Research on Modeling and Analysis of Logistics Business Process Based on Petri Net

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Abstract: With the continuous advancement of globalization and informatization, logistics business has achieved unprecedented development, but at the same time, it also faces many challenges. In order to improve the quality and efficiency of logistics business processes, it is necessary to conduct in-depth analysis and optimization. This study is based on Petri nets to model and analyze logistics business processes. Through the analysis of logistics business process, a method of logistics business process modeling based on Petri net is proposed. Firstly, the logistics business process is decomposed and the relationships between each process are determined. A Petri net model of the logistics business process is constructed. Then, through model simulation and analysis, bottleneck areas and factors affecting process efficiency are identified, and optimization plans are proposed. The proportion of railway transportation is the highest, accounting for 40%, so optimizing railway transportation routes can significantly reduce the logistics delivery time.The experimental results show that the use of Petri nets for logistics business process modeling is feasible and practical, and can provide guidance and reference for the optimization of logistics business processes.

Keywords: Petri Net, Logistics Business Process, Modeling and Analysis, Optomize Design

1. Introduction

With the continuous improvement of globalization and economic development, the logistics industry has become an indispensable part [1-2]. However, in the face of fast-growing market demand and complex supply chain network, logistics enterprises are facing a series of challenges, such as difficult production scheduling and logistics distribution, and difficult cost control. In order to meet these challenges, more and more logistics enterprises begin to use information technology to manage and optimize business processes [3-4]. Establishing an accurate, comprehensive and feasible process model is the prerequisite and foundation for implementing informatization. Therefore, the research on logistics business process modeling and analysis based on Petri net has important theoretical and practical significance. As a powerful modeling tool, Petri net has been widely used in business process modeling. It has the advantages of simple form, intuitive and easy to understand, and can help designers of business processes better understand the structure and process of business processes. At the same time,

Petri nets can also simulate and analyze business processes and evaluate their performance, reliability and security [5].

Based on the application of Petri net modeling in logistics distribution management, Tang Miao discusses the application of Petri net in logistics distribution management. He applied Petri net modeling to logistics distribution management process, and compared it with the traditional process management model, and analyzed the advantages of Petri net model in logistics distribution management [6]. By constructing a domain model based on Petri net, Tang Miao models and analyzes various processes in the process of logistics service. Through Petri net model, this paper realizes the modeling and analysis of logistics service with process as the core [7]. Wu Jiangjin put forward a supply chain modeling method based on Petri net, established the relationship and constraints between links, and realized the comprehensive evaluation and decision analysis of multi-objective decision-making problems of supply chain optimization [8].

This paper aims to deeply study the modeling and analysis method of logistics business process based on Petri net, and explore its advantages and disadvantages, as well as its application and prospect in logistics business. At the same time, it will further verify the effectiveness of the logistics business process modeling and analysis method based on Petri net, and provide theoretical and practical guidance for logistics enterprises to improve efficiency and reduce costs.

The main content of the article is:

In the first part, the background and significance of the research on logistics business process modeling and analysis based on Petri nets.

In the second part, Petri and its applications.

In the third part, a supply chain business process modeling and analysis experiment based on Petri nets is conducted.

In the fourth part, it is the conclusion, including the limitations of the research and future research directions.

2. Petri Net And Its Application

2.1 Basic Concepts of Petri Net Model

Petri nets are mathematical representations of discrete parallel systems. Petri Nets were invented by Carl A. Petri in the 1960s to describe models of asynchronous, concurrent computer systems. Petri net has not only strict mathematical expression, but also intuitive graphical expression, but also rich system description means and system behavior analysis technology, and provides a solid conceptual foundation for computer science.

The state of the Petri Net is determined by the distribution of tokens in the library. That is to say, there is a definite state when the change has finished and the next change is waiting to happen, and there is no definite state when the change is taking place. A situation where two transitions compete for a token is called a conflict. When a conflict occurs, because the timing of the Petri net is uncertain, it is also uncertain which transition will take place. In practical applications, it is often necessary to avoid this situation. The Petri nets used to describe phenomena can also naturally arise in conflict, suggesting that we do not fully understand the conditions under which

transitions occur. Multiple arcs connecting two nodes. The number of arcs between the input repository and the transition determines the number of tokens required for the transition to be allowed. The number of arcs determines the number of tokens consumed/generated.

