

Hazardous Chemicals Transportation Decision Method Based on Intelligent Logistics System

Hongmei Sun, Lina Chen, Jianquan Fu*

Shijiazhuang University of Applied Technology, Shijiazhuang 050081, China

fujwe_mf@163.com

The logistics transportation optimization scheduling method based on intelligent decision system is the development trend of the future logistics industry. Based on the intelligent decision-making technology of dangerous goods logistics, and also the combination of wireless radio frequency identification (RFID) and wireless sensor network (WSN), this paper constructs a decision-making method for hazardous chemicals transportation based on intelligent logistics system, and for the defects existing in the current transportation process of hazardous chemicals. Then, it proposes the intelligent optimization scheduling model of hazardous chemicals logistics path, which optimizes the information collection methods in traditional hazardous chemicals logistics, realizes the dynamic monitoring of dangerous goods logistics, and effectively reduces the occurrence probability of hazards. Meanwhile, in this paper, the traditional Petri net has been improved to construct a Petri net-based logistics process optimization algorithm with workflow weighting performance. This algorithm can describe and model the whole process of logistics in a hierarchical way, perform multi-dimensional performance analysis on the logistics process, and accurately find the defects in the logistics process, so as to get the optimal dangerous goods logistics distribution strategy. The example verification results show that the proposed model in this study has high practicability, which can provide the optimal transportation decision-making scheme for hazardous chemicals under the complicated conditions of multi-operation nodes, multi-flow direction and multi-transport modes.

1. Introduction

Hazardous chemicals are flammable, explosive, corrosive, and susceptible to infection. Improper handling during storage and transportation can cause serious harm to the human body and the environment, and under long-term conditions, they can seriously affect the surrounding environment, economic and regional development seriously (Zhao, 2007; Bu et al., 2013). Thus, it is the current research focus to strengthen supervision and control of hazardous chemicals at the management level, and optimize their dynamic identification and positioning at the technical level (Samanlioglu, 2013; Repoussis, 2009).

In the logistics transportation process of dangerous goods, GPS, RFID, GIS and other positioning technologies are used to locate and track the dangerous goods in real time (Xu et al., 2014; Dan and Lu, 2009; Vahidov and Kersten, 2005), e.g., the web-based dangerous goods supply chain logistics decision system, RFID-based dynamic monitoring method for dangerous goods storage and transportation, and information collection and dynamic supervision models based on the comprehensive use of location tracking methods such as GPS, and RFID etc. (Xu and Huang, 2017; Wang et al., 2013; Zhang, 2013; Xu and Teng, 2013). However, the above research is only limited to the local sampling supervision of the warehousing and transportation process through the information collection during the dangerous goods transportation. There have been relatively few studies on the real-time monitoring and intelligent transportation decision-making for the whole process of dangerous goods transportation (Laarabi et al., 2014).

The intelligent decision-making of logistics transportation is a new type logistics optimization scheduling method developed in recent years. At present, there have been relatively fewer researches on logistics transportation scheduling methods based on intelligent decision-making system (Chiriac et al., 2005). It mainly includes multi-agent technology-based intelligent decision-making methods, expert system-based intelligent logistics optimization scheduling, and Petri net technology-based logistics optimization scheduling (Balbo and

Pinson, 2007; El-Ghamrawy et al., 2011; Zunino and Campo, 2009). The intelligent decision-making system can theoretically better solve the problems of optimal path selection, distribution vehicle scheduling, and safe distribution of hazardous chemicals in the process of logistics transportation, and provide powerful technical support for efficient and safe transportation of logistics (Han et al., 2014; Slowinski and Roman, 2011; Liu and Chu; 2007).

Based on the intelligent decision-making technology of dangerous goods logistics, and the combination of wireless RFID and WSN, this paper constructs a decision-making method for dangerous chemicals transportation based on intelligent logistics system, and proposes intelligent optimization scheduling of hazardous chemicals logistics path for the defects existing in the transportation process of hazardous chemicals. The research conclusions can provide a scientific theoretical reference for the safe and efficient transportation of hazardous chemicals.

2. Modelling and analysis for intelligent logistics system of hazardous chemicals

Figure 1 shows the overall business process for hazardous chemicals. It can be seen from the figure, the entire logistics business process is from the upstream producer to the downstream customer, and the hazardous chemicals must go through the entrusting party, the agent, the main transport unit and the outsourcing transport unit.

Due to its high risk and particularity, hazardous chemicals are more complicated in logistics process than traditional logistics transportation. There are more business interactions between different transport units, so logistics information tracking and product monitoring are also more complicated.

