MLIT⁽¹⁾. However, efficient management is needed to maximize the benefits and minimize the waste of utilizing pallets. A potential solution to the current issues and better logistics efficiency is pallet rental services or pallet pooling, which is a form of sharing economy.

The followings are a few of the many problems facing the logistics society right now, and how using rental pallets can help:

1. Inappropriate cargo loading and handling can damage the cargo and the pallets themselves. Moreover, pallets can be lost due to theft and idle pallets need to be properly stored. Rental pallets are expected to be used longer, so they are more often of tougher designs and materials such as plastics. And the user does not need to be concerned about the maintenance such as repairing and sanitization, and storage when not in use.
2. When the ownership of pallets between the sender and receiver of goods are different, the goods already loaded on pallets have to be shifted again onto another owner's pallets, which are wasteful actions in the supply chain⁽²⁾. This also defeats the goal of intermodal palletization and unit-load system, which is one of the aims of palletization. When both parties are using rental pallets from the same provider, the logistics waste of pallet transferring can be reduced⁽³⁾.
3. After pallets are used to transport goods, a trip

back just for empty pallets is usually required. Moreover, it takes time to discharge the cargo from the pallets, which causes waiting time. In the case of rental pallets, the sender's truck can proceed to the next destination instead of carrying back empty pallets.

4. Rental pallets can also reduce environmental burden on the environment. It has been found that rental pallet and joint collection system can reduce life cycle CO2 compared to purchased pallet^(4, 5).

While one can expect such benefits when using rental pallets over purchased pallets, more work is needed to accurately compare rental pallets to purchased pallets. And deciding which one to use, has to be done on a case-by-case basis, as the most cost-effective pallet system will vary depending on the conditions the pallets are used.

1.2. Research Purpose

This research aims to make the decision of choosing between purchased pallet and rental pallet easier. Factors influencing the decision, present and future economic trends will be discussed. Also, global and Japanese local problems in the logistics industry, which can be alleviated by the improvement of efficiency by optimal pallet usage will be explored.

In this study, a mathematical model which will compare the different costs related to the usage of different pallet systems is developed. Using the model, trends of the cost under specific conditions are studied. The turning point, which is the exact length of usage time up to when renting pallets are more cost effective will be calculated. The change in this turning point caused by the change in some conditions of interest will be analyzed.

2. Methodology

2.1. Outline of the Mathematical Model

The basic costs related to using pallets for delivering goods from node A to B, in a supply chain will be compared, for using: (1) Purchased pallet and (2) Rental pallet. It is assumed that there is a constant pallet demand D , and cargo loading at A (from empty pallets, A' to loaded pallets, A) and unloading at B (from loaded pallets, B to empty pallets, B') are done every day. T_A, T'_A, T_B, T'_B are the average holding times at each point respectively. Time required per trip T_t , and transportation cost per trip C_t are assumed to be the same for both cases.

2.1.1. Model for Purchased Pallet

When using purchased pallet, the empty pallets are to be returned to the initial loading point, node A, thus requiring a return trip. The delivery trips have intervals of f and return trips have intervals of f' respectively.

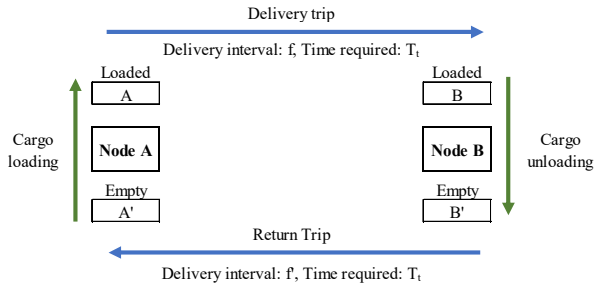


Figure 1 Model for using purchased pallet

2.1.2. Model for Rental Pallet

When using rental pallet, the required number of pallets can be ordered to node A to be delivered at the required time. After being used to carry goods to node B, the pallets are retrieved by the rental service at a convenient. For simplicity, it is assumed that T'_A and T'_B are negligible.

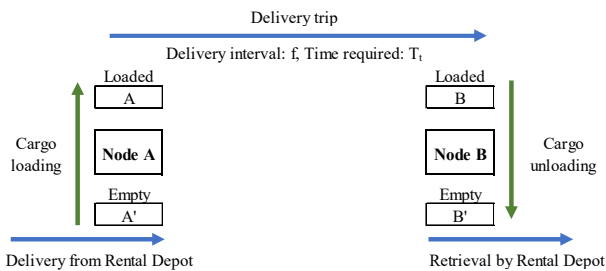


Figure 2 Model for using rental pallet

2.2. Mathematical Equations

The total costs are compared in units of 'yen per day' at any given time. The total cost associated with using pallets will be summarized by equation (1).

$$\text{Total cost} = \text{Pallet cost (PC)} + \text{Transportation cost (TC)} + \text{Storage cost (SC)} \quad (1)$$

Each cost will be broken down differently for purchased pallet and rental pallet.

