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Research Article

Graph Evaluation and Review Technique for Emergency Logistics Distribution in Complex Environment

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Emergency logistics is one of the important measures to solve the unconventional sudden disaster. The research on the distribution design of emergency logistics project has an important supporting role for the whole emergency rescue system. Therefore, it is necessary to analyze and plan the emergency logistics project scientifically in order to better serve the emergency rescue system. In view of the defect that the current emergency logistics model cannot completely describe the whole emergency logistics process, this paper proposes a new emergency logistics distribution model by using GERT random network. From the perspective of system, this model fully considers the possible situation in the process of emergency material transportation and puts forward the corresponding countermeasures, so as to improve the transportation efficiency of rescue materials in the actual disaster relief activities to speed up disaster relief. Based on the properties of moment generating function and the calculation method of Mason formula, this paper fully considers the success probability, risk probability, delivery time, and other factors of the distribution route and puts forward the transshipment scheme of each logistics site to the disaster sites. After that, the effectiveness of GERT stochastic network in the process of emergency distribution is verified by an example of a logistics distribution route, which provides decision-making basis for relevant departments. Compared with the literature, this paper uses GERT network model to intuitively and clearly express the overall process of emergency material distribution, breaks through the thinking mode of simply choosing the distribution path in the distribution process, combines with the dynamic changes of the distribution environment, and comprehensively considers the timeliness and traffic capacity of emergency material distribution in sudden disasters, so as to provide reference for emergency management in complex and random situations for decision-making reference.

1. Introduction

Emergency logistics and military logistics are closely linked at first. After World War II, with the deepening of the understanding of sudden disasters, emergency logistics as the premise of solving sudden disasters system has been gradually recognized by people. The United States, Japan, Australia, and some European countries are pioneers in disaster research, which has entered a mature stage of development. However, facing the needs of complex emergency relief activities, especially the challenge of medical material transportation under the impact of the COVID-19, the emergency logistics system needs to be more flexible and adaptive. It is important to study the problem of emergency logistics route planning to improve transportation efficiency in complex and changing transportation environment. Sudden disasters have the characteristics of insufficient precursors, prone to secondary and derivative disasters, serious losses and consequences, and difficulty in accurate prevention and effective control [1]. First proposed by Carter, emergency logistics is a special logistics activity that guarantees emergency supply of materials in response to public emergencies such as natural disasters, accidents, public health incidents, and social conflicts. Although it is the same as normal logistics in its essential attributes, there is a big difference. It is the material supply realized to meet the sudden material demand in a special period; the demand has the characteristics of strong timeliness, high uncertainty, and high supply risk [2]. With the frequent occurrence of emergency events such as the Wenchuan earthquake, the Haiti earthquake, the Chile earthquake, and the Nepal earthquake, more and more researchers have begun to pay attention to the issue of emergency logistics. The suddenness, paroxysmal, and destructive nature of sudden disasters and the urgency of emergency rescue make emergency logistics require timely and fast response. From the actual feedback information of work, the emergency logistics system should solve the following problems: How to locate the emergency facility [3, 4]? How to optimize the transportation route of emergency supplies [5, 6]? The former mainly solves the location allocation problem of facilities, and the latter solves the transportation and distribution problems of the entire logistics system. Therefore, it is necessary to study the emergency logistics distribution problems in emergencies.

Scholars study emergency logistics from various angles. For example, from the perspective of traditional emergency logistics network optimization [7], in order to further reflect the dynamics of the network, especially considering the information network [8], due to the advantages of parallelism, genetic algorithm is introduced [9]. Most of these studies ignore the complexity and dependence of emergency systems and may lose their research value for practical applications to a certain extent. Some scholars consider the coordination of the emergency rescue system based on the uncertainty of the system [10, 11]. However, emergencies are uncertain, and the damage caused is also unpredictable; the emergency logistics distribution environment is complex and uncertain.

There are many theories and methods for studying logistics routing and scheduling problems, such as stochastic programming model [12–14], nonlinear programming model [15, 16], integer programming model [17], multiobjective model [18–20], and robust optimization method [21]. Most of the existing studies consider a certain emergency logistics dispatch model based on ideal conditions, and most of them assume that the emergency logistics network is always connected normally after a disaster and the vehicle travel time between any sites is not affected by the disaster. The various problems encountered in the actual disaster are not considered from the perspective of emergency logistics process, such as road congestion and construction caused by secondary disasters. These uncertainties will affect the time and volume of logistics distribution. Graph evaluation and review technique (GERT) is a network technology that can reflect the relationship between a variety of random factors and random variables. In the GERT model, many kinds of random components such as time, cost, quality, benefits, and the randomness problems of various activities in the system and their mutual influence can be dealt with; thus it provides an effective way for the research of many complicated problems with many random factors. Compared with the above literature, this paper uses GERT network model to intuitively and clearly express the overall process of emergency material distribution, which combines with the dynamic changes of the distribution environment and comprehensively considers the timeliness and traffic capacity of emergency material distribution in sudden disasters, so as to provide reference for emergency management in complex and random situations for decision-making reference.

2. Graph Evaluation and Review Technique

Graph evaluation and review technique (GERT) is a combination of network theory, probability theory, simulation technology, and signal flow graph. It uses directed network graph with probability to analyze, which is completely based on the real emergency logistics distribution process. It allows considering the feedback loop of logistics distribution lines, the selection and abandonment of each distribution path, and the learning effect brought about by repeating a certain process [22]. This method is not affected by the inherent limitations of the method itself.

