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Study on Route Optimization of Methanol Safety Transportation Routing

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Optimal routing is an important part of the methanol road transportation research. Optimal routing of methanol is different from those general optimal routing processes. Methanol optimal routing need to take into account the risk of path, the possible consequences of the accident and emergency response capabilities around the path and other factors This paper includes two aspects of research, one is the risk analysis of methanol road transportation, the other is optimal routing based on risk assessment.

1. Introduction

With the rapid growth of the production and transportation of methanol materials, the number of methanol materials accidents is growing. The methanol materials accidents have not only brought transport disasters, more importantly, the result could be enormous number of injuries and deaths, economic losses and environmental damage and other consequences. Choosing a safer transportation route of methanol materials is one of the effective measures to reduce the risks and consequences of accidents (Bonvicini et al., 2008). In the life cycle of methanol materials (hazmat), the transportation activity plays a vital role. With the traffic volume continuously increasing, hazmat accidents do happen, usually resulting in casualties, property damage and environmental problems. Due to the risks associated with this special cargo, hazmat transportation (HMT) has always been concerned by the public. Many attempts to design a safe and effective transportation network for hazmat have been made by both academics and practitioners (Bonvicini et al., 2011).

Nowadays, many study results of HMT network design have been achieved, but prior researches have at least four limitations. The first limitation goes to the "route selection problem". In order to optimize the transportation network for hazmat, it is necessary to identify optional routes, since not all the available routes are suitable for hazmat shipments. However, so far, this area hasn't received attention. Indeed, some advanced algorithms, rather than simple judgments based on road condition or people's experience, should be used to solve this problem.

Second, the hazmat transportation should be broken into two parts: inter-city transportation and intra-city transportation, each of which will adopt different optimization methods, owing to the differences between their impedance characteristics. However, no previous research has ever made such a distinction (Wu et al, 2016).

Third, some concerns, such as avoiding transportation disruptions, and diversifying transportation risks, should also be taken into consideration.

Last, in spite of rich literature on the route optimization, the optimization of hazmat transportation network has received little attention. While the former usually focuses on a shipment from a single origin to a single destination (SOSD), the latter also includes shipments from a single origin to multiple destinations (SOMD) or shipments from multiple origins to multiple destinations (MOMD). Due to the nature of hazmat, findings drawn from the SOSD case are not necessarily applicable to the SOMD or MOMD cases. The above-mentioned three cases deserve further systematic exploration and should be discussed in details one by one (List et al., 2001).

According to `Road Transport of Dangerous Goods Regulations', dangerous goods that is with explosive, flammable, toxic, corrosive, radioactive and other features; and in the transport, handling and storage process, the goods likely to cause personal injury, property damage and environmental pollution, so the goods need special protection. As dangerous goods are often the product of many other raw materials, that is an important role in the national economy plays. As the national economy and industrial development, dangerous goods and people production activities have the increasingly close relationship, the dangerous goods demand variety and the dangerous goods demand quantity are also showing a rising trend year by year, the transport volume of dangerous goods increases rapidly (Bottelbergha et al., 2010).

Dangerous goods road transport is an important public safety issue. In dangerous goods transport process, we must ensure the safety of transport but also to ensure the transport of the economy. Choosing the route, that ensure the government of dangerous goods transportation safety needs and the economic needs of transportation enterprise, is government and transportation enterprises are facing an important issue (Fabiano et al., 2012; Fabiano et al., 2015). Bi-level programming model can solve the contradiction between the government of dangerous goods transportation safety needs and the economic needs of transportation enterprise, and can be better optimized to achieve the purpose.

2. Optimization design of methanol road transportation

Latest years, with the continuous improvement of the degree of marketization of our country and the continuous promotion of the pace of reform, the development of China's logistics industry is very rapid. Methanol materials become a moving dangerous source in the way of transportation as a special cargo logistics links (Erhan et al., 2015). According to the relevant departments of statistics, 80% of China's methanol materials are transported through of road transport, and 80% of methanol materials transport accidents occurred in the road transport as well. Once the methanol materials transport accident happens, the harm to the personal property safety and environmental will be very serious because of the particularity of methanol materials. Therefore, the safety of road transport of methanol materials should not be ignored.

