

## Retraction

# Retracted: Analysis of Multiobjective Scheduling Model for Emergency Management under Multiresource Combination of Disaster Chains

### Complexity

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### References

- [1] D. Su, X. Lei, Y. Wang, and H. Wang, "Analysis of Multiobjective Scheduling Model for Emergency Management under Multiresource Combination of Disaster Chains," *Complexity*, vol. 2021, Article ID 2962058, 12 pages, 2021.

Research Article

# Analysis of Multiobjective Scheduling Model for Emergency Management under Multiresource Combination of Disaster Chains

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This paper analyzes the formation mechanism of urban hazard chains. The results demonstrate that the complex interaction between the disaster-bearing bodies under the action of disaster-causing factors is the direct cause of urban hazard chains. The analysis of the energy effects of urban hazard chains shows that the coupling of the excitation energy released by the causative agent and the energy of the disaster-bearing bodies is the fundamental cause of urban hazard chains. Based on the description of the dynamical mechanism of the urban disaster chain system, this paper first sets up a disaster scenario and considers the effect of the time lag to establish a system dynamics model of the urban disaster chain and urban disaster management. The model of urban disaster management system dynamics shows the mutual influence and complementary relationship between disasters and the economy, pointing out that emphasizing the spill-over effects of disaster management systems can improve the effectiveness of disaster mitigation. This study also uses equilibrium entropy and brittle entropy theories to characterize the vulnerability of single-function networks and the degree of brittle association of each lifeline subsystem, respectively, and establishes a model for assessing the sensitivity of lifeline systems to disaster damage. Built on the collection and feedback of information from disaster areas after the occurrence of emergencies, this paper establishes a deterministic multihazard emergency resource dispatches model and an uncertain multihazard emergency resource dispatch model.

## 1. Introduction

The first task of urban hazard research is to define urban hazards. As the urban hazard system is an extremely complex giant system, its occurrence and evolution process have extremely complex characteristics, such as orderliness, sudden change, irreversibility, ambiguity, grey characteristics, and long-term unpredictability, which cannot be described by the traditional Newtonian mechanics, and there are quite a lot of achievements in the study of urban hazard mechanism using nontraditional mathematical and physical methods [1].

Urban disaster prevention and mitigation are complex natural-economic-social system projects consisting of

disaster investigation, evaluation, monitoring, forecasting, prevention, resistance, relief, postdisaster reconstruction, etc. [2, 3]. The whole process deals with many factors and a large-scale, requiring a huge investment of human, material, and financial resources [4]. The effectiveness of disaster prevention and mitigation depends on the level of research and management of disaster prevention and mitigation. Therefore, it is extremely important to strengthen the research and construction of a scientific disaster prevention and mitigation command and decision support system using modern technology [5]. Many scholars have carried out systematic research in these two areas, including urban disaster risk assessment, which provides the basis for urban safety planning and urban disaster prevention and

mitigation decisions, urban disaster prevention, and mitigation planning, which provides security for urban development, and disaster simulation decision support systems, which provide a basis and solution for disaster prevention and mitigation decisions [6].

As shown in Figure 1, disaster risk research is the basis for building a comprehensive disaster prevention and mitigation system and formulating corresponding emergency management countermeasures. In Figure 1, “1, 2, 3, 4, ...” indicate the labels of disaster factors, and we unify the disasters into two categories, human disasters and natural disasters. A large number of disaster prevention and mitigation practices at home and abroad have shown that correct disaster risk assessment results are the basic basis for the optimal configuration and orderly construction of the three major disaster prevention and mitigation countermeasure systems—monitoring and forecasting system, defense system, and emergency relief system—in the time domain, and the practice of regional economic construction and social development has also put forward the urgent need to strengthen the study of regional disaster risk assessment theories and methods [7]. Since the understanding and portrayal of disaster and vulnerability are the core issues of disaster and loss assessment, and the risk of disaster loss depends on the vulnerability of the hazard-bearing body for a given hazard-causing intensity, various international disaster risk assessment methods have explored vulnerability to varying degrees [8]. Besides, the international community has developed a variety of methods or models for global, continental, national, regional, and community-based disaster risk assessment, each with its conceptual system and corresponding database, model library system, and risk map to visually represent the assessment results.

The construction of comprehensive urban disaster prevention and mitigation system is the mainstream of urban disaster research [9]. The level of a city’s comprehensive disaster prevention and mitigation capacity is not only a major indicator of the city’s overall function, but also a marker of the city’s safety and defense capacity. Therefore, strengthening urban disaster prevention and mitigation strategies, formulating and promoting comprehensive urban disaster prevention and mitigation measures, and improving the city’s ability to withstand disasters are inevitable requirements for sustainable urban development [10, 11]. Although comprehensive urban disaster prevention and mitigation have been mentioned in China’s theoretical circles for a long time, few actual research results have been made, and the process is relatively slow. As single-hazard research methods and sectoral disaster management models are becoming increasingly incompatible with the characteristics of urban disasters, changing from single-hazard prevention to integrate disaster prevention and mitigation is also an inescapable requirement of urban disaster laws [12].