In the $\mathbf{G} = (\mathbf{N}, \mathbf{A})$ network, the site types in a collection are classified as "exclusive" or "sites." Let the random variable T_{ij} be the active state of A in (ij). From the site logic, activity (ij) must be implemented on i. Therefore, to ensure the implementation of the activity (ij), it needs to know the probability of activity (ij) being executed under the condition of given site i implementation and the probability distribution of t_{ij} (discrete) or probability density function (continuous variable). The conditional moment generating function of the random variable is (ij), which is the conditional probability density function of $f(t_{ij})$:

$$M_{ij}(s) = \int_{-\infty}^{\infty} e^{st_{ij}} f(t_{ij}) \mathrm{d}t_{ij}. \tag{1}$$

When site i is implemented, the probability of activity *(ij)* being executed is P_{ij}.

Define $W_{ij}(s)$ as the transfer function of active (ij); $W_{ij}(s) = P_{ij} \cdot M_{ij}(s)$.

Each activity of G network has two parameters P_{ij} and t_{ij}, it can always find a network G' to replace G, and G' is the same as the original network structure, but there is only one parameter $W_{ij}(s)$ on each activity.

By using a principle flowchart equivalent to a function, $W_E(s)$ is $W_{ij}(s)$ function and the network function is solved according to the characteristics of the generating function of moments. Thus, two network equivalent parameters, P_E and T_E, are obtained. The moment generating function and principle in the process flowchart of GERT provide a tool to solve the random network.

3. Model Simulation

A serious disaster suddenly occurred in a place, and the national emergency logistics distribution center A delivers materials to the provincial emergency logistics distribution center B. At the same time, emergency logistics distribution centers A and B also deliver emergency relief materials to the material distribution sites scattered around the disaster area. In view of the actual complex situation, the GERT stochastic network model diagram of emergency logistics distribution process is constructed according to the situation of disaster-stricken areas by using the idea of system theory and GERT stochastic network principle, as shown in Figure 1.

In Figure 1, sites 3, 9, 12, 13, and 15 are the main disaster sites, and the disaster situation is more serious. The other sites are the disaster sites affected by emergencies, and the disaster situation is lighter. Therefore, two emergency logistics distribution centers, A and B, mainly distribute disaster relief materials to disaster sites 3, 9, 12, 13, and 15 and distribute corresponding emergency materials along the way through the disaster sites less affected by emergencies. According to the operation of emergency logistics distribution, the meaning of each activity in the network diagram is listed in Table 1.

In GERT network, the parameters such as the time required for the operation process of each activity and the probability of realization are usually analyzed by experts according to the actual situation and combined with the previous data of emergency logistics distribution, and the approximate estimation and judgment are given. In order to simplify the calculation, this paper uses two kinds of state distribution to describe the complexity of emergency logistics activities, that is, normal distribution to describe the emergency logistics distribution activities with complex road conditions and constant distribution to describe the emergency logistics distribution activities with smooth road conditions. The GERT random network parameters are shown in Table 2. The length of time is determined by the road condition and distance. The better the road condition is, the shorter the distance is, and the shorter the time is.

3.1. Calculation of Expected Time.

3.1. Calculation of Expected Time. The transportation material data from the material distribution center A to disaster site 13 are calculated as follows:

$$\begin{aligned} W_{A\longrightarrow 13} &= \frac{1\times e^{s}\times 0.95\times e^{0.5s}\times 1}{1} = 0.95e^{1.5s},\\ p_{A\longrightarrow 13} &= W_{A\longrightarrow 13}|_{s=0} = 0.95,\\ M_{A\longrightarrow 13} &= \frac{W}{p} = \frac{0.95\times e^{1.5s}}{0.95} = e^{1.5s},\\ M'_{A\longrightarrow 13} &= 1.5e^{1.5s},\\ E_{A\longrightarrow 13} &= M'_{A\longrightarrow 13}|_{s=0} = 1.5. \end{aligned} \tag{2}$$

Calculation of various data from the material distribution center A to disaster site 3 is as follows:

$$\begin{aligned} W_{A\longrightarrow 3} &= \frac{1\times e^{s}\times\left(0.6\times e^{2s+s^2}+0.4\times e^{s}\right)\times 0.8\times e^{2s+s^2}\times 0.4\times e^{s}\times 1}{1-0.4e^{s}} = \frac{0.4\times 0.8e^{4s+s^2}\times\left(0.6e^{2s+s^2}+0.4e^{s}\right)}{1-0.4e^{s}},\\ p_{A\longrightarrow 3} &= W_{A-3}|_{s=0} = \frac{0.8\times 0.4}{0.6} = 0.533\approx 0.53,\\ M_{A\longrightarrow 3} &= \frac{W}{p} = \frac{0.32e^{4s+s^2}\times\left(0.6e^{2s+s^2}+0.4e^{s}\right)}{0.535\times\left(1-0.4e^{s}\right)},\\ M'_{A\longrightarrow 3} &= 0.6\times\frac{\left[0.6\times(6+4s)\times e^{6s+2s^2}+0.4\times(5+2s)\times e^{5s+s^2}\right]\times\left(1-0.2e^{6s}\right)+1.2e^{6s}\left(0.6\times e^{6s+2s^2}+0.4e^{5s+s^2}\right)}{\left(1-0.4e^{s}\right)^2},\\ E_{A\longrightarrow 3} &= M'|_{s=0} = 9.467\approx 9.47. \end{aligned} \tag{3}$$

