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Optimization of Logistics Path of Dangerous Chemicals Based on Uncertainty Theory

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Based on the uncertainty theory, the logistics path optimization of dangerous chemicals is studied in the research. In the course of the research, time-varying parameters, fuzzy variables and fuzzy random variables are introduced to provide quantitative tools for the risk of uncertainty, so that parameters setting and problem hypothesis can better reflect the actual situation of the transport network, so as to eliminate the idealized model. At the same time, the fuzzy simulation is substituted into the genetic algorithm, and the fuzzy stochastic simulation is substituted into the particle swarm optimization algorithm to solve the location-path-dispatching model of dangerous chemicals. On the basis of the traditional heuristic algorithm, the greedy method and the self-adaptive method are used in this paper to improve efficiency of the algorithm and enhance robustness of the results. Finally, as for the small-scale model, exact value is calculated by using Lingo software and changing modes, and the exhaustive method is used to obtain all the optimal solutions. Meanwhile, the improved heuristic algorithm is used in this paper to solve this problem, and then, the comparative analysis is carried out to verify its efficiency and superiority. Finally, the genetic algorithm based on fuzzy simulation and the self-adaptive hybrid particle swarm algorithm based on the greedy method & fuzzy random simulation are proved to be improved effectively.

1. Introduction

Corrosive, flammable, explosive and toxic natures are the inherent harmful natures of dangerous chemicals, which make all links in chains of production, storage, loading and unloading, transportation, use and waste disposal pose a serious threat on the people’s lives, social property and ecological environment. (Li et al., 2017) With the rapid increase in the number of dangerous chemicals in industry, the problems caused by it have become increasingly prominent. According to statistics, in the accidents involving dangerous chemicals, more than 40% incidents happen during the transportation process (Adamiec, 2017). At present, China is in the stage of industrialization, while places of production for more than 95% of dangerous chemicals are not places of use, which depends on off-site transportation, where about 80% depends on land transportation (Zhang et al., 2017).

In recent years, the accidents of dangerous chemicals in transportation network frequently occur in China, which causes serious concern to all parties concerned. Scientific methods can provide strong guarantee for policy implementation, and the optimization decision-making of dangerous chemicals transportation has become a hot issue of scientific research (Aslam and Mukhtar et al., 2017). In view of the complex transportation network of dangerous chemicals, warehouse location, path and vehicle dispatching need to be studied together through analysis of a series of complex combinatorial optimization decision models to reduce the total risk of the dangerous chemicals transportation network, and to reduce the cost of transportation on this basis as far as possible (Babu et al., 2017).

In view of this, based on the uncertainty theory and considering time-varying, fuzzy and random factors, a more practical parameter setting and scenario study for the dangerous chemicals transportation network are provided in this paper to solve the problems of warehouse location, path choice and vehicle dispatching (Miler, 2017)

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2. Basic knowledge of the uncertainty theory

2.1 Credibility theory

Credibility theory, one of the most important basic theories of credibility research, is a mathematical method and mathematical model to study and solve various credibility problems, and a quantitative law to study credibility (Balamurugan and Saravanan, 2017). Credibility refers to the ability of the system or the equipment to complete the specified function within the prescribed time under the specified conditions (Denkena et al., 2017). Credibility measurement is self-dual (El-Sheekh et al., 2017). A fuzzy event may not happen even if its probability is 1. Even if its necessity is 0, it can happen. However, when the credibility is 1, the fuzzy event must occur. When the credibility is 0, the event certainly does not happen (Wang et al., 2017).It is a discipline based on the method of system engineering with probability theory, mathematical statistics and other mathematical tools (reliability mathematics) used to carry out quantitative analysis on credibility of the product, to determine ways to improve credibility of the product, and to improve reliability of the product to a satisfied degree by comprehensively balancing gains and losses regarding economy, function and other aspects (Fozooni et al., 2017).