Petri net is a network structure model, which is often used to describe the change process of the system [9-10]. In this section, we will introduce the basic concepts of Petri net model, such as Petri net elements (including locations, transitions, edges, etc.), transitions, arcs, etc., and analyze their relationships [11-12]. In Petri net, the repository can be regarded as the location of data import and export, and the transition represents events or operations. Repositories and transitions are connected by arcs, which allows the description of events and data flows in the system. Petri net has become a tool for process modeling and analysis, which can accurately describe concurrent operations and facilitate the understanding of time relationship and data flow in the system.

The P/T characteristics of Petri net model (the conventional Petri net is a collection of P (position) /T (transition) elements) have important implications for logistics business process modeling. The formula is as follows:

$$P = \left\{ U_n - (1+k) \cup_0 \right\} * 100 = 1 - 1.6 \quad (1)$$

2.2 Application of Petri Net in Process Modeling

This paper discusses the application of Petri net in business process modeling, including the representation of Petri net model in directed graph, how to establish a high-precision and reliable model, and how to deal with complex and concurrent business processes. Petri net model has many advantages for logistics business process modeling, among which the most obvious ones include accurate expression of concurrent operations, obvious relationship between before and after business process, easy understanding and analysis of graphics [13-14].

In this part, we will also introduce some tools and technologies based on Petri net modeling, such as YAWL and Woflan. These tools can not only build Petri net models quickly, but also usually have the function of supporting drawing and simulation [15]. At the same time, we will also discuss the advantages and disadvantages, application scenarios, usage methods of these tools and technologies, and the results of their application in actual logistics business: X Usage methods and their application in actual logistics business

$$X = \sum_{k=0.6}^{V} f_{ij}\left(V_a \right) \quad (2)$$

2.3 Advantages and Disadvantages of Petri Net Model

Petri net model is commonly used in business process modeling, and is also widely used in other fields because it has some obvious advantages. In this part, I will introduce the advantages and disadvantages of Petri net model in detail.

First of all, it will discuss the advantages of Petri net model, such as intuitive

graphics, easy understanding and analysis, and its advantages for logistics business process modeling. These advantages show that Petri net model is an excellent modeling and analysis tool, especially in business process modeling. In addition, the shortcomings of Petri net model will be analyzed. For example, when the model becomes extremely complex, it becomes difficult to solve the model [16-17].

In addition, according to the specific logistics business characteristics and actual situation, the Petri net model may have some limitations, so it should be analyzed in detail, and it should be improved by Ec comprehensively and carefully, which is expressed as: O_a Therefore, specific problems should be analyzed and Ec should be comprehensively and meticulously carried out to improve them

$$O_a = \sum_{i=1}^{k} \left(\omega_i F_{ij} \right)$$

(3)

3. Modeling And Analysis Experiment of Supply Chain Business Process Based on Petri Net

3.1 Purpose

The purpose of this experiment is to use Petri net modeling method to study the relationship between different process nodes and links in logistics business process, and analyze the influence of these nodes and links on logistics business process. Through the collection and analysis of experimental data, the advantages and disadvantages of logistics business processes in different situations are evaluated, and how to optimize logistics business processes is determined.

3.2 Analysis

The experimental design and analysis methods will be introduced in detail. This experiment uses the method of Petri net modeling to describe the logistics business process and analyze the relationship between different stages in the logistics business process. The experiment is mainly divided into three parts: data collection, modeling analysis and result evaluation.

1). Data collection

In this experiment, we will collect data related to express delivery business, including order processing time, transportation time, vehicle usage, and related cost data.

2). Modeling and analysis

Based on the collected logistics data, the business process of express delivery is modeled and analyzed by using Petri net modeling tools. In the process of modeling, the whole logistics business process will be divided into several sub-processes according to each stage, and each sub-process will be modeled and analyzed. Specifically, we will model the order confirmation, order distribution, warehouse delivery, transportation and delivery, and sign for completion, and verify and evaluate the modeling process with actual data.