$$R=C_{POP}\sum P(A) \tag{1}$$

To address these limitations, this dissertation deals with the network optimization problem associated with methanol materials road transportation and attempts to provide a systematic exploration. Here come the details. Based on literature review, limitations of prior researches are listed (Maíz et al., 2011). To fill the gap left by road segment selection, this dissertation put forward a pair of concepts about restricted segment: explicit one and implicit one. For the former the structured, screening method is employed while for the latter the neural network algorithm is employed. Both algorithms are further verified by simulation.

$$P(X)=P(A)\ P(R|A)P(X|A,R) \tag{2}$$

On the basis of the road transportation of dangerous goods systematic analysis, this paper presents the road transportation of dangerous goods road safety evaluation index system, and proposed the comprehensive evaluation method based on the fuzzy theory and neural network technology. According to the characteristics of the transport of dangerous goods and generalized impedance function definition, established the road transportation of dangerous goods road impedance function model (Shi et al., 2009). Combining the road transportation of dangerous goods of road safety evaluation and the road transportation of dangerous goods road impedance function model, and according to the Wardrop balance principle, establishment the road transportation of dangerous goods of path optimization bi-level programming model, the lower model is UE model. The bi-level programming model can meet requirements. Solve Bi-level Programming Model by simulated annealing algorithm. Through the Frank-Wolfe algorithm to solve UE model. Finally, write the corresponding program code by MATLAB, and as a case study.

$$R_i(k)=\sum_j P_{ij} D(k) \tag{3}$$

$$r_i = f(x_i)\begin{cases} 0, x_{min} = x_{max} \\ \frac{x_{max}-x_i}{x_{max}-x_{min}}\ x_{min \le x_i \le x_{max}} \\ 1\ x_i \le x_{min} \end{cases} \tag{4}$$

This paper studies the optimization of logistics path in the road transport network of methanol materials. The paper elaborates the classification and related characteristics of methanol materials, methanol materials warehouse management and the cause of the transport accident of methanol materials. Meanwhile, the paper also analyses the classification of logistics path optimization problems and concludes logistics path optimization algorithm in detail (Shen et al., 2011). On the basis of these theories, the optimization model of multi objective one-way and two-way methanol materials logistics is studied and established, whose targets include the highest security, the shortest time and the least cost. In order to emphasize the particularity of methanol materials transport, a security index P is introduced in the model. By using the fuzzy comprehensive evaluation method and analytic hierarchy process, the quantitative and qualitative methods are combined to determine the P value according to the data. Next, the paper verifies the reliability of the model method by the case of investigation data, and uses grey situation decision method to solve the problem of one way logistics path optimization model. By MATLAB programming and genetic algorithm, the question of two-way logistics path optimization model is solved. Finally, it is concluded that the model method is reasonable and feasible.

$$t_a = t_0[1 + \alpha \left(\frac{q_a}{c_a}\right)^{\beta}] \tag{5}$$

3. Result and discussion

3.1 Route optimization of methanol safety transportation routing

The dissertation proposes the concept of K-optimal transportation network, and analyzes the five differences between the K-optimal transportation network and K-shortest path. Then, the solution algorithms are studied from the three aspects SOSD, SOMD and MOMD, and the algorithms can be used to design the K-optimal transportation network of hazmat in Figure 1

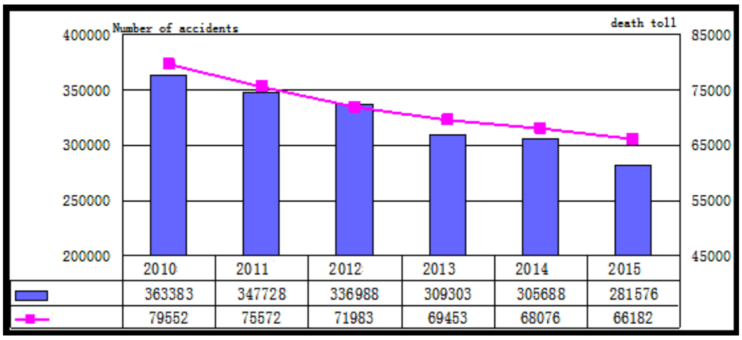

Figure 1: Road accident deaths.