2.2 Fuzzy-random parameters

In the process of dealing with practical problems, it is often necessary to map the function from random space to fuzzy variable, that is, fuzzy random variable (Gottschlich and Bellina, 2017). This can be understood as follows: in some random experiments, the results are not real or real vector, but some linguistic variables, which can be described by fuzzy numbers or fuzzy sets.
Assuming a probability space as $\Omega = (\omega_1, \omega_2, \dots, \omega_n)$ and $\eta_1, \eta_2, \eta_3, \dots \eta_n$ as fuzzy numbers,

$$p = \begin{cases} \eta_1, & \omega = \omega_1 \\ \eta_2, & \omega = \omega_2 \\ \dots, & \dots \\ \eta_n, & \omega = \omega_n \end{cases} \tag{1}$$

I.e. fuzzy random variable
For example, a fuzzy random variable with three triangular fuzzy numbers is shown in Figure 1.

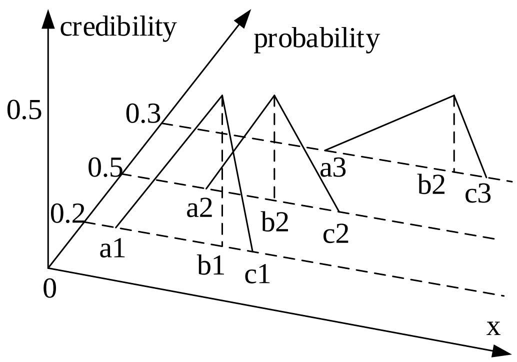

Figure 1: Fuzzy Random Variable

3. Research on transport location selection—path—dispatching of dangerous chemicals under the time-varying uncertain condition

3.1 Decision-marking on transport network warehouse location—path selection for dangerous chemicals based on the uncertainty theory

In order to reduce frequency of dangerous chemicals transportation accidents, it is necessary to analyze a series of complicated combinatorial optimization problems, which can be used to build a decision-making model for study on warehouse location and path choice, etc., finally minimizing the total risk of the whole transport network and costs required during travel and site management at the same time. Although

transportation of dangerous chemicals has become a research hotspot, the relevant data is not complete and the inherent uncertainty change factors of the transport network make the problem more complex (Hossain et al., 2017). Therefore, the uncertainty theory is introduced into the research to ensure that problem hypothesis and model building can be more practical and make the research results more instructive.
The most important objective for optimization of the dangerous chemicals transportation network is to reduce risks, which inevitably requires determination on the way of risk measurement. The recognized risk measurement method of dangerous chemicals transportation is mainly based on the analysis of the accident rate and accident impact, for which the corresponding risk measurement model is established to evaluate the risk of transportation network (Pereao et al., 2017). Commonly used risk standards for transportation of dangerous chemicals are mainly affected population caused by accident consequences, risk of the public's sensitive response and emergency rescue ability; most commonly used risk measurement models include: the traditional risk measurement model, use of population which may be exposed along the path to evaluate transportation risks of dangerous chemicals, use of accident rate to measure transportation risks of dangerous chemicals, minimum & maximum risks, relatively complex perception risk by the public, expectation-variance risk and disutility risk measurement model, etc. (Karimi et al., 2017).

3.2 Location of a transport network warehouse for fuzzy-random dangerous chemicals under the time varying condition—scheduling of vehicle dispatching

3.2.1 Random accident probability
Considering two situations— special and general, probabilities for occurrence of the situation are ω_u and ω_e, which correspond to different accident probabilities—v_u and v_e respectively, as shown in Equation (2):

$$p = \begin{cases} v_u, & with\ \omega_u \\ v_e, & with\ \omega_e \end{cases} \tag{2}$$

3.2.2 Time-varying exposure population
The traditional risk is chosen as the risk measure method for each basic path. Due to the fact that enough historical data is lacking for the number of exposed population, the number of exposed population is set as a fuzzy number, and the travel time of a vehicle has random probability, defined as a random variable. According to the traditional risk measurement equation, the risk is the product of the number of exposed population and the accident probability. Therefore, in different periods, the time-varying population risk is defined as a fuzzy random parameter based on the random characteristic of travel time.
3.2.3 Timetable optimization model
In this section, a scheduling model is constructed to optimize vehicle timetables for each warehouse-client pair, in order to obtain the best departure time and the best standing time & place to minimize the expected risk.

