Optimize Logistics cost model for shared logistics platform based on time-driven activity-based costing

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Abstract. Transportation cost management plays an important role in both traditional logistics management and supply chain logistics management. Time-driven activity-based costing bypasses the expensive, time-consuming and subjective activity investigation and is more suitable for the intermediate link of enterprise cost accounting. Linear programming is a mathematical theory and method to study the extreme value problem of objective function under linear constraints, and the optimal decision is made by using limited human, material and financial resources. Based on the concept of Shared logistics, this paper studies transport enterprises to solve problems such as information asymmetry in the process of transport. By establishing a linear programming time-driven activity-based costing accounting model, the allocation of scarce resources in transport enterprises can be reasonably solved, and the efficiency of cost accounting can be improved to achieve considerable cost savings.

1. Introduction

Traditional cost accounting methods ignore some factors that affect indirect cost accounting, such as the diversity of transportation enterprises' business, the complexity of processes and the changes of customer requirements. It makes it hard to do a better cost management [1]. The activity-based costing (ABC) method is a cost allocation method that allocates indirect costs to the corresponding product activities based on the amount of working facts, which could be the number of working time, working distance, or the operation cost, and refines the standard of product cost allocation. It increases the accuracy of cost calculation by considering the amount of resources consumed by the activity and linking the cost to the workload [2]. Cost information can be used to help managers make strategic decisions, such as process improvement, cost reduction, innovation pricing, budgeting, or outsourcing evaluation [3]. Yan and Peng built a basic model based on activity-based cost, combined logistics costs with activity-based costs, which makes the logistics more responsive. The research proved the effectiveness and accuracy of ABC logistics cost control. It provided more effective basis and support for company to make decisions [4]. Fang applied ABC to construction cost accounting, it helped the managers to determine the cost change of materials from suppliers to construction prefabricated components, and provided management personnel with data support for construction costs [5].

Although activity-based costing is accurate in cost accounting and can make product cost more competitive, the implementation of activity-based costing is relatively complicated and does not match with accounting statements and financial statements. For now, the application of activity-based costing at home and abroad is not as what people think. Gosselin found that only a small number of companies in the market use ABC, and some of these users are still not fully implemented. This is because the
traditional ABC management system is costly, difficult to use, and difficult to maintain, and it is not easy for the enterprise to modify it according to actual conditions [6].

TDABC is a simplified method based on the ABC method. It avoids the burden of the new costing model and is widely implemented in various industries, such as the medical industry and the education industry [7]. Noemie, Lionel and Borras et al. applied TDABC to the health care field. The resource costs are allocated to the treatment curriculum through the activities performed, which greatly reduces the cost of radiotherapy [8]. Deng, Ai-Min and Li et al. studied the small business based on ERP, using TDABC feasibility. With the development of cloud computing, cloud-based ERP provides a way for SMEs to use ERP. Combining Cloud ERP and TDABC provided an effective logistics cost accounting method for SMEs [9]. Ki-Myung and Ahn carefully compared traditional costing, activity-based costing (ABC) and time-driven ABC (TDABC) in logistics. It proved that TDABC is the most useful and effective of them [10]. Somapa, Cooling and Dullaert studied the possibility of small logistics companies implementing TDABC. Because of the high cost of ABC, it makes ABC not conducive to the implementation of the company. TDABC overcomes these shortcomings of ABC. Therefore, the implementation of TDABC is beneficial to improve the efficiency of small logistics [11].

This paper mainly studies the application of TDABC in logistics cost control by constructing a shared logistics platform. Through the logistics data sharing, the accuracy of TDABC cost calculation is improved, and the TDABC cost calculation model is optimized.

2. Mathematical model

2.1. Decision Support Platform Based on Shared Logistics

This paper proposes a decision support platform based on shared logistics, which solves the problems in the process of logistics information management and transportation. There are internal business and external business. The operating platform mainly includes the module of the operation progress monitoring and feedback of various transportation operations, which ensures the normal operation of daily workflow. And there are collaborative office system module, human resources system module, financial system module, resource planning system module in decision support platform and logistics information system. The system has network interface of partners, built-in cargo vehicle matcher module, cargo allocation optimizer module, route planning module and decision display area module. The decision platform collects data and integrates existing resources through resource planning system module. The next step is cargo allocation optimization module and cargo display area module. Vehicle Matching Device aims at maximizing the whole vehicle transportation, and then obtains the optimal transportation route through the route planning module, including trunk transportation and co-city land allocation. Finally, the transportation scheme is displayed in the decision-making exhibition area.