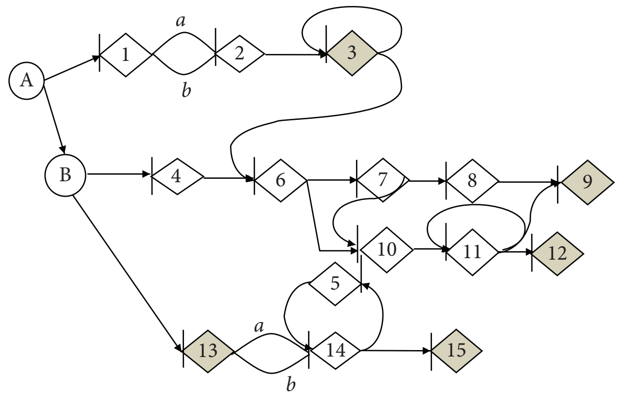

Figure 1: The route map of emergency logistics distribution center delivering materials to material distribution sites around the disaster site.

Table 1: The network diagram of the meaning of each site activity.

Activity	Activity description
(A, B)	The delivery route from the national emergency logistics distribution center A to the provincial logistics center B
(A, 1)	The delivery route from the national emergency logistics distribution center A to site 1
(1, 2)	There are two routes from site 1 to site 2. Route a is long journey but in good road condition. Route b is short distance but in bad road condition
(2, 3)	Transport supplies from site 2 to disaster site 3
(3, 3)	Disaster site 3 has a wide variety of materials, too many to load, to other sites
(3, 6)	Starting from disaster site 3, load the car back with full load and arrive at site 6
(B, 4)	Starting from the provincial logistics distribution center, load the goods to site 4
(4, 6)	From site 4 to site 6
(5, 14)	Inform the superior who has arrived at a major disaster area in advance that the road is being repaired and the convoy cannot move forward and supplement the supplies to the logistics site
(6, 7)	Some of the vehicles arriving at site 6 deliver materials to site 7
(6, 10)	Some of the vehicles arriving at site 6 deliver materials to site 10
(7, 10)	The road from site 7 to site 8 is heavily congested and difficult to pass, so vehicles can only drive up to site 10
(7, 8)	After the road is clear, the car arriving at site 7 drives to site 8
(8, 9)	Starting from site 8, go to disaster site 9
(10, 11)	Starting from site 10, go to site 11
(11, 11)	Load at site 11 and send to other areas
(11, 9)	Starting from site 11, go to disaster site 9
(11, 12)	Starting from site 11, go to disaster site 12
(B, 13)	From the provincial logistics and distribution center, a full load of supplies to disaster site 13
(13, 14)	There are two routes from disaster site 13 to site 14. Route a is long journey but in good road condition. Route b is short distance but in bad road condition
(14, 5)	The road from site 14 to site 5 was repaired successfully, and the motorcade supplied materials and transported them to the disaster area
(14, 15)	Starting from site 14, go to disaster site 15

Table 2: GERT random network parameters.

Activities	P_{ij}	Distribution type	Time (hours)	Moment function
(A, B)	1	Constant	$t = 1$	e^{s}
(A, 1)	1	Constant	$t = 1$	e^{s}
(1a, 2)	0.6	Normal distribution	$t = 2, \partial = 2$	e^{2s+s^2}
(1b, 2)	0.4	Constant	$t = 1$	e^{s}
(2, 3)	0.8	Normal distribution	$t = 2, \partial = 2$	e^{2s+s^2}
(3, 3)	0.4	Constant	$t = 1$	e^{s}
(3, 6)	0.6	Constant	$t = 3$	e^{3s}
(B, 4)	0.6	Constant	$t = 1$	e^{1s}
(4, 6)	0.9	Constant	$t = 3$	e^{3s}
(5, 14)	1	Constant	$t = 3$	e^{3s}
(6, 7)	0.4	Constant	$t = 3$	e^{3s}

Table 2: Continued.

Activities	P_{ij}	Distribution type	Time (hours)	Moment function
(6, 10)	0.6	Normal distribution	$t = 2, \partial = 2$	e^{2s+s^2}
(7, 10)	0.3	Normal distribution	$t = 1, \delta = 2$	e^{1s+1s^2}
(7, 8)	0.7	Constant	$t = 2$	e^{2s}
(8, 9)	0.8	Constant	$t = 2$	e^{2s}
(10, 11)	0.9	Constant	$t = 0.5$	$e^{0.5s}$
(11, 11)	0.3	Constant	$t = 1$	e^{s}
(11, 9)	0.5	Constant	$t = 4$	e^{4s}
(11, 12)	0.2	Constant	$t = 2$	e^{2s}
(B, 13)	0.95	Constant	$t = 0.5$	$e^{0.5s}$
(13a, 14)	0.6	Normal distribution	$t = 2, \partial = 2$	e^{2s+s^2}
(13b, 14)	0.4	Constant	$t = 1$	e^{s}
(14, 5)	0.2	Constant	$t = 3$	e^{3s}
(14, 15)	0.5	Constant	$t = 3$	e^{3s}

