Research on Railway Freight Loading and Unloading Fee Pricing Based on Time-Driven Activity-Based Costing

Mei Yin[a,1], Xiushan Jiang[*a,2], Bochao Han[b,3]

[1] 23120941@bjtu.edu.cn, [2] [*] Corresponding author: xshjiang@bjtu.edu.cn
[3] bochao.han.22@ucl.ac.uk

[a]Beijing Jiaotong University, 3 Shangyuancun, Beijing, 100044, CHN
[b]University College London, Gower Street, London, UK WC1E 6BT

Abstract. This paper addresses the issue of market adaptability of railway loading and unloading fees and introduces the Time-Driven Activity-Based Costing method (TDABC), which accurately calculates unit costs and establishes a solid foundation for pricing. By employing the cost-plus method and considering factors such as return on investment, cargo volume, and market changes, a scientifically justified pricing model is developed. To validate the feasibility and effectiveness of the pricing model, a case study is conducted using piece-packaged goods as an example. This method not only assists railway administrations in determining reasonable handling rates and supporting operational decisions but also optimizes cost accounting, promotes production efficiency, and serves as a valuable reference for the optimization and development of the railway freight transportation industry.

Keywords: Loading and unloading fee, Piece-Packaged goods, Time-Driven Activity-Based Costing, Cost-Plus pricing method

1. Introduction

Loading and unloading refer to the collective term for a series of operations that move goods from one place to another, including loading, unloading and short-distance handling in between, which are indispensable crucial components of railway freight transportation. Reasonable pricing of loading and unloading fees is of significant importance in ensuring the normal operation of railway transportation, enhancing transport efficiency, and reducing transportation costs. However, the current railway cargo handling fee rates suffer from poor market adaptability. For some categories, due to the low benchmark rates, there is a significant loss in handling settlement. Furthermore, there are regional economic disparities, yet the current rates are relatively fixed and lack flexibility, thus unable to adapt to local market demands effectively; Moreover, the current handling rates are only determined by categories, without considering the specifications or packaging of goods under the same category. Consequently, different handling methods are applied to goods of the same name but different specifications, resulting in varying operating costs, yet they are charged the same, failing to reflect the relationship between costs and prices.

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In recent years, domestic and international scholars have researched loading and unloading operations. Some scholars have focused on methods to improve loading and unloading efficiency. For example, Roy and Koster developed a comprehensive analysis model for overlapping operations of container terminal cranes to optimize the loading and unloading process[1] Meanwhile, other scholars have focused on the issue of loading and unloading costs. For instance, Vorobyov *et al* studied methods to determine transportation plans by considering the minimum costs of cargo loading and unloading operations among other factors[2]. Additionally, Zhang and Liu proposed a mathematical modeling and prediction method for port container loading and unloading engineering based on interval analysis and principal component analysis to enhance the accuracy of loading and unloading cost predictions. Addressing the characteristics of handling operations[3]. Yu studied the application of the Activity-Based Costing (ABC) method in enterprise cost management using port bulk grain handling operations as an example[4]. Ding *et al* allocated terminal handling costs to customer objects based on the Time-Driven Activity-Based Costing (TDABC) method and constructed a differential pricing mechanism for handling fees with penalty rates[5]. Yang compared the time-driven operation cost method with traditional ABC and concluded that the TDABC had advantages in allocating manufacturing costs[6]. Currently, there is limited research on handling fee pricing, mainly focused on port handling fees, with little exploration into railway handling fee pricing issues. However, the current pricing of railway handling fees in China does not fully adapt to the market, making further in-depth research necessary.

The rest of this paper is organized as follows. Section 2 introduces the TDABC model for cost accounting based on the loading and unloading operation process. Section 3 establishes the pricing model. Section 4 conducts a numerical example study using packaged goods as an example. Section 5 summarizes and concludes.

2. Cost Analysis of Railway Loading and Unloading Process Based on the TDABC Model

2.1 Analysis of railway freight loading and unloading process

TDABC is a method that automatically allocates resource expenses to cost objects using time equations. In the accounting of railway loading and unloading operation costs, the TDABC method combines costs with the time consumed by activities, allowing for a more accurate assessment of the actual cost of each activity, This provides reliable data support for the cost accounting of railway loading and unloading operations. Furthermore, the commercial environment of railway freight transportation is usually dynamic, with market demands and transportation conditions potentially changing at any time. The TDABC method, due to its dynamic monitoring and adjustment capabilities for costs, is more suited to coping with such complex and dynamic business environments. By continually updating and adjusting the activity cost rates, the TDABC method can promptly reflect the changing trends in the costs of railway loading and unloading operations.

The loading, unloading, and handling operations for railway cargo vary significantly in their workflows and corresponding operational costs due to the characteristics of the goods, packaging methods, and transportation needs. This paper will take the example of loading and unloading operations for commonly packaged goods, which are typically large in volume, moderate in weight, and often utilize fixed forms of packaging such as bags, requiring a combination of manual labor and mechanical equipment for the operations. The workflow for loading and unloading packaged goods is illustrated in **Figure 1**. Subsequently, taking the scenario where the consignor opts to temporarily store the goods as an example, the operation process will be divided into three stages: vehicle loading and unloading, horizontal transfer, and stacking operations, with a detailed cost analysis to follow.