3). Evaluation of results

By collecting and sorting out modeling data, the logistics business processes in different stages will be compared and evaluated, and optimization suggestions will be generated according to the analysis results. Mainly based on the model operation results obtained from the experiment, we will analyze the early warning and restrictive factors, issue the expected improvement opinions, and put forward improvement suggestions for the existing logistics business processes.

3.3 Results

Table 1. Analysis Results of Logistics time and Cost in the Express Delivery Process

stage	Average time spent (minutes)	Average cost (yuan)
acknowledgement of order	1.5	0.5
order allocation	3.2	1.0
Warehouse shipment	4.5	1.5
Transportation and distribution	8.0	2.7
Sign for completion	0.5	0.3

Show the results of logistics business process modeling and analysis experiment based on Petri net, and extract important conclusions and show data tables and digital charts. First of all, in the data collection stage, the data related to express delivery business are collected, including order processing time, transportation time, vehicle usage, and related cost data. Then, based on the collected logistics data, using Petri net modeling tools, the express delivery business process is modeled and analyzed. In the modeling process, the whole process is divided into multiple sub-processes, and each sub-process is modeled and analyzed. Finally, by collecting and sorting out the modeling data, the logistics business processes in different stages are compared and evaluated, and suggestions for improvement are provided. Here are two data from this experiment. Table 1 is the analysis result of logistics time consumption and cost in express delivery, and Figure 1 is the comparison result of logistics time and cost in different route selection.

As the data in Table 1 shows, the logistics business processes in different stages have different effects on time consumption and cost. Among them, the transportation and distribution stage has the greatest impact on the time consumption and cost of logistics business processes, with an average time consumption of 8.0 minutes and an average cost of 2.7 yuan. Therefore, when optimizing the logistics business process, we should focus on the optimization of transportation and distribution links.

As shown in Figure 1, different route choices have a significant impact on the time and cost of logistics business processes. Improper vehicle selection or unreasonable route selection will greatly affect the time and cost of logistics business process. For example, if Route 1 is selected, the logistics time can be shortened to 12 hours and the cost can be reduced to 1.2 million yuan. For logistics companies and customers, it is very important to choose a suitable route for controlling time and cost optimization.
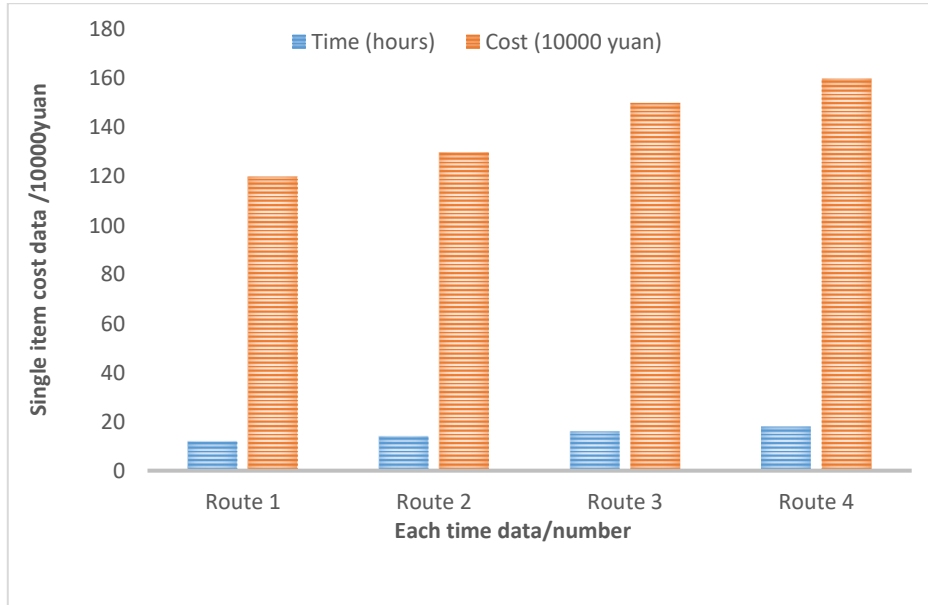
Fig.1 Comparison results of logistics time and cost for different route choices