Notation

\( \pi \): the cost savings in original problem;
\( \pi' \): the cost savings in dual problem;

\( C_j \): the marginal cost savings in \( j \) products per unit time;
\( X_j \): the number of \( j \) products produced;

\( A_{ij} \): the production cost rate of \( i \) operation used to produce \( j \) product per unit;

\( T_{ij} \): the capacity of the \( i \) operation used to produce \( j \) product per unit;

The productivity of type \( i \) operations used;
\( N_i \): the number of operations;

\( R_i \): the total productivity cost of \( i \) operations;
2.2. Linear Planning-Time-Driven Activity-Based Costing Model Based on Shared Logistics

This paper establishes the time-driven activity-based costing method in the transportation enterprise, assuming that the number of main products is $n$, and the number of operations can be classified as $m$ in the production of the product.

Form of original problem of linear programming:

$$\text{Max } \pi = \sum_{j=1}^{k} c_j x_j$$  \hspace{1cm} (1)

subject to:

$$\begin{bmatrix}
A_{i1} & T_{i1} & N_{i1} & \cdots & A_{in} & T_{in} & N_{in} \\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\
A_{m1} & T_{m1} & N_{m1} & \cdots & A_{mn} & T_{mn} & N_{mn}
\end{bmatrix}
\begin{bmatrix}
x_1 \\
\vdots \\
x_n
\end{bmatrix}
\leq
\begin{bmatrix}
R_1 \\
\vdots \\
R_n
\end{bmatrix}
\begin{bmatrix}
x_1, x_2, \ldots, x_n \geq 0
\end{bmatrix}

We can get the form of dual problem:

$$\text{Min } \pi = \sum_{i=1}^{m} R_i y_i$$  \hspace{1cm} (2)

subject to:

$$\begin{bmatrix}
A_{i1} & T_{i1} & N_{i1} & \cdots & A_{mi} & T_{mi} & N_{mi} \\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\
A_{mi} & T_{mi} & N_{mi} & \cdots & A_{m1} & T_{m1} & N_{m1}
\end{bmatrix}
\begin{bmatrix}
y_1 \\
\vdots \\
y_m
\end{bmatrix}
\leq
\begin{bmatrix}
C_1 \\
\vdots \\
C_m
\end{bmatrix}
\begin{bmatrix}
y_1, y_2, \ldots, y_m \geq 0
\end{bmatrix}

C, A, T, X, R, N are all based on the data of previous years. Under the condition of stable production and operation of enterprises and market, these data are determined. In the period of peak season or off season, unit time cost and unit operating time can be changed according to the previous data, which is a dynamic system. This is also the advantage of time-driven activity-based costing compared with activity-based costing. If $Y_i = 0$, the operation of type $i$ is non-value-added. According to the Looseness Theorem of Linear Programming, bring it into inequality $\Sigma C_i x_i \leq R_i$. There will be the left (used capacity) less than the right (agreed capacity), that is, excess $R_i$, there will be unused operating costs, the number of which is equal to the difference between the left and right data.
3. The Case of Linear Planning-Time-Driven Activity-Based Costing Model

We use the model in transportation company, it can be divided into order processing, sorting and handling operations, and transportation and delivery operations. Suppose this enterprise produces two products, Q1 and Q2, the output of these two products is expressed by $X_1$ and $X_2$ respectively, the corresponding gross profit contribution per unit product is 10 and 20 respectively. There are only three types of activities required (M1, M2, M3), the shadow prices are represented by $Y_1$, $Y_2$, $Y_3$, the total capacity cost of these three activities is $R_1$, $R_2$, $R_3$, which are assumed to be: 27, 18 and 12 respectively. The capacity cost rate is calculated from the previous data, and the capacity of each activity is estimated according to the actual operation. In case analysis, We assume that the number of activities is $N_i=1$, the amount of activities consumed per unit product is shown in Table 1, the activity time consumed per unit process is shown in Table 2, and the activity cost per unit time is shown in Table 3.