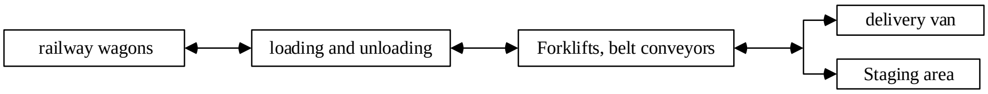

Figure 1. Railway loading and unloading operation flow of packaged goods in pieces.

2.2 Cost analysis based on the TDABC model

In the process of loading and unloading packaged goods, the application of TDABC is implemented in the following steps: 1) Determine the capacity cost rate of the main operations in loading and unloading packaged goods; 2) Estimate the capacity required by each main operation and its corresponding sub-operations, establish time equations to determine the capacity consumed by the main operation; 3) Determine the allocated capacity costs for each loading and unloading operation. The formula for calculating the capacity cost rate is expressed as:

$$r_i = c_i / T_i \tag{1}$$

The numerator of the capacity cost rate includes all expenses related to loading and unloading operations, such as wages paid to forklift drivers, equipment operational costs, maintenance costs, and other costs. These expenses are derived from financial data to calculate the cost incurred by each work group in phase i, denoted as c_i. The denominator represents the actual capacity, indicating the available production capacity. The actual working time T_i for each work group is estimated through surveys. The actual working time for loading and unloading operations, as well as stacking operations, can be used to estimate the working hours of workers, and the working hours of forklift drivers can be estimated for forklift operations. Specific costs are detailed in **Table 1**.

Table 1. Costs of loading and unloading of railroad piece packaged goods.

Operations	Using resource	Cost
loading and unloading operation	labor force	employee salaries
		management costs
	tray	depreciation cost
horizontal transportation	forklift	energy consumption cost
		depreciation cost
		maintenance costs
		river's salary
storage yard operation	labor force	employee salaries
		other costs

Time equations can integrate the time differences required by different types of operations into the cost model. The key to establishing time equations is to estimate the number of unit times for operations, which involves determining the precise time needed to complete each task. This time is generally obtained directly through observation. $t_{i,k}$ denotes the time to complete the k^{th} sub-operation of phase i . The unit time for each phase operation is calculated as follows:

$$t_i = \sum_k t_{i,k} \tag{2}$$

The cost driver rate serves as a transitional factor. It represents the constant term for allocating operation costs to products over a certain period, expressed as follows:

$$f_i = r_i t_i \tag{3}$$

Where, f_i is the cost driver rate of phase i .

Finally, calculate the cost driver quantities consumed by each operation. The operation cost allocated to a particular main loading and unloading operation can be obtained by multiplying the cost driver quantity of each operation by the unit cost driver rate. The calculation formula is as follows:

$$C_i = f_i A_i \tag{4}$$

Computing the sum of C_i yields the cost of completing a single instance of loading and unloading operations for packaged goods. In practice, each railway bureau can calculate the various costs in detail according to the operational characteristics of different categories of goods, providing managers with a reliable basis for decision-making. Furthermore, by applying the TDABC model, managers can gain clear insights into the proportion of each operation in the total cost. This allows for the precise identification of key operations, which can then be closely monitored and optimized, significantly improving the efficiency and effectiveness of business processes.

3. Establishment of a Pricing Model for Loading and Unloading Fees

Under competitive conditions, setting loading and unloading rates requires consideration of factors such as cargo availability, market competition landscape, and loading and unloading costs, to be formulated flexibly. Cost is the foundation for setting loading and unloading rates, thus, cost-plus pricing is a suitable method. Companies first calculate the unit cost of the product, and then determine the final sales price based on the expected profit margin. The determination of the profit margin can take into account various factors such as the company's financial objectives, market conditions, and competitive situation. Under this method, companies can obtain reasonable profits while ensuring cost coverage, and can also flexibly adjust their pricing strategies according to market changes to maintain competitiveness.

In the research on cost-plus pricing, Li deeply explored the close relationship between loading and unloading rates, throughput, loading and unloading costs, and company earnings and investment returns, and constructed the corresponding pricing model[7]. However, in railway transportation, the variety of goods categories and the unique loading and unloading processes for different types of goods, coupled with the indivisibility of investment, mean that average loading and unloading rates are not applicable. Therefore, a more detailed method is needed to determine the loading and unloading rates for each type of goods. The TDABC method can accurately calculate the unit cost based on the loading and unloading process of different categories of goods, which can more truly reflect the actual costs of various goods' loading and unloading operations. the adjusted pricing model is as follows:

$$P = (\sum_{i=1}^{n} C_i + \frac{(M+H)\ R_{-1}(1+\pi)}{y_t})(1+\pi+f\frac{y_t - y_{t-1}}{y_{t-1}}) \tag{5}$$

Where, P is the loading and unloading fee, M is fixed assets, H is current assets, R_{-1} is the investment return rate of the previous period, π is the inflation rate, y_t is the cargo volume of the *t* period, and y_{t-1} is the cargo volume of the *t-1* period.