The transportation material data from the material distribution center A to disaster site 15 are calculated as follows:

$$W_{A\longrightarrow 15} = \frac{e^{s}\times 0.95\times e^{0.5s}\left(0.6\times e^{2s+s^2}+0.4e^{s}\right)\times 0.5e^{3s}\times 0.2e^{3s}\times e^{3s}}{1-0.2e^{3s}\times e^{3s}} = \frac{0.095e^{10.5s}\times\left(0.6e^{2s+s^2}+0.4e^{s}\right)}{1-0.2e^{6s}},$$

$$p_{A\longrightarrow 15} = W_{A-15}|_{s=0} = \frac{0.095}{0.8} = 0.11875 \approx 0.12,$$

$$M_{A\longrightarrow 15} = \frac{W}{p} = \frac{0.095e^{10.55}\times\left(0.6e^{2s+s^2}+0.4e^{s}\right)}{0.11875\left(1-0.2e^{6s}\right)}, \tag{4}$$

$$M'_{A\longrightarrow 15} = 0.8\times\frac{\left[0.6(12.5+2s)e^{12.5s+s^2}+0.4\times 11.5e^{11.5s}\right]\times\left(1-0.2e^{6s}\right)+1.2e^{6s}\times\left[0.6e^{12.5+s^2}+0.4e^{11.5s}\right]}{\left(1-0.2e^{6s}\right)^2},$$

$$E_{A\longrightarrow 15} = M'|_{s=0} = 0.8\times\frac{0.8\times(7.5+4.6)+1.2}{0.8^2} = 13.6.$$

From the material distribution center A to disaster site 9, it can be decomposed into the following.

By the route of $A\longrightarrow 1\longrightarrow 2\longrightarrow 3\longrightarrow 6\longrightarrow 7\longrightarrow 10\longrightarrow 11\longrightarrow 9$,

$$\begin{aligned} &e^{s}\times\left(0.6e^{2s+s^2}+0.4e^{s}\right)\times 0.8e^{2s+s^2}\times 0.6e^{3s}\times 0.4e^{3s}\\ &\quad\times 0.3e^{s+s^2}\times 0.9e^{0.5s}\times 0.5e^{4s}(1-0)\times 0.4e^{s}\times 0.3e^{s}\\ &\quad= 0.00311e^{16.5s+2s^2}\left(0.6e^{2s+s^2}+0.4e^{s}\right). \end{aligned} \tag{5}$$

By the route of $A\longrightarrow 1\longrightarrow 2\longrightarrow 3\longrightarrow 6\longrightarrow 7\longrightarrow 8\longrightarrow 9$,

$$\begin{aligned} &e^{s}\left(0.6^{2s+s^2}+0.4e^{s}\right)\times 0.8e^{2s+s^2}\times 0.6e^{3s}\times 0.4e^{3s}\\ &\quad\times 0.7e^{2s}\times 0.8e^{2s}\times 0.4e^{s}\left(1-0.3e^{s}\right)\\ &\quad= 0.043e^{14s+s^2}\left(0.6e^{2s+s^2}+0.4e^{s}\right)\times\left(1-0.3e^{s}\right). \end{aligned} \tag{6}$$

By the route of $A\longrightarrow 1\longrightarrow 2\longrightarrow 3\longrightarrow 6\longrightarrow 10\longrightarrow 11\longrightarrow 9$,

$$\begin{aligned} &e^{s}\left(0.6^{2s+s^2}+0.4e^{s}\right)\times 0.8e^{2s+s^2}\times 0.6e^{3s}\times 0.6e^{2s+s^2}\\ &\quad\times 0.9e^{0.5s}\times 0.5e^{2s}\times 0.4e^{s}\times 0.3e^{s}(1-0)\\ &\quad= 0.015552e^{12.5s+2s^2}\left(0.6e^{2s+s^2}+0.4e^{s}\right). \end{aligned} \tag{7}$$

By the route of $A \longrightarrow B \longrightarrow 4 \longrightarrow 6 \longrightarrow 7 \longrightarrow 8 \longrightarrow 9$,

$$\begin{aligned} & e^{s}0.6e^{s} \times 0.9e^{3s} \times 0.4e^{3s} \times 0.7e^{2s} \times 0.8e^{2s} \\ & \quad \times\left(1-0.4e^{s}-0.3e^{s}+0.12e^{2s}\right) \\ & \quad = 0.12e^{12s}\left(1-0.4e^{s}-0.3e^{s}+0.12e^{2s}\right). \end{aligned} \tag{8}$$

By the route of $A \longrightarrow B \longrightarrow 4 \longrightarrow 6 \longrightarrow 7 \longrightarrow 10 \longrightarrow 11 \longrightarrow 9$,

$$\begin{aligned} & e^{s}0.6e^{s} \times 0.9e^{3s} \times 0.4e^{3s} \times 0.3e^{s+s^2} \times 0.9e^{0.5s} \\ & \quad \times 0.5e^{4s} \times 0.3e^{s} \times \left(1-0.4e^{s}\right) \\ & \quad = 0.008748e^{14.5s+s^2}\left(1-0.4e^{s}\right). \end{aligned} \tag{9}$$

By the route of $A \longrightarrow B \longrightarrow 4 \longrightarrow 6 \longrightarrow 10 \longrightarrow 11 \longrightarrow 9$,

$$\begin{aligned} & e^{s}0.6e^{s} \times 0.9e^{3s} \times 0.6e^{2s+s^2} \times 0.9e^{0.5s} \times 0.5e^{4s} \times 0.3e^{s} \times \left(1-0.4e^{s}\right) \\ & \quad = 0.04374e^{12.5s+s^2}\left(1-0.4e^{s}\right), \\ & W_{A\longrightarrow 9} = \frac{((1)+(2)+(3)+(4)+(5)+(6))}{\left(1-0.4e^{s}-0.3e^{s}+0.12e^{2s}\right)}, \\ & p_{A\longrightarrow 9} = W_{A\longrightarrow 9}\big|_{s=0} = \frac{0.0301+0.00311+0.015552+0.0504+0.00525+0.0262}{0.42} = \frac{0.130612}{0.42} = 0.3109 \approx 0.31, \\ & M_{A\longrightarrow 9} = \frac{W}{p} = \frac{W_{A\longrightarrow 9}}{0.3109}, \\ & E_{A\longrightarrow 9} = M'\big|_{s=0} = \frac{1}{0.3109} \times \frac{1.665 \times 0.42 - 0.1306 \times (-0.46)}{0.42^2} = \frac{1}{0.3109} \times \frac{0.759376}{0.42^2} = 13.846 \approx 13.85. \end{aligned} \tag{10}$$