Comprehensive urban hazard risk assessment remains a burning issue in disaster research. The practice of disaster research at home and abroad has shown that it is not realistic to predict and prevent disasters from occurring with complete accuracy and that it is only appropriate to adopt effective disaster risk assessment and management strategies

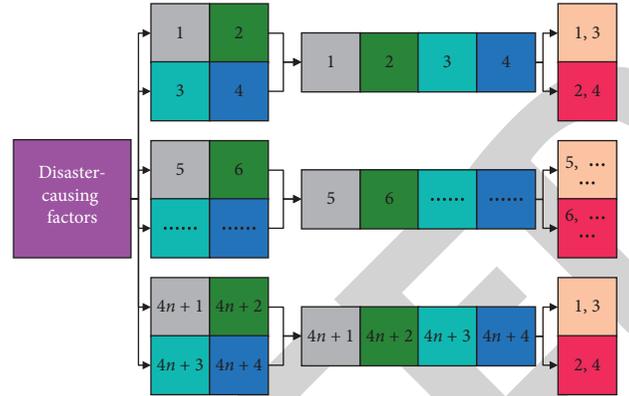


FIGURE 1: Mechanisms of disaster chain formation.

to avoid or mitigate the huge losses they cause [13]. However, the urban disaster risk system has basic characteristics such as chain effect, amplification effect, and human effect, so it is necessary to adopt simulation and other means to obtain the disaster development and evolution process under the disturbance of human activities, including the analysis of the disaster-bearing capacity of urban lifelines, to form a dynamic and comprehensive assessment model of disaster risk to truly provide a basis for disaster mitigation and risk reduction and management decisions by urban authorities at all levels [14].

This paper addresses the key issue of cross-coupling and chain evolution law of the three elements induced by urban disasters (disaster-causing factors, disaster-bearing bodies, and disaster-inducing environment) and analyzes the regular characteristics of urban disaster chains with theories of system engineering, safety science, and disaster science. It establishes a mathematical model of disaster chain effects based on complex networks according to the complex network characteristics of urban disaster systems in the evolution process by applying modern applied mathematics [15]. Based on the assessment of the vulnerability of the main disaster-bearing bodies, a comprehensive risk assessment model of urban disasters based on disaster chains is established to realize the “prior prevention” of urban disasters [16]. A multihazard emergency resource dispatch model depends on a description of the context of the emergency problem. The dispatching problem is divided into deterministic and uncertain resource dispatching according to whether the number and type of resources needed at the disaster sites are identified and the time required to dispatch various emergency resources to each disaster site [17].

## 2. System Dynamics Modeling and Analysis of Urban Disaster Chains

*2.1. Characterization of the System Dynamics of Urban Disaster Systems.* The urban disaster system is a system with many influencing factors, large scale, and complex internal structure, and at the same time, it is a dynamic system with multiple inputs, multiple outputs, multiple disturbances, and multiple temporal changes. The urban hazard system is

an organic whole consisting. As shown in Figure 2, the urban disaster system can also be seen as consisting of a disaster formation subsystem and a disaster management subsystem. The two systems interact with each other and the elements of the subsystem, and there are multiple feedback structures within them, which are a continuous process of generation and development.

The urban disaster system is a dynamic feedback system. Firstly, the formation process of catastrophes is characterized by obvious feedback dynamics. The disaster-generating environment, disaster-causing factors, and disaster-bearing bodies are the basic components of disaster formation. The environment is at the root of disasters and incidents and is the precondition and the driving force for the formation of disasters. The causative factor is the specific event induced by the source of the disaster. The causative factor acts on the disaster-bearing body and will lead to the generation of the disaster incident. The disaster risk resulting from the disaster incident and through the final disaster management makes the entire disaster incident form a closed circuit. At the same time, the dynamics of feedback are also evident in the prediction of catastrophes, the identification of disaster risks, and the corresponding management decisions [18]. Disaster prediction is a necessary condition for disaster management. Only when people are conscious of the possibility of a disastrous crisis will they be motivated to use their judgment and experience to identify disaster risks and make preliminary disaster risk assessments. Therefore, the perception of disaster risk through disaster forecasting is the source of motivation for disaster management [19]. After identifying disaster risks, if people believe that a disaster will bring an unacceptable level of risk, they will further conduct a disaster risk assessment, which will provide a detailed assessment of the likely level of impact and the possible damage caused, to fit the real state of disaster risk as far as possible and provide a basis for decision making on whether to manage the disaster.

Urban disaster systems have the basic characteristics for the study of system dynamics. Firstly, the complexity of the system and the strong chain effects caused by the interaction of the various factors of the system make it almost impossible to discuss the development process and direction of the system based on intuitive understanding and experience [20]. Moreover, the multiple feedback loops and the openness of the system make it dynamic and nonlinear, and the time lag makes it difficult to trace the causes of disasters as they are separated from the results and phenomena in space and time. Because of these characteristics of urban disaster systems, this paper introduces a system dynamics approach to analyze their structure and to describe and quantify their evolutionary laws.

*2.2. System Dynamics Modeling and Simulation of the Evolution of Urban Disaster Chains.* The built-in equations in the system dynamics modeling process are mainly based on mathematical models to characterize the system, but as the relationship strength factor is difficult to obtain based on the complete physical model and mathematical solution, it is

mainly obtained based on the statistical data of a certain city, such as the number and scale of landslides caused by a magnitude 7 earthquake in a certain city, which is the correlation degree of earthquake landslides [21–23]. This data is not transferable; that is, it can only be used for the modeling of the city, not for other cities, and the correlation covers the physical exposure of the node vulnerability, so the physical exposure should not be taken into account in the modeling process, considering that the sensitivity of the node to damage does not only show a linear relationship to the amplification of the hazard, but also show a trumpet-shaped amplification. The regional disaster response capacity of a node is expressed as the recovery capacity after a disaster, which can be characterized by the recovery and repair factor of the disaster that has occurred:

$$n_i(t) = \frac{q_i(t) - r_i(t)}{E_i(t) + r_i(t)} \cdot e^{V_s}, \quad (1)$$

where  $r_i(t)$  is the recovery and repair factor, which is determined by the disaster  $a_i$ , the maximum dedicated recovery and repair capacity  $\phi_i$ , and the proportion  $x_i(t)$  based on the actual input. As a result, the recovery and repair factor  $r_i(t)$  is expressed as

$$r_i(t) = \lim_{n \rightarrow \infty} \sum_{i=1}^n \frac{\phi_i + x_i(t)}{\phi_i - x_i(t)}. \quad (2)$$