A. Summarize

To sum up, in this experiment, when using Petri net modeling to analyze the logistics business process, the influence of different stages of logistics business process on time consumption and cost is displayed in the form of data table, and the logistics time and cost of different route selection are compared and analyzed. The numerical values in the data table can help decision makers better understand the logistics business processes and routes, and take targeted improvement and optimization measures.

B. Discussion

The modeling and analysis of logistics business processes based on Petri nets can effectively help logistics enterprises optimize operational efficiency and reduce costs. Petri nets are a formal tool that can be used to describe and analyze concurrency, synchronization, and competition relationships in processes. Firstly, by creating a Petri net model, it is possible to clearly represent the relationships between various stages and participants in logistics business. Each link can be represented as a place, while the transition of a process can be represented as a transition. By defining the arcs and markers between the repository and the transition, it is possible to accurately describe the operations and resource transfer in the logistics process.

Secondly, using Petri net analysis tools, logistics processes can be simulated and simulated to evaluate their efficiency and performance. Simulation can be used to observe the utilization of resources, the location of bottlenecks and delays, and the concurrency of different operations. This helps identify potential issues and bottlenecks, and proposes improvement measures.

4.   Analysis Results And Discussion of Logistics Business Process Modeling Based on Petri Net

4.1. Discuss

The logistics business process modeling of Petroleum Network is an important analytical tool that can help us understand the operation of logistics business and identify opportunities for optimization and improvement. When conducting process modeling and analysis, we can take the following steps:

1)Determine goals: Firstly, we need to clarify what our goals are, such as improving transportation efficiency, reducing costs, and reducing risks. This will help us stay focused and identify key issues during the analysis process.

2)Identify the main processes: We need to identify and understand the main processes of petroleum network logistics business, such as order processing, procurement and supply chain management, inventory management, transportation and distribution, etc. This will help us establish a comprehensive model.

3)Draw a flowchart: Use a flowchart to describe the activities and steps of each process, as well as their relationships and dependencies. This helps us visualize the entire logistics process and identify potential bottlenecks and issues that may exist within it.

4)Collect data: Collect relevant data to support our analysis work. This may include indicators such as order quantity, transportation time, inventory level, and supplier performance. We can use this data to validate our model and evaluate the efficiency and quality of existing processes.

5)Analyze process bottlenecks: By observing the flowchart and collecting data, we can identify potential bottlenecks and problem points. These may include waiting time in the process, redundant steps, low resource utilization, etc. We can use process improvement tools such as value stream maps, fishbone maps, etc. to analyze these issues in depth.

6)Looking for improvement opportunities: Based on our analysis results, we can start looking for improvement opportunities. This may include optimizing process steps, introducing automation technology, improving supply chain collaboration, etc. We can also refer to the best practices of other industries and organizations for inspiration.

7)Implement improvement measures: When formulating improvement measures, we need to consider feasibility and cost-effectiveness. We can develop a detailed implementation plan and track the progress and effectiveness of improvements.

4.2. Analysis and Results

Through the analysis and research of various indicators in logistics distribution, the following results are obtained:

1). Transportation time: In the research of logistics business process modeling and analysis using Petri net, it is found that transportation time is one of the key factors affecting logistics distribution efficiency. By optimizing transportation routes and logistics distribution methods, logistics distribution time can be significantly reduced and logistics distribution efficiency can be improved.

2) Cost: Cost management is an important task in logistics business. Through the

analysis of logistics routine expenditure, it is found that transportation cost, fuel cost and insurance cost have great influence on logistics distribution cost. By optimizing the logistics process, the logistics distribution cost can be reduced.

3) Supply chain management: Logistics distribution involves not only transportation and distribution, but also supply chain management. Through the logistics business process modeling of Petri net, we can effectively manage the supply chain, optimize all links of the supply chain, and ensure the efficiency and accuracy of logistics distribution.