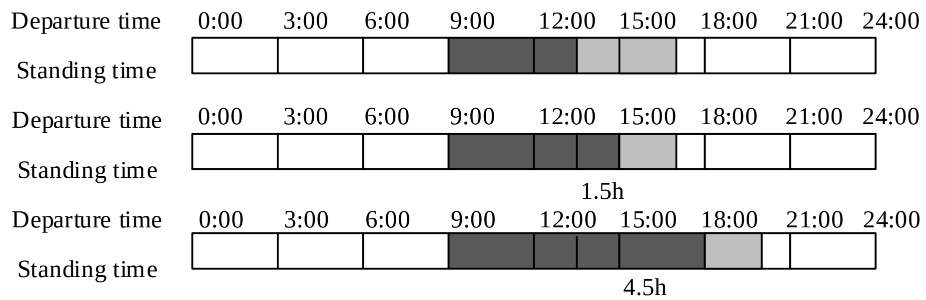

Figure 2: Schematic Diagram of Timetable

4. Algorithm design and analysis of the calculation example

4.1 Heuristic algorithm

4.1.1 Real coded method
Real coded method is used here due to its ability to process larger scale data than binary code:

Warehouse1	Client1	Client4	Client7	
Warehouse1	Client3			
Warehouse1	Client2	Client5	Client9	Client10
Warehouse1	Client6	Client8		

Figure 3: Schematic Diagram of Particle

As shown in Figure 3, the first column of each particle is number of the warehouse chosen, while number in the same line with the warehouse record is number of the client to be served.

4.1.2 Fitness function

The objective function is used as fitness function, i.e., the total risk value is used to measure the fitness, and the fuzzy simulation algorithm is used to calculate the expected value:

$$f(x,y) = \sum_{m=1}^{M}\sum_{n=1}^{N}\eta_{mn}x_{mn} + E\left[\sum_{m=1}^{M}\rho_m y_m + \sum_{m=1}^{M}\sum_{n=1}^{N}\lambda_{mn}x_{mn}\right] \tag{3}$$

4.1.3 Initialization operation

Initialization operation of the general heuristic algorithm only guarantees the feasibility of particles, while initialization based on greedy method is used in this research, as shown in Figure 4, with quality of initial particles taken into account; part warehouses randomly chosen from candidate warehouses are used to match clients with the minimum applicable warehouses first, at the same time, warehouses with the minimum service risks should be selected in a concentrated way from chosen warehouses, later on, clients with the second less available warehouses should be arranged, and so on.