The calculation of various parameters from the material distribution center A to disaster site 12 can be broken down as follows.

By the route of $A \longrightarrow 1 \longrightarrow 2 \longrightarrow 3 \longrightarrow 6 \longrightarrow 7 \longrightarrow 10 \longrightarrow 11 \longrightarrow 12$,

$$\begin{aligned} & e^{s}\left(0.6^{2s+s^2}+0.4e^{s}\right) \times 0.8e^{2s+s^2} \times 0.6e^{3s} \times 0.4e^{3s} \\ & \quad \times 0.3e^{s+s^2} \times 0.9e^{0.5s} \times 0.2e^{2s} \times 0.4e^{s} \times 0.3e^{s}(1-0) \\ & \quad = 0.00124e^{14.5s+2s^2}\left(0.6e^{2s+s^2}+0.4e^{s}\right). \end{aligned} \tag{11}$$

By the route of $A \longrightarrow 1 \longrightarrow 2 \longrightarrow 3 \longrightarrow 6 \longrightarrow 10 \longrightarrow 11 \longrightarrow 12$,

$$\begin{aligned} & e^{s}\left(0.6^{2s+s^2}+0.4e^{s}\right) \times 0.8e^{2s+s^2} \times 0.6e^{3s} \times 0.6e^{2s+s^2} \\ & \quad \times 0.9e^{0.5s} \times 0.2e^{2s} \times 0.4e^{s} \times 0.3e^{s} \times 1 \\ & \quad = 0.00622e^{12.5s+2s^2}\left(0.6e^{2s+s^2}+0.4e^{s}\right). \end{aligned} \tag{12}$$

By the route of $A \longrightarrow B \longrightarrow 4 \longrightarrow 6 \longrightarrow 7 \longrightarrow 10 \longrightarrow 11 \longrightarrow 12$,

$$\begin{aligned} & e^{s} \times 0.6e^{s} \times 0.9e^{3s} \times 0.4e^{3s} \times 0.3e^{s+s^2} \times 0.9e^{0.5s} \\ & \quad \times 0.2e^{2s} \times 0.3e^{s} \times \left(1-0.4e^{s}\right) \\ & \quad = 0.00349e^{12.5s+s^2}\left(1-0.4e^{s}\right). \end{aligned} \tag{13}$$

By the route of $A \longrightarrow B \longrightarrow 4 \longrightarrow 6 \longrightarrow 10 \longrightarrow 11 \longrightarrow 12$,

$$e^{s} \times 0.6e^{s} \times 0.9e^{3s} \times 0.6e^{2s+s^{2}} \times 0.9e^{0.5s} \times 0.2e^{2s} \times 0.3e^{s} \times \left(1 - 0.4e^{s}\right) = 0.0175e^{10.5s+s^{2}}\left(1 - 0.4e^{s}\right),$$

$$W_{A\longrightarrow 12} = \frac{(\mathrm{I} + \mathrm{II} + \mathrm{III} + \mathrm{IV})}{\left(1 - 0.4e^{s} - 0.3e^{s} + 0.12e^{2s}\right)},$$

$$p_{A\longrightarrow 12} = W_{A\longrightarrow 12}\big|_{s=0} = \frac{0.00124 + 0.00622 + 0.0021 + 0.0105}{0.42} = 0.0478 \approx 0.05, \tag{14}$$

$$M_{A\longrightarrow 12} = \frac{W}{p} = \frac{W_{A\longrightarrow 12}}{0.0478},$$

$$E_{A\longrightarrow 12} = M'\big|_{s=0} = \frac{1}{0.0478} \times \frac{0.2355 \times 0.42 - 0.02 \times (-0.46)}{0.42^{2}} = \frac{1}{0.0478} \times \frac{0.10811}{0.42^{2}} = 12.82.$$

The GERT network parameters calculated from the above emergency supplies dispatching center to multiple emergency supplies distribution networks are all active calculated values, as shown in Table 3.

According to the random network model of emergency distribution GERT and the calculated values of the parameters of emergency distribution activities of each emergency logistics distribution center in the network, the following conclusions can be drawn:

(1) The probability of successful delivery of emergency supplies to disaster site 3 is 0.53, the risk to be borne is 47%, and the arrival time is 9.47 hours. This conclusion shows that the success probability of distribution to disaster site 3 is close to the risk probability. It should increase the quantity of materials to make up for the material loss and delay after transportation failure. When the materials in disaster site 3 are sufficient, they can be converted into material storage transfer station to supply resources for other disaster areas.