As shown in Figure 1, as to the inter-city hazmat transportation, the SOSD case is firstly analyzed: different methods of network optimization are used depending on whether the road network is underdeveloped or developed. For the former the uncertain evaluation method is employed while for the latter a chromosome marker multi-objective genetic algorithm is proposed. After the SOSD case, SOMD and MOMD cases are also discussed in details. Optimization models and algorithms for the SOMD case are proposed after a closer look at centralized services with single vehicle, collaborative services with multiple vehicles and decentralized services with multiple vehicles, while those for the MOMD case are proposed by distinguishing collaborative services with multiple vehicles from decentralized services with multiple vehicles.
Similarly, as to the intra-city hazmat transportation, the SOSD case is firstly analyzed: depending on whether the road network is underdeveloped or developed, different methods of network optimization are used. For the former the uncertain evaluation method is employed while for the latter a multi-objective genetic algorithm is proposed. After the SOSD case, SOMD and MOMD cases are discussed. The dissertation applies multi-objective chance constrained programming techniques, by considering centralized services with single vehicle, collaborative services with multiple vehicles and decentralized services with multiple vehicles in the case of SOMD, and by differentiating collaborative services with multiple vehicles from decentralized services with multiple vehicles in the case of MOMD.

$$\min Z(X) = \sum_a \int_0^{x_a} T_a(\omega) d\omega$$

$$\text{s.t.} \begin{cases} \sum_k f_0^{rs} = q_{rs}, & \forall r,s \\ f_k^{rs} \geq 0, & \forall k,r,s \end{cases} \tag{6}$$

$$x_a = \sum_r \sum_s \sum_k f_k^{rs} \delta_{a,k}^{rs}, \forall a$$

The concept of transport network point and edge repeatability and its formula are proposed. By applying the new formula, the solving method for K-Pareto optimal transportation network with SOMD and MOMD is set up. Case studies show that the method is feasible, the K-Pareto optimal transportation networks can not only meet the purpose of transportation risks diversification, but also avoid some disruption road, well complete the design task of hazmat transportation.

The optimization methods proposed in simulation, the testing results show that this dissertation have been verified by computer methods are feasible and the study results can provide basic theory support for safeguarding the transportation safe of hazmat.

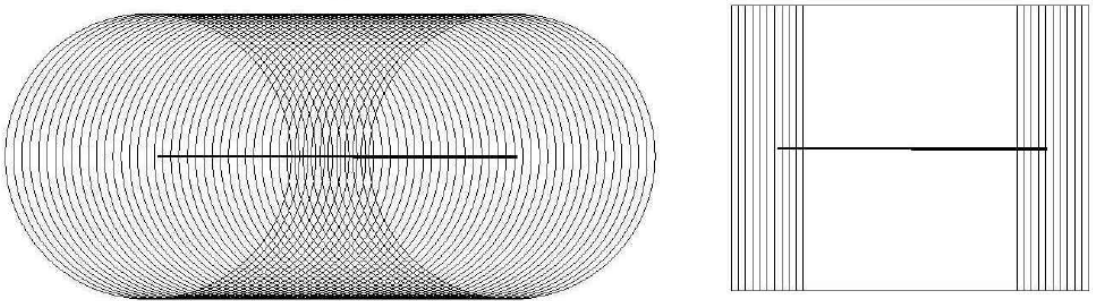

Figure 2: Influence area of road traffic accident of common dangerous goods.

As shown in Figure 2, first, this paper studied the results of previous studies and the condition of methanol materials transportation in today's China; put forward improved risk analysis models which are more reasonable and accurate, including the accident risk model, the influence range model and the environmental destruction model. Calculation results using historical data show that the improved models are more accurate and reasonable, and at the same time the new models also put forward higher requirements to the information gathering of methanol materials transportation; based on the risk analysis of methanol materials road transportation, this paper researched several aspects of optimal routing were in Table 1.

Table 1: Results of evaluating result by experts and evaluation result by ANN

Evaluating result by experts			Evaluation result by ANN		
1	2	3	1	2	3
0.6342	0.7036	0.6351	0.56696	0.63223	0.70424
4	5	6	4	5	6
0.6899	0.6591	0.7339	0.63488	0.69011	0.65802
7	8	9	7	8	9
0.7734	0.8413	0.7479	0.93427	0.77449	0.83808
10	11	12	10	11	12
0.8176	0.7161	0.7524	0.7485	0.81627	0.71642
13	14	15	13	14	15
0.5881	0.6721	0.6745	0.7548	0.59028	0.66999
16	17	18	16	17	18
0.6776	0.7349	0.7350	0.67616	0.67335	0.73593
19	20	21	19	20	21
0.7344	0.6183	0.6569	0.85353	0.77471	0.8164
22	23	24	22	23	24
0.7301	0.7714	0.6488	0.65405	0.73045	0.77204