2.2.1. Equations for Purchased Pallet

Equation (2) expresses the pallet cost when using purchased pallet (PC_P). C_P is pallet usage cost and T_P is average storage and transportation time required from A to B and back to A.

$$PC_P = C_P \times D \times T_P \quad (2)$$

Equation (3,4,5) expresses the transportation cost when using purchased pallet (TC_P). $C_T, C_{T'}$ are transportation cost during time T_t , and f, f' are time interval between each trip, for delivery and return respectively.

$$C_T = \frac{T_t}{f} \times C_t \quad (3)$$

$$C_{T'} = \frac{T_t}{f'} \times C_t \quad (4)$$

$$TC_P = \frac{C_t}{f} + \frac{C_t}{f'} \quad (5)$$

The storage cost when using purchased pallets (SC_P) will be expressed in equation (6). The time stored will be taken as $(T_A + T'_A + T_B + T'_B)$, and it will be assumed that the pallets are stored in stacked piles of n pallets, with surface area of S , at a warehouse with rental cost of C_S .

$$SC_P = C_S \times S \times \frac{D \times (T_A + T'_A + T_B + T'_B)}{n} \quad (6)$$

From equation (1, 2, 5, 6), the total cost associated with using purchased pallet ($C_{P,Total}$) can be summarized by equation (7).

$$C_{P,Total} = PC_P + TC_P + SC_P \quad (7)$$

2.2.2. Equations for Rental Pallets

Equation (8) expresses the pallet cost when using rental pallet (PC_R). C_R is pallet rental fee and T_R is average storage and transportation time required from A to B.

$$PC_R = C_R \times D \times T_R \text{-----}(8)$$

Equation (9) expresses the transportation cost when using rental pallet (TC_R).

$$TC_R = \frac{C_t}{f} \text{-----}(9)$$

The storage cost when using rental pallet (SC_R) will be expressed in equation (10). The time stored will be taken as $(T_A + T_B)$.

$$SC_R = C_S \times S \times \frac{D \times (T_A + T_B)}{n} \text{-----}(10)$$

From equation (1, 8, 9, 10), the total cost associated with using rental pallet ($C_{R,Total}$) can be summarized by equation (11).

$$C_{R,Total} = PC_R + TC_R + SC_R \text{-----}(11)$$

3. Results of Sensitivity Analysis

The comparison model was structured based on the mathematical equations. Calculations and visualizations were carried out by applying the above-mentioned values, using Microsoft Excel, version 2107. For the calculations done for this research, practical assumed values typical to the field will be used. Warehouse rental cost is based on Kanto region of Japan⁽⁶⁾ and the purchasing price and rental fee of pallets are taken from Nippon Pallet Pool Co.,Ltd.⁽⁷⁾. Transportation cost is based on the standard fare decided by the Japan Trucking Association⁽⁸⁾.

Table 1 Values of Variables

Variable Name	Symbol	Value	Unit	Remarks
Pallet demand	D	20	pallet/day	
Warehouse rental cost	C _S	40.40	yen/m ² /day	Japan, Kanto region
Surface area of pallet	S	1.21	m ² /pallet	T11 Type (JISZ0601)
No. of pallets per stack	n	10		
Purchasing price		7000	yen/pallet	Nippon Pallet Pool Co.,Ltd.
Service life		3650	day	10 years
Pallet rental fee	C _R	8	yen/pallet/day	Nippon Pallet Pool Co.,Ltd.
Distance between node A and B		30	km	
Time required per trip	T _t	0.04	day	calculated with average travel speed of 30km/h
Transportation cost per trip	C _t	28120	yen	10 ton class

We observed the change in each cost due to the change in Average holding time of goods, which is denoted by $(T_A + T_B)$. With the increase in average holding time, PC_R showed a higher increase rate than PC_P , TC_R showed a much higher decrease rate than TC_P , and both SC_P and SC_R increased proportionally with similar slopes (figure 3).

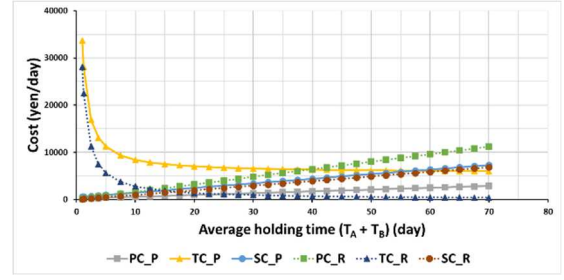


Figure 3 Cost breakdown vs Average holding time

Figure 4 depicts the change in the total cost of using purchased pallet ($C_{P,Total}$) and rental pallet ($C_{R,Total}$) with the increase in average holding time. When the average holding times were low, $C_{R,Total}$ was lower than $C_{P,Total}$. But as the average holding time increased, $C_{R,Total}$ showed a much sharper increase until it finally overcame $C_{P,Total}$ at $T_A + T_B = 51.8$, which is the “turning point”. Simply said, logistic managers should use rental pallet if the predicted average holding times are lower than the turning point, and they should use purchased pallet if not.