(2) The probability of successful distribution of emergency materials to disaster site 9 is 0.31, which needs to bear 69% of the risk, and it is estimated that it will take 13.85 hours. The probability of successful distribution of emergency materials to the disaster site 9 is low and the risk is high. This is because there is congestion from site 7 to site 8 during transportation. In addition, some materials are transferred to the disaster area after meeting the needs of disaster site 3. It is necessary to dispatch enough emergency materials from provincial emergency logistics distribution center B to the disaster area, dredge the traffic, and open up a green channel. At the same time, the vanguard team bypasses the congested area and transports materials from site 11 to disaster sites 9 and 12 at the same time.

(3) The probability of successful distribution of emergency supplies to disaster site 12 is 0.05, which needs to bear 95% of the risk. It is estimated that it will take 12.82 hours. From the model, it can be seen that there are four distribution routes leading to disaster site 12, which should increase the possibility of successful distribution to a certain extent. However, after calculation, we find that there are still some problems, such as low success rate of distribution, high risk, and long transportation time, which lead to the possibility of this phenomenon. The factors are as follows: ① like the materials transported to disaster site 9, some of the relief materials must meet the needs of the disaster site in front before they can be delivered, and ② the road condition from site 7 to site 8 is very poor, which brings about risks to the distribution process.

(4) The probability of successful distribution of emergency materials to disaster site 13 is 0.95, which needs to bear 5% of the risk and is expected to take 1.5 hours. The probability of success is the largest among all disaster areas. This is because the road conditions leading to disaster site 13 are good, and they are directly distributed by the provincial emergency logistics distribution center, which reduces the risk of transshipment from other places.

(5) The probability of successful delivery of emergency supplies to disaster site 15 is 0.12, which needs to bear 88% of the risk. It is estimated that it will take 13.6 hours. This is because site 14 to disaster site 15 may encounter road damage halfway and need to transit at site 5, which increases the time and risk.

From the model, it can be seen that if the emergency logistics distribution center is established in advance between site 9 and site 12, the risk of transferring materials from other disaster sites can be reduced, and the distribution process can be completed in the shortest time, which can improve the success probability to a certain extent. When the transportation link of rescue materials breaks in the process of emergency relief, the successful distribution will be caused. When the road patency probability is too low, we should immediately take a detour plan and remove obstacles to establish a green channel. In addition, through the establishment of emergency logistics distribution, we can

Table 3: Active calculated values of the GERT network parameter

Activity	Realize probability P_{ij}	Risk probability $P_V = 1 - P_E$	Expected time (hours)
$W_{1\longrightarrow 3}$: emergency supplies to disaster site 3	0.53	0.47	9.47
$W_{1\longrightarrow 9}$: emergency supplies to disaster site 9	0.31	0.69	13.85
$W_{1\longrightarrow 12}$: emergency supplies to disaster site 12	0.05	0.95	12.82
$W_{1\longrightarrow 13}$: emergency supplies to disaster site 13	0.95	0.05	1.5
$W_{1\longrightarrow 15}$: emergency supplies to disaster site 15	0.12	0.88	13.6

reduce transportation links and effectively reduce transportation risks.

3.2. The Number of Times Expected in a Complex Environment. Suppose that the situation suddenly changes, and a new disaster site 21 appears behind the disaster area. Disaster site 21 has a long way to go, and the required materials can only be transferred from site 11. The terrain of the road from site 11 to disaster site 21 is complex and easy to be blocked. In this environment, the emergency logistics strategy is as follows: as long as there is a jam in the front, the transport vehicles return to the upper site to wait until the road is clear and then start the distribution. Let the road patency probability $p = 0.7$ and probability of blockage $q = 0.3$. Mark each traffic with z; then the coefficient u of z^u is the number of attempts to transport from site 11 to disaster site 21. According to the known data, the probability of transportation success, risk probability, and expected times are calculated.

There are six first-order loops in Figure 2, which are (1) self-loop of site 11, (2) self-loop of site 16, (3) self-loop of site 19, (4) self-loop of site 18, (5) loop 16 ⟶ 17 ⟶ 16, and (6) loop 18 ⟶ 19 ⟶ 20 ⟶ 18. Their values are, respectively, qz, qz, qz, qz, $pz \times qz$, and $pz \times qz \times pz \times pz \times qz$.

There are twelve second-order loops in Figure 2, which are (1) self-loop of site 11 and self-loop of site 16, (2) self-loop of site 11 and loop of 16 ⟶ 17 ⟶ 16, (3) self-loop of site 11 and self-loop of site 19, (4) self-loop of site 11 and self-loop of site 18, (5) self-loop of site 11 and loop of 18 ⟶ 19 ⟶ 20 ⟶ 18, (6) self-loop of site 16 and loop of 18 ⟶ 19 ⟶ 20 ⟶ 18, (7) self-loop of site 16 and self-loop of site 19, (8) self-loop of site 16 and self-loop of site 18, (9) loop of 16 ⟶ 17 ⟶ 16 and self-loop of site 19, (10) loop of 16 ⟶ 17 ⟶ 16 and self-loop of site 18, (11) loop of 16 ⟶ 17 ⟶ 16 and loop of 18 ⟶ 19 ⟶ 20 ⟶ 18, and (12) self-loop of site 18 and self-loop of site 19. Their values are, respectively, $qz \times qz$, $qz \times qz \times pz$, $qz \times qz$, $qz \times qz$, $qz \times pz \times pz \times qz$, $qz \times pz \times pz \times qz$, $qz \times qz$, $qz \times qz$, $pz \times qz \times qz$, $pz \times qz \times qz$, $pz \times qz \times pz \times qz \times qz$, and $qz \times qz$.

