Journal of Engineering Management and Systems Engineering
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# Optimization of Emergency Stockpile Siting: A Review of Models, Influencing Factors, and Future Research Directions

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**Received:** 10-07-2024 **Revised:** 11-20-2024 **Accepted:** 11-28-2024

**Citation:** H. Y. Liu, Z. Wu, and L. N. Yu, "Optimization of emergency stockpile siting: A review of models, influencing factors, and future research directions," *J. Eng. Manag. Syst. Eng.*, vol. 3, no. 4, pp. 226–235, 2024. https://doi.org/10.56578/jemse030404.



**Abstract:** The strategic location of emergency supply depots is critical for enhancing pre-disaster preparedness and post-disaster relief efforts. Given the inherent uncertainties and risks associated with natural and man-made disasters, ensuring the swift and effective delivery of relief materials to affected areas is pivotal for minimizing disaster impacts and safeguarding lives and property. This review synthesizes the current body of research on the siting of emergency stockpiles, providing a comprehensive analysis of the factors influencing site selection. Key factors such as the geographic scope of disaster response, hydrographic conditions, transportation infrastructure, and accessibility to affected populations are examined. Various siting models are evaluated to optimize resource allocation, minimize logistics costs, and improve supply chain responsiveness during emergencies. This review also identifies key challenges within the existing literature, including limitations in model algorithms, disaster stage considerations, optimization criteria, and the degree of stakeholder involvement in decision-making. Notably, while previous research has often focused on isolated factors, this study emphasizes the need for an integrated approach that accounts for dynamic, diversified, intelligent, and human-centered considerations. Dynamic models are essential to adapt to the unpredictable nature of disasters, while diversified approaches are necessary to address the varying needs of different disaster types and affected populations. Intelligent decision-making tools, incorporating data analytics and real-time information, can enhance the efficiency and accuracy of site selection processes. Human-centric models, focusing on the actual needs of disaster-affected communities, are critical for ensuring the effectiveness of relief operations. The review concludes by outlining future research directions, emphasizing the importance of developing adaptable, sustainable, and context-specific siting models. Future investigations should focus on the practical application of emerging technologies, such as big data analytics, artificial intelligence, and remote sensing, to refine siting models and improve their responsiveness in a rapidly changing global landscape. These advancements are expected to contribute to more efficient and cost-effective emergency supply systems, better equipped to address the evolving challenges of global disaster risks.

**Keywords:** Emergency stockpile; Site selection; Optimization models; Logistics; Disaster response; Influencing factors; Intelligent systems; Human-centered design

## 1 Introduction

As societies continue to develop and grow economically, the scope and capacity of human activity increases [1]. At the same time, however, the frequency and severity of natural disasters and public safety incidents have risen, posing a great challenge to emergency management. These events are usually sudden and devastating, requiring emergency services to quickly deliver large amounts of relief supplies to affected areas [2]. How to respond to these events has become a pressing issue globally. In 2023, global economic losses due to natural disasters amounted to US$380 billion, mainly due to strong earthquakes and severe convective storm activity in the United States and Europe. Earthquakes in Turkey and Syria, floods in China, and Hurricane Otis were the costliest events of the year, and these disasters caused massive damage globally, the costs of which often had to be borne by local governments [3]. As shown in Figure 1, the data graph shows the global natural disaster losses as a percentage of GDP from 2010 to 2022, and based on the information in the graph, it can be concluded that the percentage of natural disaster losses is very high, which seriously affects the economic development of the country.