This model considers both the actual costs of loading and unloading operations for various goods and ensures that enterprises can obtain reasonable profits when providing services. Accordingly, each railway bureau can accurately determine the unit cost of each type of goods based on the actual loading and unloading processes, and price them by taking into account capital investments and fluctuations in the volume of business.

4. Case study

Taking the loading and unloading fees for railway packaged goods as the subject of study, this paper conducts an example analysis based on the model, using data generated from the Chengdu Bureau's loading and unloading operation cost data as a reference. The monthly consumed cost, capacity, and capacity cost rate for each operation group are shown in **Table 2**.

Table 2. Production capacity cost rate of each task group.

Operations	Energy costs	Depreciation cost	Maintenance cost	Employee salaries	Management costs	Total cost	Monthly production capacity	Capacity cost rate
Loading and unloading operation	0.0	0.0	0.0	751503	18660	770163	666437	1.2
horizontal transportation	13131	45614	24189	407760	0.0	490695	222146	2.2
storage yard operation	0.0	0.0	0.0	375752	0.0	375752	444291	0.8

The unit operation time for each operation group was estimated through observation, as shown in **Table 3**.

Table 3. Work time of each work group unit.

Loading and unloading operation time		Horizontal transportation time		Storage yard operation time	
preparation work	0.1	preparation work	0.1	preparation work	0.1
unloading a cargo from a railway carriage	0.2	waiting for the tray to fill up	0.3	unloading goods from pallets	0.2
stacked on pallets	0.02	moving goods to designated locations	1.5	stacking and sorting	0.1
		return	1		
total	0.32		2.9		0.4

Generally, one ton of packaged goods requires 20 instances of loading or unloading vehicle operations, 1 instance of forklift horizontal transport operation, and 20 instances of stacking operations. The cost driver unit costs for each operation group were calculated as shown in the following **Table 4**, The cost for one ton of goods was calculated as follows: C=0.384*20+6.38+0.32*20=20.46（yuan/ t）

Table 4. Cost driver unit cost calculation for each task group.

Operations	Capacity cost rate	Unit Time（min）	Cost driver unit cost（yuan）
Loading and unloading operation	1.2	0.32	0.384
horizontal transportation	2.2	2.9	6.38
storage yard operation	0.8	0.4	0.32

According to the freight volume data from 2016 to 2023 published by the Chengdu Statistical Bureau, as shown in **Table 5**, this paper employed the least squares method for curve fitting. Through meticulous calculation and analysis, the following quadratic fitting curve formula has been obtained: $y_t = 6.905x^2 - 297.6x + 3882$， it is predicted that the freight volume of the Chengdu Bureau will reach 7.168 million tons in 2024.

Table 5. Cargo volume of Chengdu Bureau from 2016 to 2023.

Year	2016	2017	2018	2019	2020	2021	2022	2023
Railway freight volume (10 thousand tons)	933.4	796.4	663	766.0	735.6	647.5	736.1	647.6

Assuming the previous period's return on investment is 7.5%, with a total of 600 billion yuan in fixed and current assets, an annual inflation rate estimated at 2%, and an f-value set at 0.5, the loading and unloading fee rate for unitized packaged goods is calculated as follows：

$$p = \left(20.46 + \frac{60000 \times 7.5\% \times (1+2\%)}{716.8}\right) \times \left(1 + 2\% + 0.5\frac{716.8 - 647.6}{647.6}\right) = 28.83$$

The calculated handling rate for Chengdu Bureau's finished packaged goods was RMB 28.83 per ton, much higher than the stipulated RMB 11.2 per ton, but close to the local logistics market's RMB 20-30 per ton. It shows that the calculation result of this paper is more reasonable. This rate can cover the costs of loading and unloading operations while also taking into account future inflation and asset appreciation. Such calculation results are of great significance for the operational decision-making and cost control of enterprises, contributing to the enhancement of their competitiveness and profitability.

5. Conclusion

Given the current inadequacies in the market adaptability of railway loading and unloading fee rates, this paper delves into the pricing mechanism for these fees. The TDABC model is introduced to accurately calculate the unit cost. This method not only enhances the precision of cost accounting but also provides a solid foundation for subsequent pricing. Moreover, it enables cost allocation according to operational processes, allowing railways to perform horizontal comparative analysis to identify and specifically improve segments with low production efficiency. Subsequently, by taking into consideration factors such as return on investment, freight volume, as well as future inflation, and asset appreciation, a scientifically sound and reasonable pricing model was developed. This model ensures that the loading and unloading rates can cover operational costs while fully considering market fluctuations and long-term development trends. Railway bureaus can apply this method to calculate their respective costs and establish reasonable loading and unloading rates, thereby addressing the issues of settlement deficits and the inability to closely match market rates by region. However, it must be noted that this study has not fully considered factors such as market competition and seasonal variations. The impact of these factors on loading and unloading rates is significant and will be an important direction for future research.

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