There are nine third-order loops in Figure 2, which are (1) self-loop of site 11 and self-loop of site 16 and self-loop of site 19, (2) self-loop of site 11 and self-loop of 16 and loop of 18 ⟶ 19 ⟶ 20 ⟶ 18, (3) self-loop of site 11 and self-loop of site 16 and self-loop of site 18, (4) self-loop of site 11 and self-loop of site 18 and loop of 16 ⟶ 17 ⟶ 16, (5) self-loop of site 11 and self-loop of site 18 and self-loop of site 19, (6) self-loop of site 11 and self-loop of site 19 and loop of 16 ⟶ 17 ⟶ 16, (7) self-loop of site 11 and loop of 16 ⟶ 17 ⟶ 16 and loop of 18 ⟶ 19 ⟶ 20 ⟶ 18, (8) self-loop of site 16 and self-loop of site 18 and self-loop of site 19, and (9) self-loop of site 18 and self-loop of site 19 and loop of 16 ⟶ 17 ⟶ 16. Their values are, respectively, $qz \times qz \times qz$, $qz \times qz \times pz \times pz \times qz$, $qz \times qz \times qz$, $qz \times qz \times pz \times qz$, $qz \times qz \times qz$, $qz \times qz \times pz \times qz$, $qz \times pz \times qz \times pz \times pz \times qz$, $qz \times qz \times qz$, and $qz \times qz \times pz \times qz$.

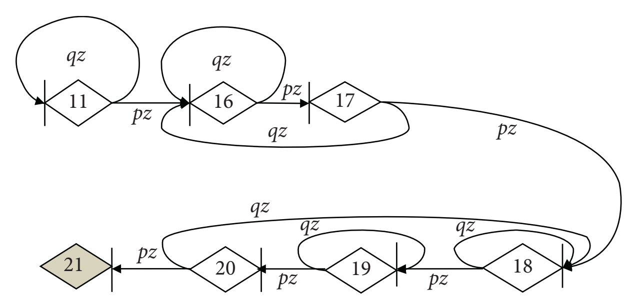

Figure 2: Random network diagram for distribution.

There are two fourth-order loops in Figure 2, which are (1) self-loop of site 11 and self-loop of site 16 and self-loop of site 18 and self-loop of site 19 and (2) self-loop of site 11 and loop of 16 ⟶ 17 ⟶ 16and self-loop of site 18 and self-loop of site 19. Their values are, respectively, $qz \times qz \times qz \times qz$ and $qz \times pz \times qz \times qz \times qz$.

$$\begin{aligned}\Delta = 1 &- \left(4qz + pqz^2 + p^2qz^3\right) \\ &+ \left(6q^2z^2 + 3pq^2z^3 + 2p^2q^2z^4 + p^2q^3z^5\right) \\ &- \left(4q^3z^3 + p^2q^3z^5 + p^3q^2z^5 + 3pq^3z^4\right) \\ &+ \left(q^4z^4 + pq^4z^5\right).\end{aligned} \tag{15}$$

There is only one path from site 11 to disaster site 21, whose value is p^6z^6; and there are no loops in contact with the path, so $\Delta_1 = 1$.

$$W = \frac{p^6z^6 \times 1}{\Delta} = \frac{p^6z^6}{1 - 4qz + \left(6q^2 - pq\right)z^2 + \left(3pq^2 - p^2q - 4q^3\right)z^3 + \left(2p^2q^2 - 3pq^3 + q^4\right)z^4 + \left(pq^4 - p^3q^2\right)z^5}. \tag{16}$$

When $p = 0.7$ and $q = 0.3$ are substituted into equation, we can get

$$W = \frac{0.117649z^6}{1 - 1.2z + 0.33z^2 - 0.066z^3 + 0.0396z^4 - 0.0252z^5}. \tag{17}$$

Take the derivative of z with respect to W and set $z = 1$ to get the expected value of the number of attempts; namely,

$$W'|_{z=1} = \frac{0.705894 \times 0.0784 + 0.083013134}{0.0784^2} = 22.5094 \approx 23. \tag{18}$$

It takes 23 attempts to reach disaster site 21 at one time, which may be due to poor road conditions. Almost every road in front of the transportation site needs to be sorted out before passing. In order to reduce the risk of transportation failure, we can establish an emergency logistics reserve center in the nearby area in advance to transport and reserve disaster relief materials in advance. It can directly transport the materials from the reserve center to the disaster site, which improves the response speed of emergency rescue and the arrival rate of transportation.

4. Conclusions

Timely and reasonable resource distribution is one of the preconditions to ensure the normal development of emergency rescue activities, which is of great significance to improve the emergency rescue system. How to complete the task of emergency logistics distribution efficiently and with low risk is a challenge for the emergency logistics project. In this paper, GERT network is used to build a simulation model of emergency logistics distribution for emergency distribution of material reserve base to multiple disaster sites, analyze the transportation problems that may exist in the actual rescue, and calculate the realization probability and risk of logistics distribution in the transportation scheme of each logistics site to the disaster site and between the disaster sites, aiming at different realization probability and actual situation. This paper puts forward some effective countermeasures, such as increasing the transportation volume of materials, establishing temporary transfer centers, and opening up green channels, and draws conclusion that the reasonable layout of emergency logistics distribution centers can effectively reduce the risk of logistics distribution and improve the success probability. The conclusion provides a strategic reference for ensuring the efficient and safe transportation of rescue materials to the disaster-stricken areas. Compared with other traditional research methods of emergency logistics, GERT network considers the feedback self-loop problem, so it is more advanced, and the results are more accurate and closer to the actual situation.