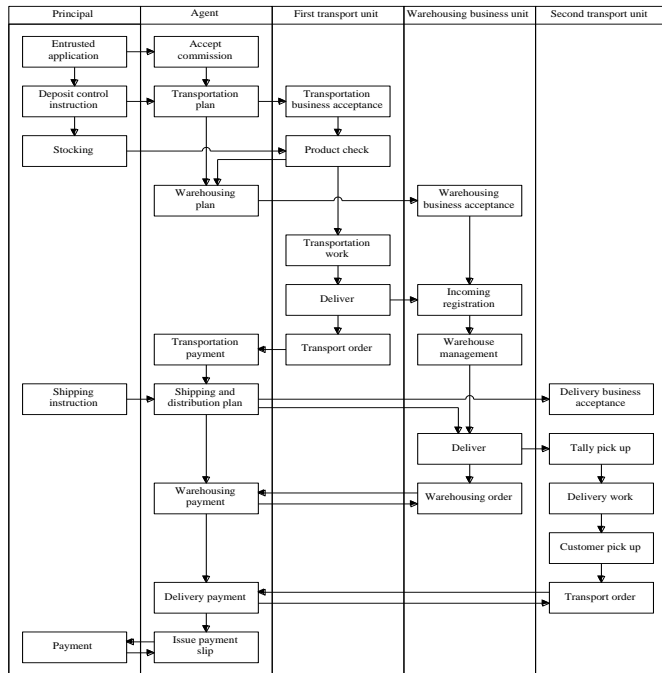


Figure 1: Overall business process of hazardous chemicals

Based on the logistics business process in Figure 1, an intelligent logistics supervision framework for hazardous chemicals based on RFID and WSN was proposed, as shown in Figure 2. RFID and WSN technology can ensure the purely mechanized supervision of hazardous chemicals during transportation, avoiding human and environmental damage caused by manual monitoring.

3. Intelligent logistics optimization scheduling method for dangerous chemicals based on improved Petri net

In this paper, a Petri net-based logistics process optimization algorithm for workflow weighting performance was constructed by improving the traditional Petri net algorithm. Firstly, it's defined as follows: A complete Petri net can be expressed as (WF_net). WF_WCPn is its subset, and also the basic structure of Petri net. Its four basic structures can satisfy the basic working nature of Perti net workflow.

In order to ensure the effectiveness of the basic structure in the Petri net, the following conditions must be met.

$$\forall_M (I \xrightarrow{\bullet} M) \Rightarrow (M \xrightarrow{\bullet} O) \tag{1}$$

$$\forall_M (I \xrightarrow{\bullet} M \wedge M(O) \geq 0) \Rightarrow (M = O) \tag{2}$$

$$\forall_{t \in T} \exists_{M, M'} I \xrightarrow{\bullet} M \xrightarrow{t} M' \tag{3}$$

Where, I is the initial library, O is the termination library, and M is any reachable library.

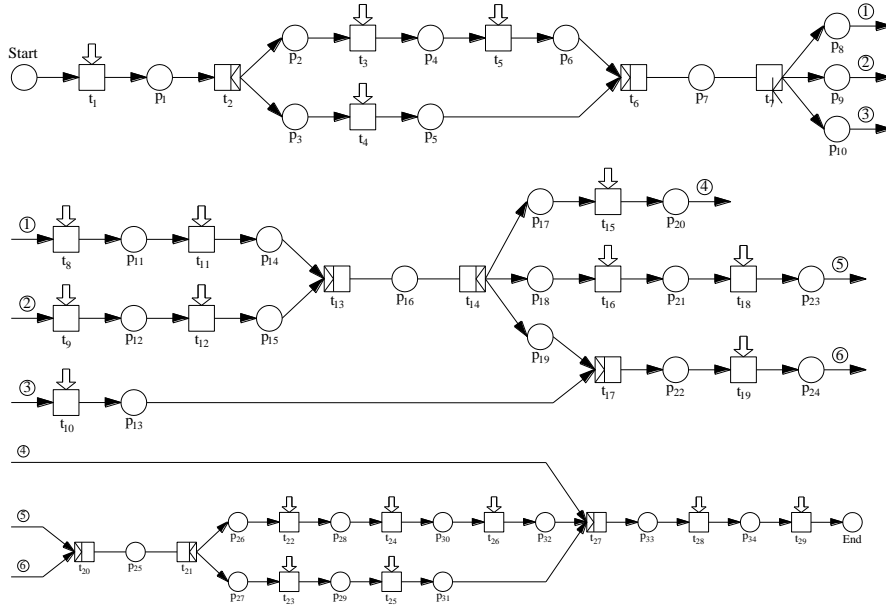


Figure 5: Overall Petri net model of hazardous chemicals intelligent logistics

The Petri net-based logistics process with workflow weighing performance is as follows:

- (a) Make the initial planning of the Petri net workflow;
- (b) Design the workflow of the Petri net from top to bottom;
- (c) Analyse the active and passive elements of each layer's module structure. When the actual logistics entity is interpreted as the active element, in the Petri net it's denoted by the T element (active element), and when it is interpreted as the passive element, the P element (passive element) is used;
- (d) Determine the transition process of the in-network library based on the mapping relationship between the actual logistics and the Petri net;
- (e) Determine the colour set of each library, and normalize each performance indicator λ_i of the system;
- (f) Determine the weight relationship of different performance indicators;
- (g) Calculate the basic structural performance of the Petri net in the following formulas:

Sequence structure:

$$\frac{1}{\lambda} = \sum_{i=1}^n \frac{1}{\lambda_i} \tag{4}$$

Parallel structure:

$$\frac{1}{\lambda} = \sum_{i=1}^n \frac{1}{\lambda_i} - \sum_{i=1}^{n-1} \sum_{j=i+1}^n \frac{1}{\lambda_i + \lambda_j} + \sum_{i=1}^{n-2} \sum_{j=i+1}^{n-1} \sum_{k=j+1}^n \frac{1}{\lambda_i + \lambda_j + \lambda_k} + \dots + (-1)^{n-1} \frac{1}{\sum_i \lambda_i} \tag{5}$$

Selection structure:

$$\frac{1}{\lambda} = \sum_{i=1}^n \frac{\alpha_i}{\lambda_i} \tag{6}$$

Loop structure:

$$\frac{1}{\lambda} = \frac{1}{1-\alpha} * \left(\frac{\alpha}{\lambda_1} + \frac{1}{\lambda_2} \right) \tag{7}$$

(h) Reconstruct the system structure of each layer and calculate the overall performance of the Petri net
 According to the above steps, an overall Petri net model based on intelligent logistics of hazardous chemicals is established, as shown in Figure 5. The whole model is divided into two major elements, T and P, which explain the key elements as follows: t_1 indicates business commission, t_2 indicates release task, t_3 is preparation of logistics plan, t_4 is deployment of dangerous chemicals, t_5 is planned transportation, t_8 is the information check and inspection before the dangerous goods are shipped out, t_{11} indicates that the logistics is started, t_{24} indicates that the customer accepts the goods, and t_{25} - t_{29} indicates the final settlement of the balance payment.

P_1 indicates the state of logistics start, P_2 is the state of the logistics centre during the planning period of goods, P_4 and P_5 indicate the status of goods distribution and handover, P_8 and P_9 indicate the status of product information check and preparation for delivery, P_{12} and P_{13} are completion status of warehousing and distribution planning, P_{15} - P_{20} indicate the logistics related status, and P_{29} - P_{34} are the final settlement status.

4. Example verification

Taking the single cargo logistics process of certain dangerous goods logistics transportation company as an example, the effectiveness and superiority of the proposed hazardous chemicals transportation decision method were verified. Figure 2 shows the network diagram of certain dangerous goods logistics transportation for this company.

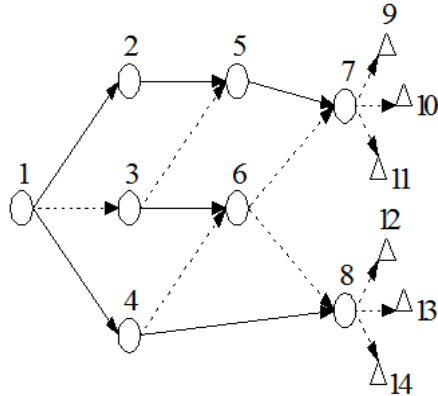


Figure 2: Transportation network of dangerous goods logistics company

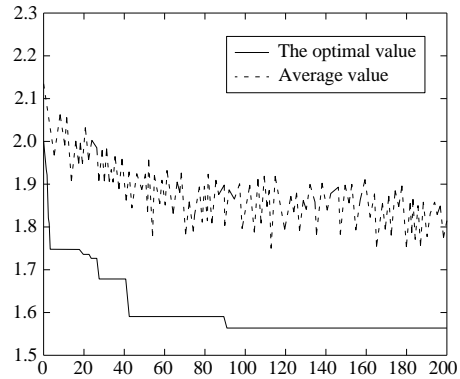


Figure 3: Relation curve between number of iterations and target values

In Figure 2 above, node 1 is the starting point of dangerous goods transportation, node 9-14 are the end points, and node 2- 8 are the transit nodes of logistics transportation in which different transportation modes can be used for transportation. In this study, both rail and road transport modes are adopted, as shown in the figure, where the dotted line indicates the use of road transport, and the solid line is the use of rail transport.