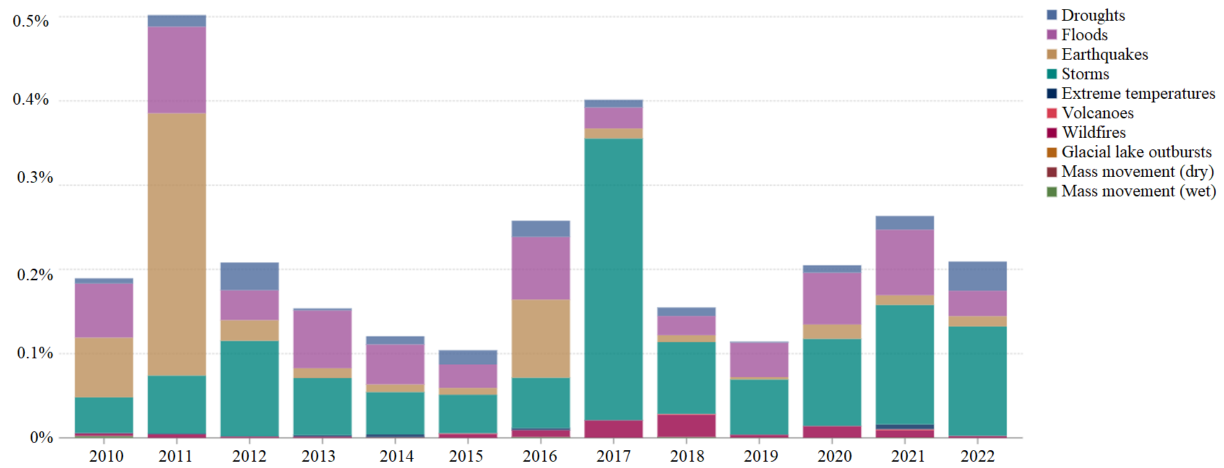


**Figure 1.** Economic losses from natural disasters as a percentage of GDP, 2010-2022

China, for example, has suffered successive serious natural disasters in recent years. In 2021, Zhengzhou, Henan Province, was hit by a historically rare, exceptionally heavy rainstorm, causing serious casualties and property damage; in 2022, the Pearl River Basin experienced large basin floods; and in 2023, the Beijing-Tianjin-Hebei region was hit by another torrential rainfall and flooding, resulting in 5,512,000 people being affected, and the direct economic losses amounting to 165.79 billion yuan. Natural disasters and public emergencies occur frequently and have a huge impact on human society. From the Zhangbei Earthquake in 1998 to the Wenchuan Earthquake in 2008 to the new Crown Pneumonia epidemic in recent years, these events not only have wide-ranging impacts but also serious consequences. Their suddenness and uncertainty have brought about significant negative impacts on the development of the affected areas and, at the same time, exposed problems in the siting process of emergency stockpile depots. In the event of an emergency, the lives of the affected people may be put at risk due to insufficient supply of materials, especially food and drinking water [4]. Therefore, it is crucial to accurately and effectively distribute relief supplies to the affected areas in a timely manner. Scientific siting of emergency supplies storage depots can effectively replenish emergency supplies and minimize the transportation distance for the deployment of supplies needed in disaster areas [5]. The site rescue is even more time-consuming. On-site rescue is a race against time, the transportation efficiency of emergency supplies is directly related to the success or failure of the rescue mission, and is a factor to be considered in the rescue process [6]. It is a factor to be considered during the rescue process.

Effectively preventing and responding to emergencies has become a major challenge for government departments. How to site emergency stockpiles is a major challenge for such emergency management [7]. In response to these problems, the Ministry of Emergency Management (MEM) has called for the improvement of disaster prevention and control capabilities, the establishment of a sound emergency stockpile, and the strengthening of relief in disaster areas, which further promotes the research on the siting system of the emergency stockpile [8]. In order to improve the capacity and level of emergency supplies, the Chinese government has taken a series of measures. For example, according to the 14th Five-Year Plan for Emergency Materials Security, by 2025, China will have built a multi-level emergency materials security system that is unified, hierarchically managed, of appropriate scale, complete in variety, reasonably laid out, multifaceted and coordinated, responsive, intelligent and efficient throughout the entire process. This includes optimizing the structure and layout of the central government's reserves, integrating the central government's various types of emergency materials reserves for major natural disasters and accidents, and unifying planning and management. At the same time, it will also improve the "central-provincial-municipal-county-township" five-level emergency material reserve network, improve the usual rotation of emergency materials and service efficiency, and ensure that emergency materials are available, quickly deployed, and used at critical moments. In addition, in order to ensure the mobilization of emergency supplies, the government will improve the emergency supply network at five levels: central, provincial, city, county and town. In addition, in order to ensure that emergency supplies are mobilized quickly and efficiently, the Chinese government also encourages logistics enterprises, social organizations and volunteers to participate in the "last-mile" distribution of emergency supplies, so as to improve the timeliness and accuracy of the distribution of supplies. At the same time, it is promoting the integration of data on emergency supplies, strengthening the sharing of information on emergency supplies among various types of subjects, including the government, enterprises, and social organizations, and promoting the interconnection of information among multiple subjects, multiple levels, and the entire process.