| Product operation | M1 | M2 | M3 |
|-------------------|----|----|----|
| Q1                | 4  | 2  | 1  |
| Q2                | 3  | 5  | 6  |

| Product operation | $T_1$ | $T_2$ | $T_3$ |
|-------------------|-------|-------|-------|
| Q1                | 2     | 1     | 1     |
| Q2                | 3     | 1     | 2     |

| Product operation | M1 | M2 | M3 |
|-------------------|----|----|----|
| Q1                | 1.6| 1.6| 0.8|
| Q2                | 0.8| 4.0| 2.4|

Using activity-based costing to solve the following problems:

The original model:

$$\max \pi = 10X_1 + 20X_2$$

s.t. $\begin{cases} 4 & 3 & X_1 \\ 2 & 5 & X_2 \leq \begin{pmatrix} 27 \\ 18 \\ 12 \end{pmatrix} \\ X_1, X_2 \geq 0 \end{cases}$

The dual Model:

$$\min \pi = 27Y_1 + 18Y_2 + 12Y_3$$

s.t. $\begin{cases} 4 & 2 & 1 & Y_1 \geq \begin{pmatrix} 10 \\ 20 \end{pmatrix} \\ 3 & 5 & 6 & Y_2, Y_3 \geq 0 \end{cases}$

Using time-driven activity-based costing to solve the following problems:

The original model:

$$\max \pi = 10X_1 + 20X_2$$
The dual Model:

\[
\begin{align*}
\min \pi &= 27y_1 + 18y_2 + 12y_3 \\
\text{s.t.} \\
&\begin{cases}
2 \times 1.6 \times 1 & 3 \times 0.8 \times 1 \quad x_1 \\ 1 \times 1.6 \times 1 & 1 \times 4 \times 1 \quad x_2 \\ 1 \times 0.8 \times 1 & 2 \times 2.4 \times 1 \\
\end{cases} \\
&x_1, x_2 \geq 0
\end{align*}
\]

These models are both solved by Excel. By comparing the solutions of linear programming activity-based costing model and linear programming time-driven activity-based costing model, it is found that their resource utilization rate is similar in this case. The cost savings calculated by linear programming time-driven activity-based costing model are more than that calculated by linear programming activity-based costing method. The savings are 20 units higher. In order to determine the scientific nature of conclusions, ten different categories are selected according to different resource constraints. The values are (35,27,22), (30,22,17), (50,30,20), (40,28,24), (52,34,27), (45,20,15), (57,36,28), (65,50,40), (62,45,35), (60,40,30), and calculated again. Cost savings of the two models under different resource constraints.

It can be concluded from Figure 2 that:

1. For a transportation enterprise, adopting different resource viewpoints may lead to the use of different systems to determine the product mix. If this viewpoint is based on the resources used, in terms of the cost savings calculated, linear programming time-driven activity cost The method model is more accurate than the linear programming activity-based costing model.

2. The time-driven activity-based costing system will be more suitable for small logistics enterprises than the activity-based costing system. The time-driven activity-based costing system has proved to be more flexible than the activity-based costing system, avoiding the complex investigation work in the activity-based costing method, and using the two parameters of unit operating time and unit time cost to carry out the cost. Accounting is more in line with the flexible and changeable business characteristics of small logistics enterprises.

![Figure 2. Cost savings for the two models](image-url)
4. Conclusion
It is the measurement standardization that limit the shared logistics model. In the future, with the development of shared economy, shared logistics is the correct area that we should focus on. In this paper, we introduce a decision support platform based on shared logistics, which can effectively solve the "bottleneck" of the application of shared logistics. This platform can be used to collect and integrate data in the process of time-driven activity-based costing, aimed at reducing the cost errors caused by subjective factors in the process of cost accounting of transportation enterprises. Finally, through the comparison and analysis of the linear programming time-driven activity-based costing model and the linear programming activity-based costing model, it is concluded that the enterprise time-driven activity-based costing accounting system is easy to update data and has lower implementation cost, which improves the efficiency of transportation work.

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