In particular, the largest dedicated rescue and restoration capacity,  $\phi_i$ , is determined by factors such as the emergency response team for the disastrous event  $a_i$  and the material stockpile. And the proportion of emergency repair inputs  $x_i(t)$  differs for the two different time-effect evolutionary behaviors:

$$\begin{cases} n_i(t) = 1, x_i(t) = 0, \\ n_i(t) \geq n_{cr}, x_i(t) = 1, \\ 0 < n_i(t) < n_{cr}, x_i(t) = 0. \end{cases} \quad (3)$$

If the subnode  $a_i$  is affected by the unbroken evolutionary behavior, the restoration input ratio  $x_i(t)$  is determined according to the disaster loss degree. When the disaster loss degree of node  $a_i$  is 0, the restoration input ratio  $x_i(t)$  is 0. When the disaster loss degree of node  $a_i$  is greater than the critical value  $N_i$ , the maximum special rescue and restoration capacity will be fully committed, that is,

$$\begin{cases} N_i(t) = 0, x_i(t) = 1, \\ N_i(t) \geq N_{cr}, x_i(t) = 1, \\ 0 < N_i(t) < n_{cr}, x_i(t) = 1. \end{cases} \quad (4)$$

*2.3. Analysis of Simulation Results of a Dynamical Model of an Urban Disaster Chain System.* The coupling between urban disaster systems and system dynamics has been analyzed earlier, indicating that the system dynamics model of urban disaster chains has good scope suitability. During the construction of the model, the elemental structure of the model and the causal feedback relationships of the model, as

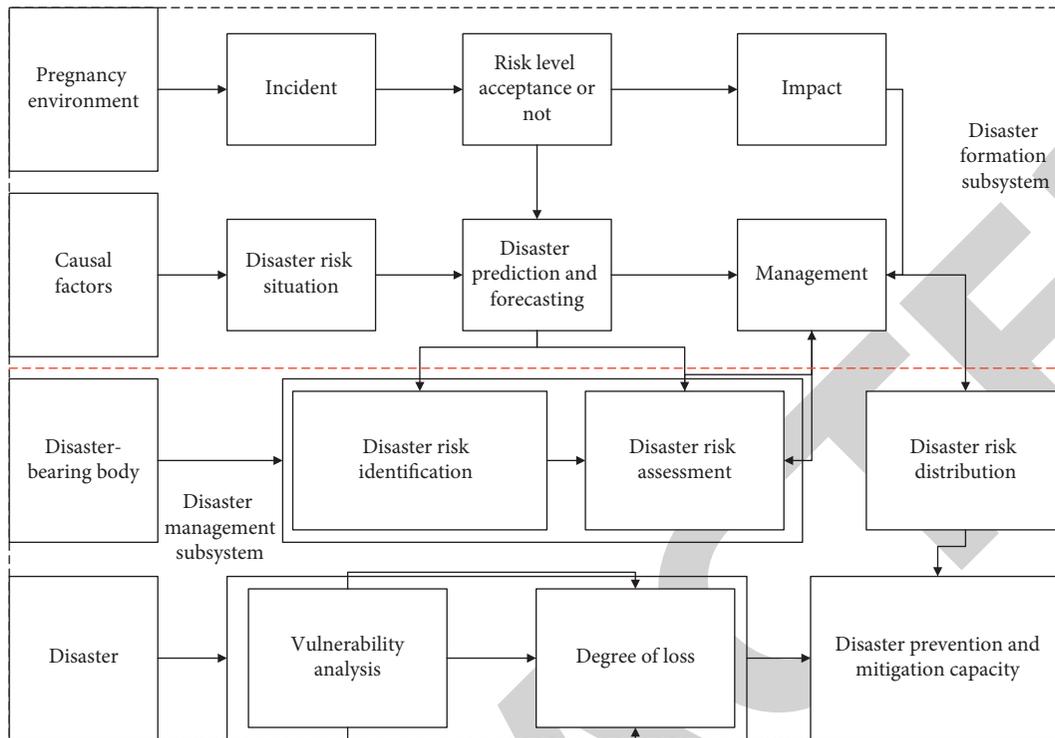


FIGURE 2: Schematic diagram of the dynamics of a disaster system.

well as the pertinent mathematical relationships, can be well matched, and therefore, the model structure is also in line with the requirements [24–27]. In terms of parameter validation tests, to be able to reproduce the dynamic evolutionary behavior of the urban hazard chain and, at the same time, to represent the actual situation as far as possible through the chain parameters, the parameters in the model are set to match the actual process of the urban hazard system as far as possible, and in terms of the magnitude of the parameters, all variables, parameters, initial values, and mathematical relationship equations of the model meet the requirements for consistency of magnitude.

Many factors influence the development of a disaster chain, some of which have a significant impact on the development of the chain but are difficult to control by humans; others play an equally important role in the development of the chain, can be controlled by technical and managerial means, and will be analyzed utilizing a model focused on the simulation of the process and results of their influence to derive the degree of sensitivity of their impact on the system.

The vulnerability indices included in the model are the water facility vulnerability index, the building vulnerability index, the urban lifeline vulnerability index, the enterprise vulnerability index, and the human vulnerability index. Figure 3 reflects the changes in the main disaster loss indicators for the same values of the vulnerability indices, 0.6, 0.4, and 0.2, respectively, and the trend of the curves shows that the reduction of the vulnerability indices of the system can significantly reduce the disaster loss rate and the degree of disaster loss, but the reduction of the vulnerability indices

from 0.6 to 0.4 is relatively larger than the increase of the vulnerability indices from 0.4 to 0.2. The reduction in the vulnerability index from 0.6 to 0.4 is relatively greater than that from 0.4 to 0.2. The main parent hazard events that cause disaster losses are hazard sources, mudflows, landslides, and flood damage, where hazard sources, mudflows, and landslides mainly impact the hazard-bearing bodies within a relatively short period after the occurrence of the disaster, resulting in significant damage to the hazard-bearing bodies, and, later, due to the effect of rainfall factors, can trigger the reassurance of mudflows and flood events to cause further damage to the respective hazard-bearing bodies. The impact of the flooding event on the respective hazard-bearers will be repeated at a later stage due to the rainfall impact factor. In the later stages of the disaster, when vulnerability indicators are reduced, the rate of building damage is significantly reduced, and the rate of lifeline damage and casualties is reduced to zero, both because the vulnerability of water facilities is reduced, and flooding does not occur, and because the reduced vulnerability of buildings and lifelines allows the chain of subsequent disasters such as fire and explosion accidents and industrial accidents to be broken.