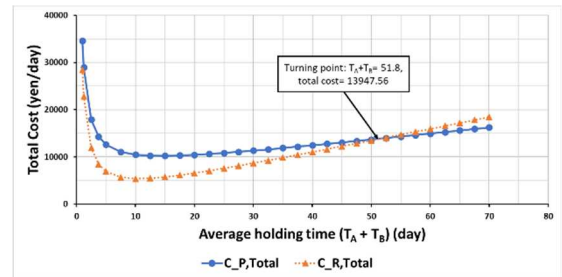


Figure 4 Total cost vs Average holding time

Next, we observed the effect of changing C_R on the turning point. Under the otherwise same conditions, just a decrease of C_R from 8 to 6, could make the turning point shift from $T_A + T_B = 51.8$ to 77.2 (figure 5).

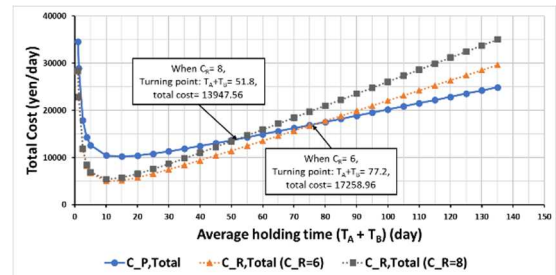


Figure 5 Effect of C_R on Turning Point

Figure 6 shows the trend of turning points with the change in C_R . The area under the curve can be

taken as the conditions preferring the use of rental pallet and the area above the curve are the conditions favoring the use of purchased pallet.

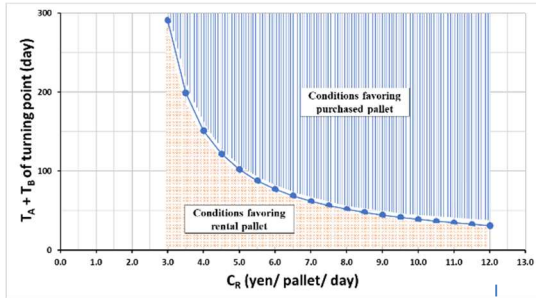


Figure 6 Turning Point vs C_R

Finally, we observed the effect of changing transportation times (T_t) and costs (C_t), Figure 7 shows the trend of turning points when the distance between node A and B are varied from 10 to 200 km. Similarly to Figure 6, the graph divides the areas of conditions favoring the use of rental pallet and the use of purchased pallet.

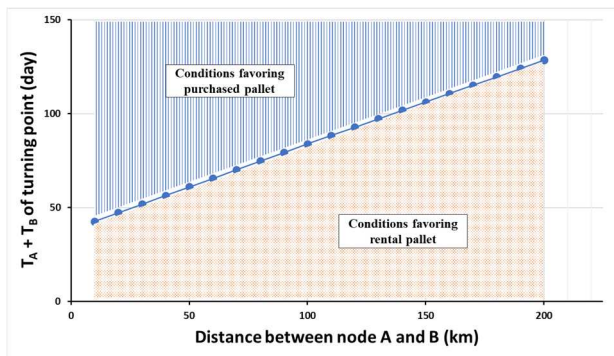


Figure 7 Turning Point vs Distance between nodes

4. Conclusion

The mathematical model developed in this research can compare the different costs related to the usage of purchased pallet and rental pallet. The 3 different costs: pallet costs, transportation costs and storage costs may show different trends under each condition, but the total costs can be compared, and the turning point can be referred to support the choice between purchased pallet and rental pallet.

From the calculations, it is found that for goods planned to have a long holding time, purchasing pallet is more cost-effective. But for goods with a short holding time, using rental pallets has more profound benefits

Logistic managers should also consider the effect

each variable has on the total cost, especially when that variable has potential to vary considerably in the near future. In this research, the effects of pallet rental cost and transportation cost are thoroughly analyzed. The average holding time of the turning point changes exponentially with the change in pallet rental cost. The transportation cost has a bigger effect on the total cost when using purchased pallet but only a slight effect when using rental pallet, which makes the latter more desirable in the future.

In this study, practical values typical to the field are used but some are assumed. Further analysis can be done more realistically by applying actual logistics data, and comparing with the results from this model.

More accurate comparison can be done by adding more types of costs related to the usage of pallets to the model, such as cost of equipment used together with pallets, labor wages, maintenance, disposal fees and so on.

5. References

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