4) Distribution efficiency: Logistics distribution efficiency is an important indicator to measure the quality of logistics distribution. In the research of logistics business process modeling and analysis using Petri net, it is found that the improvement of logistics distribution efficiency can be achieved by optimizing logistics process, improving logistics distribution mode and optimizing supply chain. The improvement of distribution efficiency can significantly improve the competitiveness of logistics enterprises. As shown in Figure 2:
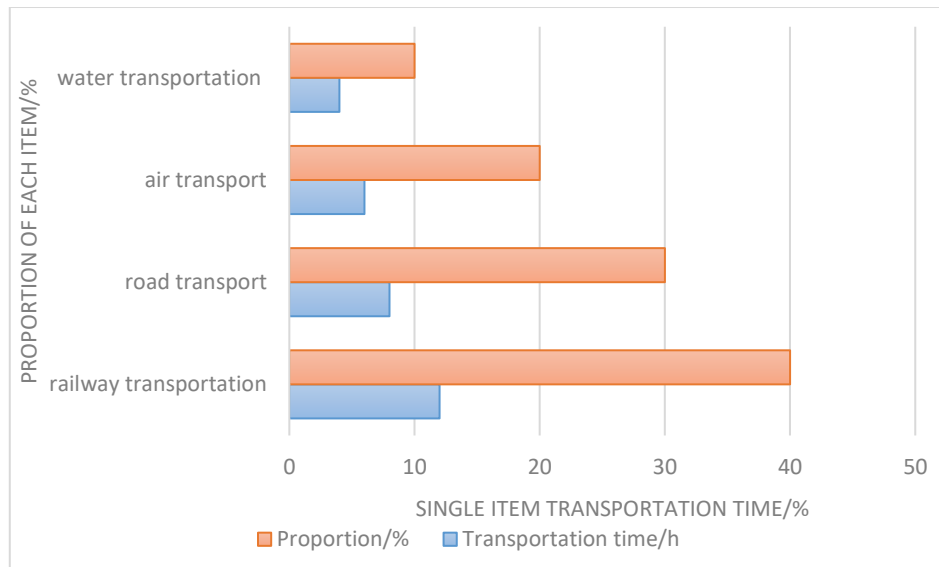

Fig.2   Transportation Time Analysis Table

As shown in Figure 2, in the analysis of transportation time, the proportion of transportation time in different modes of transportation is displayed. As can be seen from the data in the figure, the proportion of railway transportation is the highest, accounting for 40%, so optimizing railway transportation routes can significantly reduce the logistics delivery time.

4.3. Strategy

Based on the above analysis results, the following strategies can be formulated:

1. Optimize logistics distribution mode: According to the transportation time analysis table, we can explore the feasibility of optimizing distribution mode, such as increasing railway transportation lines to improve transportation efficiency.

2. Managing logistics distribution costs: By optimizing logistics distribution cost management, such as reducing transportation costs, fuel costs and insurance costs, we can reduce logistics distribution costs and improve the competitiveness of enterprises.

3. Improve the supply chain: Through the logistics business process modeling of Petri nets, we can find out the problems existing in supply chain management and optimize them, thus improving the efficiency and accuracy of logistics distribution.

4. Strengthen information construction: Optimizing the logistics distribution process needs to focus on information construction, which can be better measured through data collection and analysis.

5. Conclusion

Through the research and application of Petri net in logistics business process modeling, we can draw the following conclusions: Petri net is an important modeling tool, which can provide a clear and intuitive process model and be used for real-time simulation and optimization. In logistics system, Petri net model can help enterprises determine the best operation scheme, improve the operation process and improve logistics efficiency. At the same time, Petri net model also has important application value in logistics business process optimization, scheduling, control and monitoring. Especially in the current industrial 4.0 era, Petri nets have played an important role in digital transformation, which is helpful to realize the intelligence and automation of logistics systems. Therefore, the application and research of Petri net will help to promote the modern transformation and upgrading of logistics system and enhance the core competitiveness of logistics industry.

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