Figure 4 shows how the rate of damage to buildings varies with each vulnerability indicator. Buildings are first impacted by the source of the hazard, followed by landslides and mudslides caused by cooperation with rainfall and weather events. The rate of damage to buildings also varies cyclically with the cycle of rainfall factors. The trend in the rate of damage to urban lifelines in response to changes in the vulnerability indices is consistent with the rate of damage

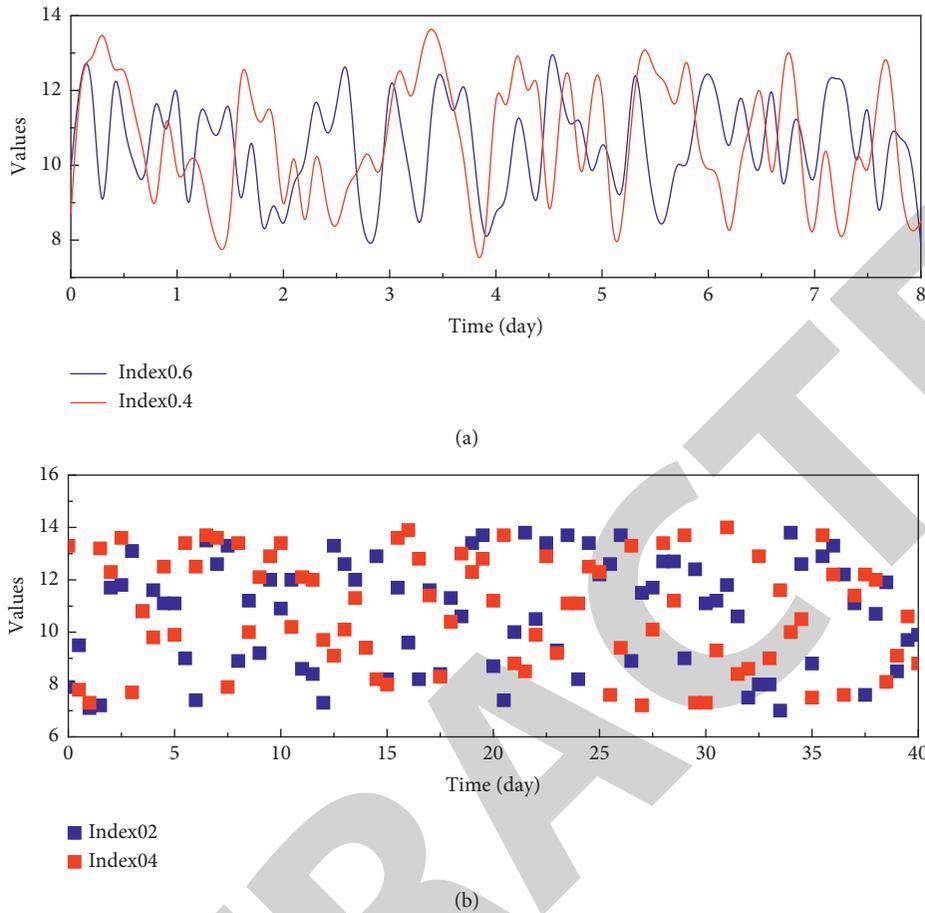


FIGURE 3: Effect of vulnerability index on building damage rates.

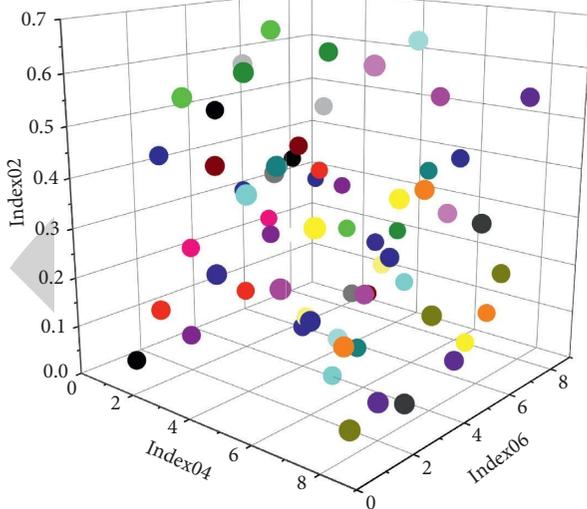


FIGURE 4: Impact of urban lifeline damage of vulnerability index.

to buildings, as the factors affecting them are similar to those affecting buildings, except that the strength of the associated factors is not the same. As each vulnerability index decreases, its loss rate decreases significantly; especially, when

the vulnerability index reduces to 0.2, the loss rate tends to level off at a later stage.

In the simulation results, the recovery and repair factor for buildings is only 0.12. This is explained by the fact that the casualties caused by buildings are mainly determined by their vulnerability. Once a building is damaged by a disaster, the casualties are determined, and the recovery and repair of the building at a later stage do not have a significant influence on the casualties.