The objective functions were set: Z_1 the minimum damage caused by dangerous goods in the process of logistics transportation, and the Z_2 minimum transportation cost required. Then, the objective functions are expressed as:

$$Z_1 = \sum_{f \in F} \sum_{k \in K} \sum_{(i,j) \in p_f^k} \sum_{t \in T} Q_f x_{ij}^{tk} R_{ij}^{tk} / \psi_{ij}^k \tag{8}$$

$$Z_2 = \sum_{f \in F} \sum_{k \in K} \sum_{(i,j) \in p_f^k} \sum_{t \in T} Q_f x_{ij}^{tk} c_{ij}^k + \sum_{f \in F} \sum_{k \in K} \sum_{j \in o(f)} Q_f y_i^{tk} c_i^k \tag{9}$$

The constraint conditions are:

$$\sum_{(i,j) \in P^f} x_{ij}^{fk} - \sum_{(i,j) \in P^f} x_{ji}^{fk} = \begin{cases} 1, i \in o(f) \\ -1, i \in d(f), f \in F, P_l^f \in P^f \\ 0, else \end{cases} \quad (10)$$

$$\sum_{k \in K} x_{ij}^{fk} \leq 1, f \in F \quad (11)$$

$$Q_{ij} \leq \min_{(i,j) \in P^f} (\theta_{ij}) \quad (12)$$

$$T_1 \leq S_o^f + \sum_{k \in K} \sum_{(i,j) \in P^f} \sum_{t \in T} x_{ij}^{fk} t_{ij}^{Tk} + \sum_{i \in o(f)} \sum_{k_1 \in K} \sum_{k_2 \in K} x_{ij}^{fk} t_{k_1 k_2}^i \leq T_2 \quad (13)$$

For this, the formula 10 restricts the directionality of the logistics transportation; the formula 11 restricts the logistics transportation mode; the formula 12 constrains the upper limit of the logistics transportation capacity; the formula 13 restricts the logistics transportation time.

The hazardous chemicals transportation decision model of the intelligent logistics system proposed in this paper was used to solve the example. Figure 3 shows the relationship between the number of iterations and the target value, indicating that as the number of iterations increases, the calculated target value of the logistics transportation scheme is also optimal, and the optimal solution is obtained at the 90th iteration.

Table 1 lists the hazards and transportation costs of different logistics paths. It can be seen from the table that the hazardous chemical transportation decision model using the intelligent logistics system proposed in this paper can select the optimal transportation mode and path, and also greatly reduce the transportation cost, e.g., the 1-11 logistics paths only uses road transportation, the cost is only 3.63 million yuan, and the number of people involved along the way is 1.6 million. In the 1-10 logistics paths, the cost of both using the railway and highway mode has soared to 5.44 million Yuan, involving a population increase of 1.7 million; in 1-12 and 1-13 logistics paths, 1-13 select pure road transport, with the total cost of only 3.9 million yuan, while the 1-12 involves population of more than 100,000 people, but the cost is reduced by 2.8 million yuan.

Table 1: Hazards and transportation costs of different logistics paths

Flow direction	Path and transportation mode selection	Departure time	Involved population	Cost
1→9	1→2→5→7→9	[8,9)	209	778
1→10	1→2→5→7→10	[5,6)	169	540
1→11	1→3→5→7→11	[4,5)	159	359
1→12	1→4→6→8→12	[2,3)	189	671
1→13	1→3→6→8→13	[5,6)	209	386
1→14	1→4→8→14	[7,8)	149	572

5. Conclusions

Based on the intelligent decision technology of dangerous goods logistics, and the combination method of RFID and WSN, this paper constructs the hazardous chemicals transportation decision method based on intelligent logistics system, and then proposes the intelligent optimization scheduling of hazardous chemicals logistics path for the defects existing in the transportation process of hazardous chemicals. The research conclusions are as follows:

(1) The intelligent optimization scheduling model optimizes the information collection method in the traditional dangerous chemical logistics, realizes the dynamic monitoring of dangerous goods logistics, and effectively reduces the occurrence probability of harm.

(2) The traditional Petri net is improved, and a Petri net-based logistics process optimization algorithm for workflow weighting performance is constructed. The algorithm can hierarchically describe and model the whole process of logistics, and perform multi-dimensional performance analysis on the logistics process. It can also accurately find the defects in the logistics process, so as to get the optimal dangerous goods logistics distribution strategy.

(3) With the minimum harm and minimum transportation cost as the optimization goal, the intelligent decision model proposed in this paper was verified by an example. The verification results show that the algorithm can provide the optimal hazardous chemicals transportation decision-making scheme under the complicated conditions of multiple operating nodes, multiple flow directions and multiple transportation modes. This model has a high practicability.

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