In the rescue process of these public emergencies, they often face problems such as insufficient supply of materials, inefficient supply, and unfair distribution of materials. In order to solve these problems, it is particularly important to choose a reasonable location for the emergency material reserve center. A reasonable location can significantly improve the efficiency of material supply and service quality. However, the location of an emergency stockpile is a complex process involving several disciplines, including disaster management, logistics management, operations research and management, etc. This requires us to utilize these disciplines in a comprehensive manner. This requires us to comprehensively apply the theories and methods of these disciplines to establish a scientific site selection model and decision-making framework. The purpose of this paper is to introduce the current research status of emergency stockpile siting, summarize the existing theoretical methods, and explore the possible development direction of future research.

In summary, in the face of natural disasters and public emergencies, the establishment of scientific siting of emergency stockpiles is of great significance in reducing disaster losses and protecting people's lives and property.

## 2 Current Status of Research on the Siting of Emergency Stockpiles

As shown in Figure 2, according to the statistics of academic attention to emergency stockpile siting from China Knowledge Network, from 2014 to 2024, the related literature on emergency stockpile siting showed a steady growth trend, and peaked in 2023, which illustrated the gradual increase of research scholars' attention to emergency stockpile siting, and the gradual increase in the amount of literature published.

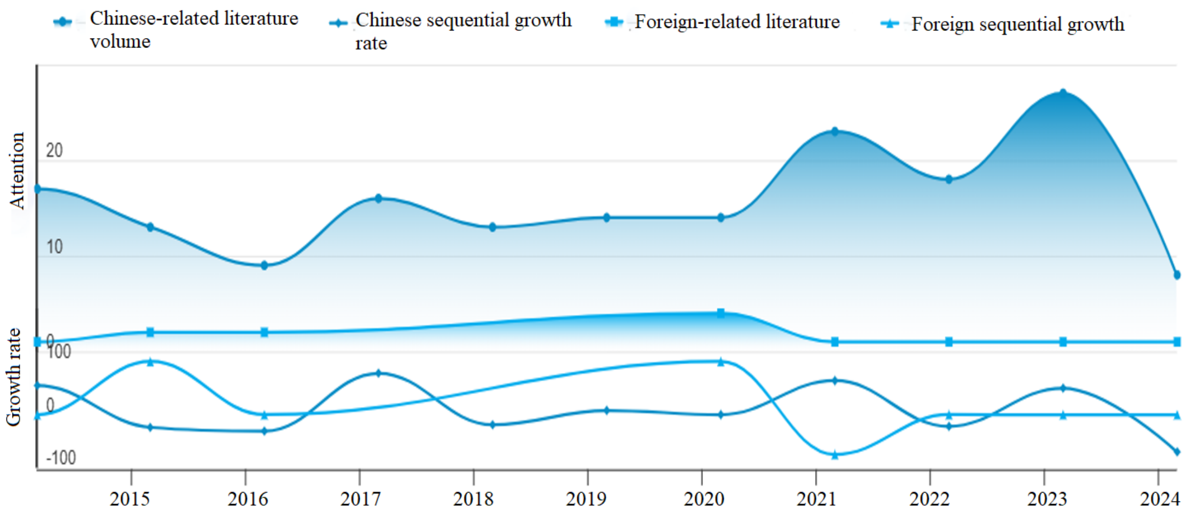


**Figure 2.** Statistical map of academic concerns about the siting of emergency stockpiles

### 2.1 Current Status of Related Theoretical Research

Relevant researchers and scholars have accumulated a great deal of practical experience in the selection of sites for material warehouses and the related aspects of inventory management, material deployment, information technology application, risk control, and transnational cooperation, which provide valuable reference and inspiration for countries in the construction and management of emergency material warehouses.