### 3. Two-Tier Emergency Material Dispatch Analysis with Multiple Resource Combinations and Multiple Objectives

3.1. A Study of Two-Tier Emergency Material Dispatch under a Variable Road Network. Large-scale natural disasters are occurring increasingly frequently around the world, causing serious disruption to people's living environment and causing huge losses. When disasters such as earthquakes and mudslides occur, in addition to causing huge economic losses, they can also cause many casualties, which is why it is an important issue to study the dispatch of emergency supplies in the event of a sudden disaster. In the case of earthquakes, mudslides, and other disasters, not only are

roads destroyed and interrupted, but many emergency supplies need to be provided in a short period. Besides, in the event of road disruptions, research into how to quickly arrange the dispatch of emergency supplies, improve the reliability of emergency solutions, reduce in-transit delivery time, and reduce costs is of immense practical importance in handling such events [28].

However, in most cases, it is sometimes difficult to ensure that rescue supplies are available after a disaster, and there is a need to consider and optimize the route, distribution of supplies, and choice of a rescue center. As shown in Figure 5, most of these studies are based on single-tier emergency relief networks, with a single type of transport and emergency supplies, and do not consider the actual situation in depth.

For the characteristics of emergency relief in the early postdisaster period, to more quickly form the peripheral distribution center to deploy large quantities of supplies to the affected point, directly from the distribution center using road transport relief supplies, it cannot guarantee fast and timely distribution of large quantities of relief supplies to the affected point, considering combining the transport characteristics of different modes of transport to adapt to different distribution situations, to establish an intermediate layer distribution center for the distribution of relief supplies. The establishment of an intermediate layer is conducive to the advantages of various means of transport, so that supplies can be distributed to the disaster site more quickly. Firstly, the distribution center uses trains, planes, and cars to transport the supplies to the nearby distribution center or sends some of the relief supplies to the damaged road section caused by the disaster and repairs it, saving the travel time of the road section; then multiple distribution centers use road transport to transport the emergency supplies to each disaster demand point, forming a distribution center-distribution center/damaged road section-disaster demand point. This is two-level planning and emergency dispatching model, which allows for more timely delivery of supplies to the affected demand points according to the characteristics of the different modes of transport and road condition information.

In order not to lose generality and easy to model, this paper constructs a two-tier rescue model for postdisaster emergency supplies, dividing the entire distribution process of rescue supplies into two layers to describe the upper and lower layers, with the upper layer being the distribution process of supplies being delivered to the middle tier distribution center from the material collection and distribution points and the lower layer being the distribution process of supplies being distributed to different disaster sites from the middle tier distribution center. Therefore, this paper establishes a mathematical model of multiple depot resource supply points and multiple emergency relief demand points under two-tier planning from the actual situation, which is of great reference significance in providing reasonable material dispatching solutions to solve sudden disaster events, especially after disasters that lead to damage to part of the road network.

*3.2. A Case Study of Two-Tier Emergency Material Dispatch under a Variable Road Network.* There is location information of all distribution centers, as well as demand points and primary distribution points. The affected people and the relief workers at the demand points are in urgent need of survival necessities, as well as the tools to make repairs. The distribution of supplies to distribution centers and road networks at distribution points can be carried out by a variety of transport modes, but the distribution of supplies from distribution centers to individual sites is restricted by the conditions and can only be carried out by vehicles, of which the maximum load capacity is known. It is necessary to allocate supplies for emergency repairs to dramatically reduce the distribution time delay and to pass by the normal distribution road network time. Considering the extreme lack of relief supplies at the beginning of the earthquake, the number of relief supplies was established at the same level as the living supplies needed in the affected areas. The start time of the transport task is zero. The time windows for relief supplies at the affected point are both determined according to the actual situation. As shown in Figure 6, there are 600 units of relief supplies by the emergency supplies collection and distribution point to safeguard the needs of the area. The fixed cost of vehicle travel is 300 RMB/vehicle, the cost of travel is 6 RMB/h, the maximum load is 150 units, and the average speed of travel is 38 km/h. The penalty cost is 200 RMB/h, when the time window limit for the affected site is not satisfied. The two road sections that need to be repaired require relief supplies of 12 units and 18 units, respectively, and if the road is in an impassable condition, if the damaged section is chosen not to be repaired, the distance to the section is set to a sufficiently large integer  $M$ ; here, it is set to 1000. Take into account the actual situation as follows: the total sample is set to 240, the initial probabilities are set to 0.01, the maximum number of iterations is 100, the maximum number of searches is 100, and the program is run 20 times to get the best result.

The data for the fully rehabilitated road network is significantly smaller than that for the nonrehabilitated road network or only partially rehabilitated road network, where the target value for the fully rehabilitated road network state is much smaller than that for the other road network states. When comparing the transport costs of the different road networks, the transport costs of the network formed by the full repair of the damaged sections are much lower than the transport costs of the ruined condition of the network. This is because both damaged sections are critical shortest routes from the distribution point to the affected area, and damage to them would result in a significant increase in transport costs and a decrease in transport efficiency. The benefits of repair are greater than the costs incurred, so the results achieved in this paper are optimal for the entire network. If there is only sufficient relief material to repair part of the route, the route with the greater benefit from repair will be chosen, so that the material can be delivered to more unnatural demand points in the shortest possible time. This shows the practical value and significance of analyzing and comparing the overall network and exploring the impact of