However, the distribution type assumption of GERT network model activity parameters is simple in this paper; in addition, there are many areas not involved in the research. In complex environment, how to scientifically measure GERT random network activity parameters in order to more truly describe the actual situation of emergency logistics distribution and how to reasonably arrange the distribution plan (including material distribution and vehicle type selection, path planning, etc.) will be further studied.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] Q. H. Zhao, "Construction of fractal emergency logistics management system and its guarantee mechanism for major emergencies," *Jianghuai Forum*, vol. 4, pp. 13–20, 2020.
[2] W. N. Carter, "Natural disasters," *The Macedon Digest*, vol. 9, no. 4, pp. 32-33, 1994.
[3] C.-F. Zhu, Z.-K. Zhang, Q.-R. Wang, and F. Mauriello, "Path choice of emergency logistics based on cumulative prospect theory," *Journal of Advanced Transportation*, vol. 2019, pp. 1–11, 2019.
[4] J. R. Feng, W. M. Gai, J. Y. Li, and M. Xu, "Location selection of emergency supplies repositories for emergency logistics management: a variable weighted algorithm," *Journal of Loss Prevention in the Process Industries*, vol. 63, pp. 1–5, 2020.
[5] L. Lu and X. Luo, "Emergency transportation problem based on single-valued neutrosophic set," *Discrete Dynamics in Nature and Society*, vol. 2020, pp. 1–8, 2020.
[6] B. J. Qiu, J. H. Zhang, Y. T. Qi, and Y. Liu, "Grey-theory-based optimization model of emergency logistics considering time uncertainty," *PLoS One*, vol. 10, no. 9, pp. 1–13, 2015.
[7] A. Haghani and S.-C. Oh, "Formulation and solution of a multi-commodity, multi-modal network flow model for disaster relief operations," *Transportation Research Part A: Policy and Practice*, vol. 30, no. 3, pp. 231–250, 1996.
[8] C. F. Zhu, Z. K. Zhang, and C. X. Ma, "Research on emergency logistics dynamic network based on super network," *Latin American Applied Research*, vol. 47, no. 1, pp. 11–16, 2016.
[9] F. S. Chang, J. S. Wu, C. N. Lee, and H. C. Shen, "Greedy-search-based multi-objective genetic algorithm for emergency logistics scheduling," *Expert Systems with Applications*, vol. 41, no. 6, pp. 2974–2956, 2014.
[10] C. F. Zhu and H. J. Li, "Coordinated operation mechanism and coupled analysis of the virtual emergency logistics system," *Statistics & Decisions*, vol. 38, no. 8, pp. 54–56, 2014.
[11] B. Zheng, Z. Ma, and S. L. Li, "Integrated optimization of emergency logistics systems for postearthquake initial stage based on bi-level programming," *Journal of Systems Engineering*, vol. 29, no. 1, pp. 113–125, 2014.
[12] G. Barbarosoğlu and Y. Arda, "A two-stage stochastic programming framework for transportation planning in disaster

response," *Journal of the Operational Research Society*, vol. 55, pp. 43–53, 2017.

[13] A. M. Caunhye, Y. Zhang, M. Li, and X. Nie, "A location-routing model for prepositioning and distributing emergency supplies," *Transportation Research Part E: Logistics and Transportation Review*, vol. 90, pp. 161–176, 2016.

[14] B. Zhang, H. Li, S. Li, and J. Peng, "Sustainable multi-depot emergency facilities location-routing problem with uncertain information," *Applied Mathematics and Computation*, vol. 333, pp. 506–520, 2018.

[15] M. Ahmadi, A. Seifi, and B. Tootooni, "A humanitarian logistics model for disaster relief operation considering network failure and standard relief time: a case study on San Francisco district," *Transportation Research Part E: Logistics and Transportation Review*, vol. 75, pp. 145–163, 2015.

[16] K. Chang, H. Zhou, G. Chen, and H. Chen, "Multiobjective location routing problem considering uncertain data after disasters," *Discrete Dynamics in Nature and Society*, vol. 2017, pp. 1–7, 2017.

[17] S.-L. Hu, C.-F. Han, and L.-P. Meng, "A scenario planning approach for propositioning rescue centers for urban waterlog disasters," *Computers & Industrial Engineering*, vol. 87, pp. 425–435, 2015.

[18] S. Khalipourazari and A. A. Khamseh, "Bi-objective emergency blood supply chain network design in earthquake considering earthquake magnitude: a comprehensive study with real world application," *Annals of Operations Research*, vol. 283, pp. 355–393, 2019.

[19] Y. Deng, W. Zhu, and F. Wang, "Research on multi-objective robust vehicle routing problem in emergency logistics," *Computer Engineering and Applications*, vol. 55, no. 1, pp. 248–255, 2019.

[20] Y. Zhou, J. Liu, Y. Zhang, and X. Gan, "A multi-objective evolutionary algorithm for multi-period dynamic emergency resource scheduling problems," *Transportation Research Part E: Logistics and Transportation Review*, vol. 99, pp. 77–95, 2017.

[21] A. Bozorgi-Amiri, M. S. Jabalameli, and S. M. J. Mirzapour Al-e-Hashem, "A multi-objective robust stochastic programming model for disaster relief logistics under uncertainty," *OR Spectrum*, vol. 35, no. 4, pp. 905–933, 2013.

[22] Y. C. Feng, *Random Network and its Application*, Beijing Institute of Aeronautics Press, Beijing, China, 1987.