In the area of research on the siting of emergency supply depots. Exploration in this area can be traced back to the German economist Alfred Weber, who in his 1909 book, The Theory of Industrial Location, first posed the problem of how to determine the location of a material storage site with the aim of minimizing the total distance to the site for all visitors, a problem that was later named the Weber problem or the economist's problem [9]. August Lösch conducted research on the service location problem in trade flows and transportation networks, considering that the circulation of goods between or within regions depends on transportation costs, meaning that industrial location is determined by these costs. He expanded the Weber theory in the fields of international trade and regional economics [10]. Site selection decisions usually need to consider a number of factors such as geographic location, transportation accessibility, distribution of material demand, inventory costs, environmental risks, etc. Therefore, researchers tend to adopt a multi-factor comprehensive evaluation method and establish a multi-objective decision-making model in order to assess the pros and cons of different site selection options more comprehensively. In recent years, with the emphasis on the uncertainty of disaster occurrence and the dynamic changes in the demand for emergency supplies, research has begun to explore the application of dynamic and stochastic planning methods to the siting of emergency supply depots, which perform better in dealing with uncertainty and help to improve the robustness of siting decisions.

Stockpile management, as a core aspect of the emergency stockpile system, involves determining reasonable stock levels, types and quantities of materials, and developing strategies for replenishing and rotating stocks. The purpose of the study is to ensure rapid access to the required materials in emergency situations, while effectively preventing waste and expiration. In related research, emergency material inventory management emphasizes the deep integration with various parts of the supply chain-such as procurement, production, and sales-in order to achieve overall synergistic optimization. By constructing a complex supply chain network model, the interactions between various links are analyzed in depth, so as to develop an optimal inventory control strategy. For example, the use of RFID technology, barcode scanning and other modern technical means to realize real-time monitoring and management of inventory, to ensure the transparency and accuracy of emergency supplies. With the wide application of cloud computing, big data and other advanced technologies in the field of inventory management, through the in-depth analysis and processing of a large amount of data, it is possible to more accurately predict the demand for materials, optimize inventory allocation, reduce inventory costs, and thus significantly improve the efficiency and accuracy of inventory management.

Although research in the field of emergency material reserves started relatively late, it has progressed rapidly, and rich research achievements have been made to date. In the research on the siting of emergency material depots, scholars have proposed a variety of models and methods to cope with the problem, as it is a complex topic involving multiple disciplines. These include the site selection decision model based on the hierarchical analysis method [11]. The site selection decision model utilizing the TOPSIS entropy weighting method [12], spatial analysis model based on GIS technology [13] and a site optimization model based on multi-objective planning [14]. In addition, some scholars combine the specific cases and the specific decision-making models with the spatial analysis model by GIS technology. In addition, some scholars have conducted in-depth case analysis and empirical research on the siting of emergency supplies warehouses by combining specific cases and actual situations. They have analyzed the unique needs and characteristics of emergency supplies warehouse site selection for different types of emergencies, such as earthquakes, floods, etc., and proposed corresponding site selection strategies and optimization means. At the same time, the study also emphasizes the development of policies and standards for the siting of emergency supply depots. To this end, various countries have issued a series of relevant policies and standards, covering aspects such as site selection principles, construction standards, and management norms, providing guidance for the scientific construction and efficient management of emergency material reserves.