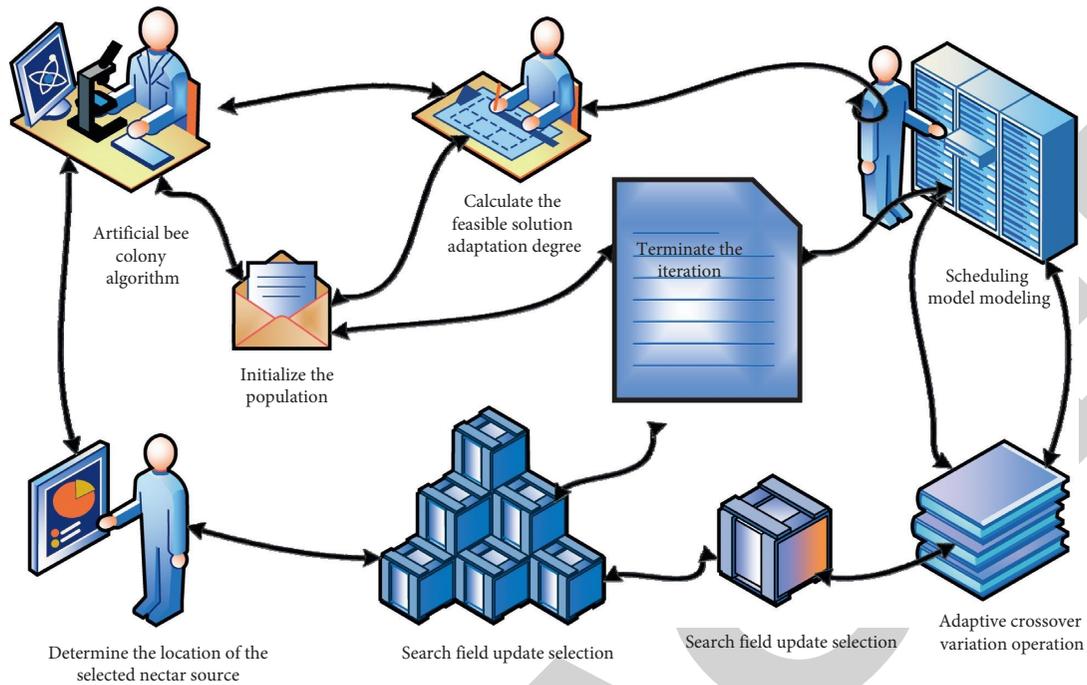


FIGURE 5: Optimization process of emergency material dispatch in case of the variable road network.

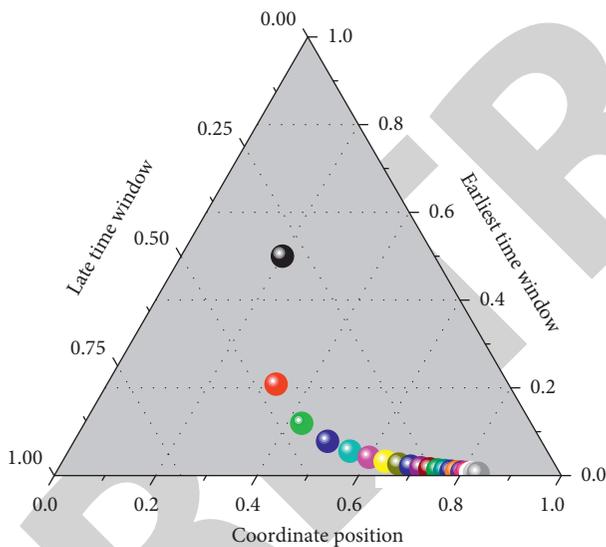


FIGURE 6: Time window corresponding to the disaster site and relief supplies.

route costs and benefits under different road networks, given that the network is variable.

**3.3. Performance Comparisons of Multiresource Combination Multiobjective Contingency Scheduling Algorithms.** There are few similar examples and algorithms available for the scheduling of emergency supplies for multiple relief points in the case of movable road networks, so a direct comparison is not possible. Here, to analyze the performance of this algorithm, the genetic algorithm and the improved artificial bee colony algorithm were used in the path optimization

phase in the case of neither of the road networks being repaired to carry out comparison tests in the same environment. As the genetic algorithm and the artificial bee colony algorithm are changed, a comparison of the algorithms with different population numbers about 500 iterations is considered here, and the comparison tests are shown in Figure 7.

After comparison, it can be seen that when the population size is large, this algorithm has certain advantages over genetic algorithm. While comparing the standard artificial bee colony algorithm, it has advantages for different problem sizes. It can be found that the convergence rate of the algorithm is faster, which indicates that the adaptive strategy in this paper is effective.

## 4. Evaluation and Analysis of the Security Posture of Multilayered Disaster Chains

**4.1. Evaluation of Trends in Security Changes in Disaster Chain Networks.** The meaning of “posture” includes both “state” and “trend.” The security posture of the urban rail disaster chain network includes both the state of the urban rail transit system when a disaster occurs and the tendency of the disaster to spread to fresh disasters. In the actual situation, there are often only one or several disasters occurring at the same time; therefore, in this paper, the safety level of the most serious disaster among the current disasters is taken as the safety “state” of the urban rail transit system when evaluating the “state” of the urban rail transit disaster chain network. The network model constructed in Chapter 3 is used to find the probability and direction of disaster propagation, and then to evaluate the “trend” of the disaster chain network. Based on the consideration of the magnitude

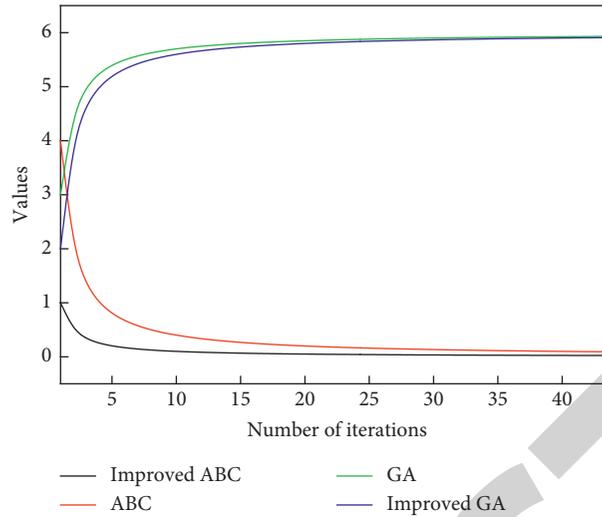


FIGURE 7: Algorithm comparison iteration diagram.

of the consequences caused by different urban rail transit disasters and the relationship between the disaster and other disasters, this paper establishes an evaluation index system for urban rail transit disasters. The results of the disaster itself are measured by the number of casualties and property damage, while the relationship between the disaster and other disasters is measured by the degree of entry, exit, and centrality of the nodes in the network.