3.2 An example

First, we generalized the procedures and considerations of optimal routing. (Figure 3)
Second, we adopted the principle used in HSE management system to improve the optimal routing process, which is to regard the emergency response capability as a quantitative factor of the optimal routing index, and then established a new methanol materials road transportation optimal routing index system based on "prior prevention and rescue after". (Figure 4)
Third we analysed the models and algorithms commonly used in optimal routing, and established multi-objective optimal routing models using the Fuzzy Neural Network and Analytic Hierarchy Process. Finally, we did a case study of butadiene road transportation in Guangzhou, made a quantitative assessment of the leakage rate, casualty risks and environmental damage risks of butadiene transportation. We carried on single-objective optimal routing simulations including shortest time, least casualty, minimal environmental damage and best emergency capability, analysed the differences of different routing results. Finally, we realized the multi-objective optimal routing based on the Fuzzy Neural Network and Analytic Hierarchy Process by adopting ArcGIS platform, ALOHA simulation software and MATLAB software, and put forward some suggestions on the topic of methanol materials route optimization, path line banning policy and construction of emergency response facilities as shown in Figure 5.

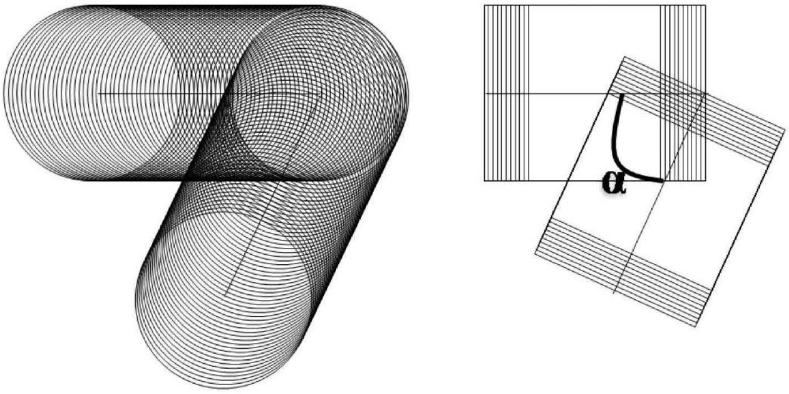

Figure 3: Error comparison between the semicircle influence region and the rectangular influence region.

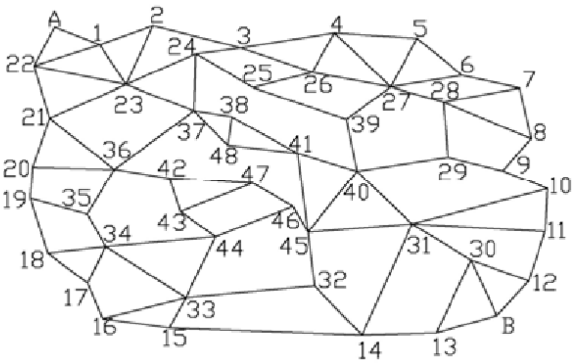

Figure 4: Effect of flow velocity and electrolysis time on pH of the solution by electrochemical process

The result was shown in Figure 4,

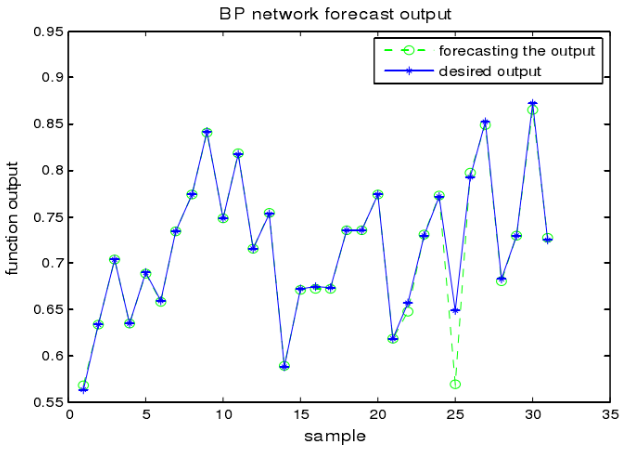

Figure 5: Forecast output of neural network.

4. Conclusion

This paper establishes the methanol materials logistics path optimization model with the safety index P to give more practical significance in methanol material path optimization, thus the problem of the methanol materials logistics path optimization can be well solved. And the transportation path can be more safety, higher efficiency and more economical. Therefore, this paper is significant to the theoretical research and practical applications.

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