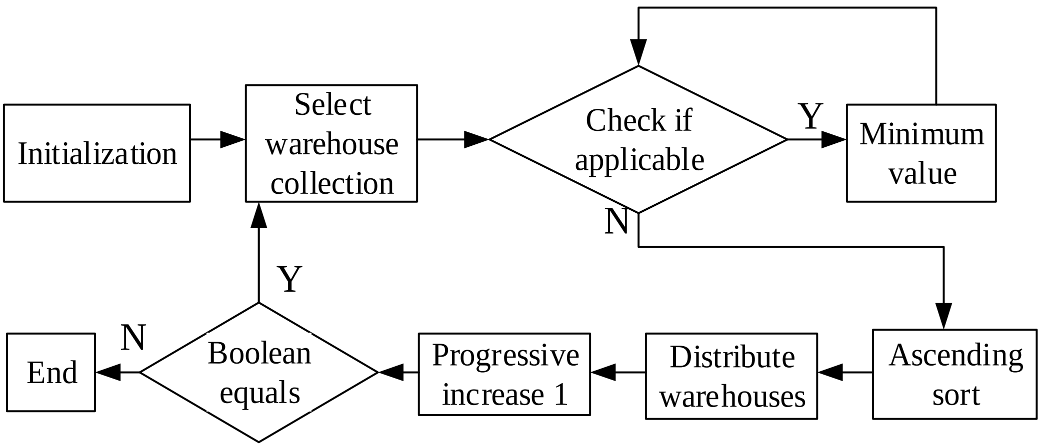

Figure 4: Flow Diagram of Initialization

4.2 Analysis of the calculation example

Calculation example of location-path for transportation of dangerous chemicals is mainly used for solution calculated by Lingo software to verify effectiveness of genetic algorithm based on fuzzy simulation algorithm. By changing setting of credibility level, observe change of optimal solution, influence between cost and risk and change degree, change of speed and precision of the algorithm.

By transforming the credibility model of a small-scale calculation example into a deterministic programming model, Lingo 14.0 is used for solution. At the same time, the genetic algorithm based on fuzzy simulation is used to solve the problem under the same parameter setting. Assuming number of particles as 50, and the maximum number of iterations as 30 generations, the results are shown in Figure 6. It can be learnt that the method is applicable.

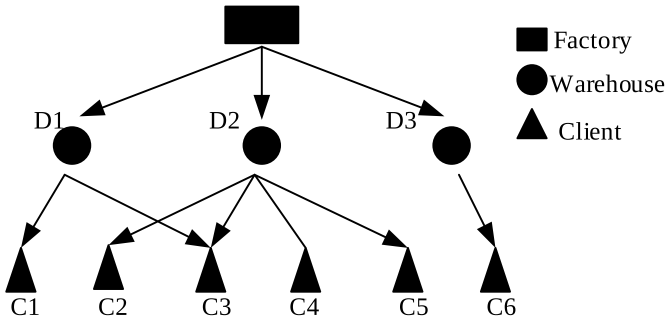

Figure 5: Schematic Diagram of Location-Path Small-Scale Calculation Example

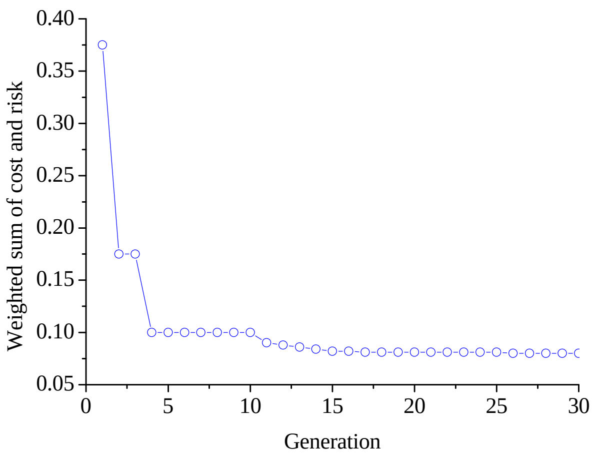

Figure 6: Convergence Graph of Genetic Algorithm with Weight as λ=0.8

5. Conclusion

With the transportation cost and the population exposure risk defined as fuzzy variables in this research, the fuzzy chance constrained model is established to study the location-path problem of dangerous chemicals, which successfully applies credibility planning to the transportation optimization problem of dangerous chemicals. Furthermore, time-varying attributes of the transportation network are taken into consideration to optimize the vehicle timetable. Considering randomness of travel time and uncertain characteristics of exposed population density and its lack of historical data, the exposed population density is defined as a fuzzy number, and risks in the time-varying environment can be assumed as fuzzy random parameters. At the same time, the fuzzy simulation based on dichotomy is used to calculate the chance constraint value, and the fuzzy random simulation based on numerical integration method is used to obtain the expected value risk under the time-varying situation. In order to promoting optimization of the heuristic algorithm, it can be found from the adaptive method I that at different calculation stages, the cross and mutation parameters are changed, so that the algorithm can guarantee range & width of overall optimization and speed & depth of local optimization. Finally, conclusions made from solving the calculation example have verified effectiveness and robustness of the proposed model and algorithm.

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