When a disastrous event occurs in a system, the directions in which the disaster is likely to propagate can be determined based on the constructed disastrous chain network. If the importance of each propagation direction (i.e., the directed edges in the disastrous chain network) can be evaluated, it is possible to determine which secondary disasters need to be presented first when dealing with disasters. In this paper, we propose a method for evaluating the importance of the directed edges in a disastrous chain network based on a comprehensive evaluation method, combined with evaluation indicators for the destructiveness of complex networks, and rank the importance of the disaster propagation process.

The values of the three indicators corresponding to each edge are calculated separately, as shown in Figure 8. The average path length and connectivity are metrics designed to measure the impact of the removal of that hazard propagation process on the established hazard chain network and should be calculated as the difference between the value of the original network and the value after the removal of that edge. For edges where the difference is zero, it is reassigned to the smallest of the remaining edges under this metric. In this paper, it is assumed that the removed edge is not disconnected, and the length of all paths passing through the removed edge is reassigned to the length of the most anthropological path in the original network.

**4.2. Security Posture Evaluations of Urban Systems.** The construction of the urban multilayer disastrous chain network model enables the evaluation of the safety state of the

urban safety system under a hypothetical disaster scenario. As the sample data in the disaster incident database increases, the evaluation results become more accurate. The urban disaster contribution matrix is processed, and the disastrous event initiation probability matrix can be obtained by comparing each element with its corresponding protagonist element. As some of the hazards have a low probability of occurrence, the probability of propagation deviates from the actual situation in case of insufficient samples but still reflects a certain extent the magnitude of the probability of reciprocal triggering between them. With the establishment of a comprehensive disaster database, the propagation probabilities will gradually approach the actual situation as the sample size increases.

In Figure 9, different levels represent the intensity of dependence; 1–5 are evaluation methods, disaster database construction, evaluation indicators, evaluation quality, and data volume. According to the spatial division of the various functions of the urban system, a multilayered urban rail disaster chain network including a three-dimensional structure of resources is constructed. As each area differs greatly in terms of the type of equipment and facilities, the types of disasters that may occur are not the same. Therefore, the first task in constructing a multilayer network is to clarify the disasters that may occur in each region. Based on the theories and methods of single-hazard risk assessment, scholars at home and abroad have made certain achievements in the study of multihazard risk assessment, but there are still problems such as the difficulty of realizing absolute risk assessment, the choice of comprehensive multihazard methods, and the difficulty of clarifying the interrelationships between hazard types. As shown in Figure 9, the quantitative assessment of multihazard risk relies on the development of quantitative evaluation methods on the one hand and the construction of disaster databases on the other. Therefore, it is still difficult to assess the absolute risk level of a region, i.e., the probability of a certain hazard-bearing body suffering losses within a certain time. For the latter two issues, the authors believe that the key to a comprehensive

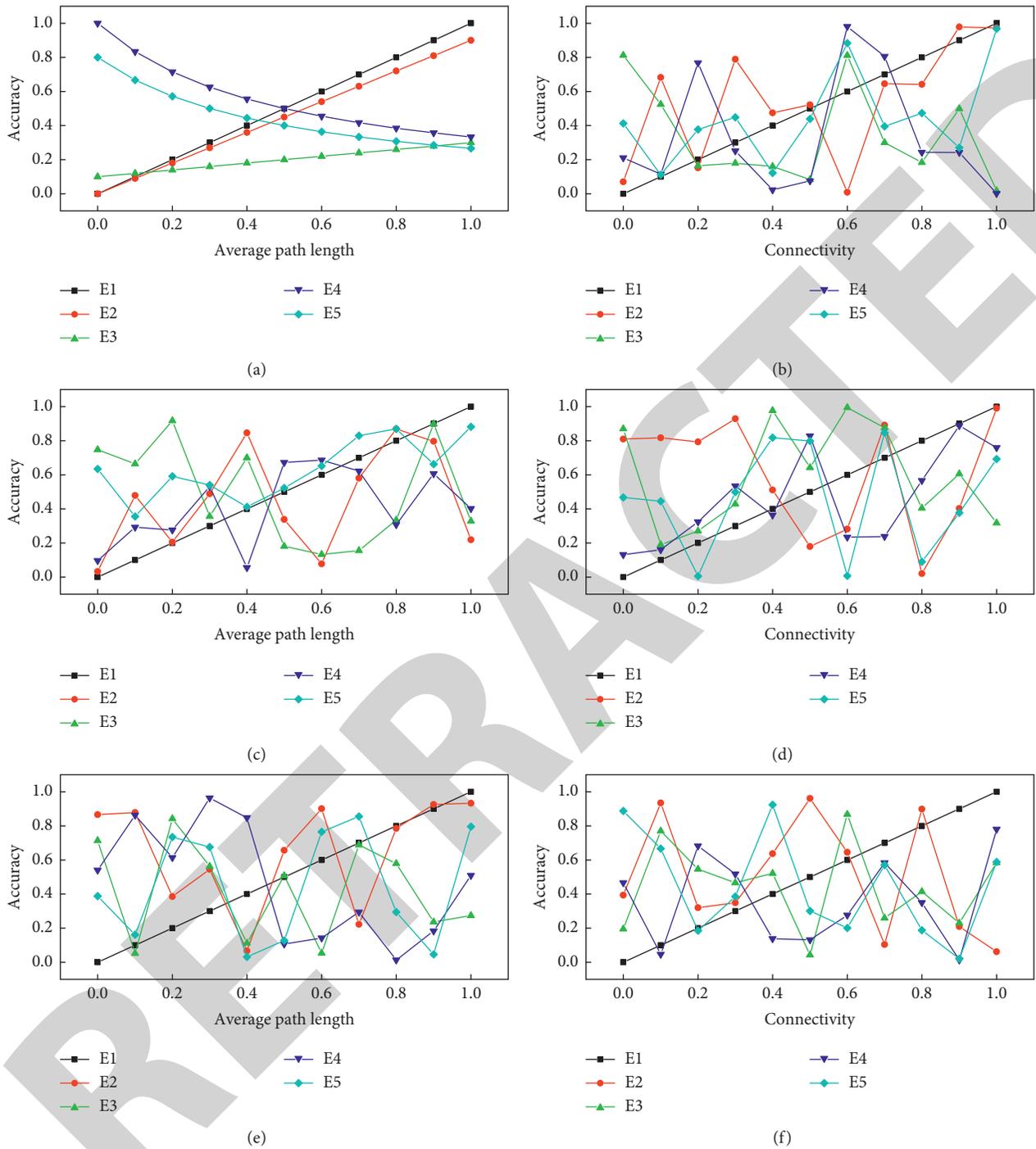


FIGURE 8: Calculated results of key parameters for safety changes in disaster propagation.

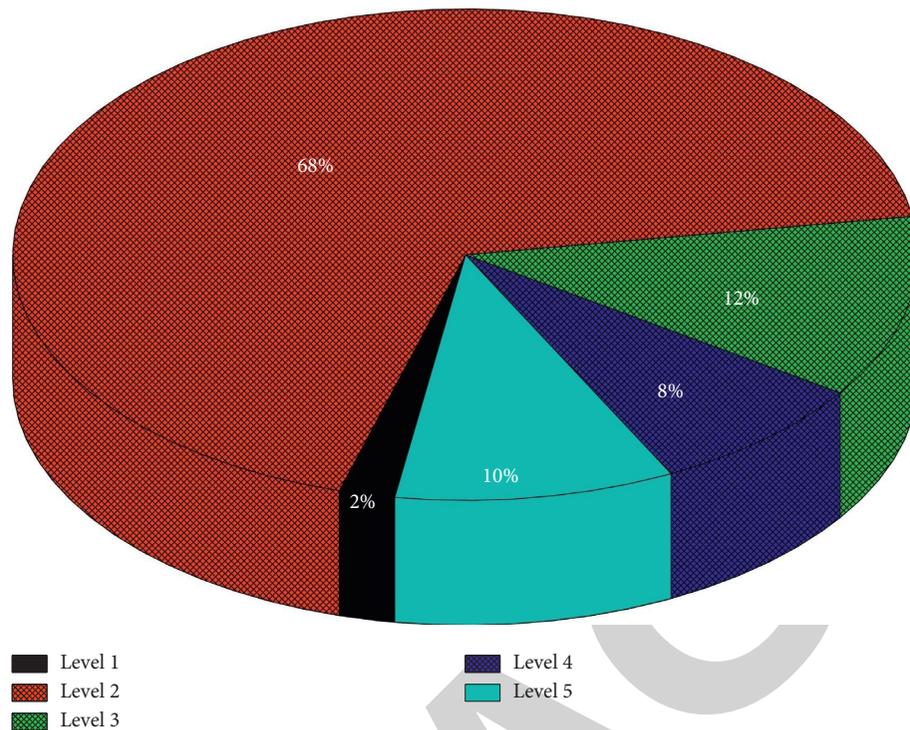


FIGURE 9: Disaster chain network security state change trend affiliation matrix.

multihazard risk assessment is to clarify the interactions between the various hazard types and to reflect them in the multihazard risk assessment methodology.

## 5. Conclusion

Because of the enormous damage caused by urban disasters and the increasing amplification effect of urban disasters with the accelerated urbanization process, this paper first analyzes the city as a specific disaster-bearing body, based on the evolution of the disaster chain and using the system dynamics research method.

The current situation and development trend of urban disaster research at home and abroad were analyzed from three aspects: urban disaster mechanism research, urban disaster prevention, and mitigation technology research, and urban disaster emergency response and management research, and it was concluded that there are still problems of urban disaster research focusing on a single type of disaster, more research on natural disasters, and less research on man-made disasters, etc. It pointed out the urban comprehensive disaster prevention and mitigation system, urban disaster comprehensive risk assessment, nonengineering disaster prevention measures, etc. It is pointed out that a comprehensive urban disaster prevention and mitigation system, comprehensive urban disaster risk assessment, and nonengineering disaster prevention measures are issues worthy of further exploration in urban disaster research. Based on the above analysis, a theoretical discussion on the evolution of urban disaster chains from a microscopic perspective is proposed by applying the system dynamics approach, and the established model is applied to the

comprehensive urban disaster risk assessment from a macroscopic perspective, thus providing a theoretical basis for the construction of integrated urban disaster prevention and mitigation system.

The chain effects of four typical urban hazards are, namely, earthquake hazard chains, flood hazard chains, typhoon hazard chains, and blizzard and low-temperature freezing hazard chains. It is pointed out that urban hazard chains have complex network structure characteristics, and the analysis from the energy perspective shows that the coupling of the excitation energy released by the disaster-causing body and the energy of the disaster-bearing body is the fundamental cause of the hazard chains. The general rules of urban hazard chains are analyzed. The evolution of hazard chains is characterized by the stage of incubation, and from the perspective of temporal effects, they are separated into two different types of evolutionary behavior: continuous and transient effects. Based on the network structure of disaster chains, the mathematical model of disaster chains based on the interaction between parent and child disaster nodes, and considering the temporal effects in the process of disaster evolution, a complex network-based disaster chain mathematical model is established to describe the disaster loss rate and disaster loss degree of each disaster node, based on which a disaster chain breakage mitigation model based on the vulnerability of network nodes and the vulnerability of connecting edges is proposed. When a sudden catastrophe occurs, the road network may be interrupted, affecting the speed of rescue. In this case, it is necessary to quickly establish an emergency coordination rescue mechanism and build a two-layer planning model for emergency coordination, which can speed up emergency coordination rescue

and can better balance the distribution of emergency supplies and route planning.

## 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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