In the context of frequent disasters, research on emergency material inventory management is particularly significant. Whether it is natural disasters or sudden public health events, ensuring an adequate supply of emergency materials is crucial for the smooth conduct of rescue operations. The scope of research in this field is broad and deep, primarily focusing on the following aspects: model optimization, demand forecasting, risk control, and policy and regulation analysis. In the area of model optimization, researchers have explored optimization methods in a variety of scenarios, such as incomplete demand information, government-corporate cooperation, centralized inventory management, replenishment strategies, and reserve quantity decisions. In the area of demand forecasting, researchers have conducted forecasting studies for typhoons, earthquakes, floods, and other types of disasters, and have used a variety of models to solve them. In the area of risk management, the shortage risk of inventory materials has become the focus of scholars' attention. In terms of policy and regulatory research, research results on the informationization, intelligence and digital transformation of emergency stockpiles have increased significantly since 2012. For example, Sun et al. [15] explored the digital transformation of emergency stockpiles and put forward a proposal to strengthen the modernized governance system of national emergency stockpiles. Xue and Wang [16] emphasized that in order to build a perfect emergency material security system, it is necessary to effectively integrate the three links of production, stockpiling and deployment.

In the field of material distribution and transportation in response to emergencies, along with the rapid development of Internet technology, researchers are actively integrating advanced technologies into emergency material dispatch research. By using high-tech means such as big data and cloud computing, they are conducting accurate forecasts of material demand and in-depth analysis of dispatching decisions, aiming to enhance the scientific nature and efficiency of dispatching activities. In addition, by utilizing IoT technology, the researchers were able to realize real-time monitoring and tracking of material information to ensure that the materials could be quickly and accurately transported to the disaster areas. Further, researchers are also exploring the application of cutting-edge technologies, such as artificial intelligence and machine learning, to advance the intelligent process of emergency material dispatching, optimize dispatching strategy, improve operational efficiency, and reduce risks in the dispatching process. These research results not only extend the scope of emergency material dispatching research from basic model building to strategy optimization, efficiency enhancement, risk management, and other dimensions, but also provide solid technical support and a theoretical basis for actual emergency management.

From the point of view of existing research, studies related to emergency stockpile siting mainly focus on key areas such as solving siting models, demand forecasting, inventory management, and material distribution. In the research progress of emergency material depot siting, most of the early research focuses on single-objective decision-making or simple bi-objective decision-making problems, while over time, the research gradually shifts to consider the emergency reserve depot siting problem under multi-objective decision-making, and these research projects have continued to make progress in the model building, the selection of solution methods, and the optimization of the methods. However, there is still room for further research in some aspects: first, the research on combining emergency stockpile siting with inventory management and material deployment is not sufficient; second, constructing an effective multi-objective optimization model and properly dealing with the balance between objectives usually requires the use of advanced methods such as improved genetic algorithms, which are not yet sufficiently applied in the field of emergency stockpile siting; third, there are significant differences in social and economic factors, types of natural disasters, and needs in different regions, and the generalizability of the existing research results needs to be verified.

### 2.2 Emergency Stockpile Site Selection Model

**Table 1.** Emergency stockpile siting model

| Reference | Algorithmic Model | Disaster Stage | Optimization Indicators | Attention to Persons Affected by the Disaster | Message Status |
|---|---|---|---|---|---|
| Wu et al. [17] | P-center theory | pre-disaster | Number of reserve bases | no | static (as in electrostatic force) |
| Pang et al. [18] | Improvement of TOPSIS | pre-disaster | Indicator evaluation methodology | no | static (as in electrostatic force) |
| Ji et al. [19] | Gray system theory | pre-disaster | Multi-attribute weighting | no | static (as in electrostatic force) |
| Sari et al. [20] | Hierarchical analysis and fuzzy TOPSIS | pre-disaster | Time | yes | static (as in electrostatic force) |
| Zhang and Huang [21] | Data envelopment method (computing) | pre-disaster | Maximum coverage, timeliness, and storage | no | static (as in electrostatic force) |
| Feng et al. [22] | Multi-Criteria Decision-Making | pre-disaster | Indicator Weights, Evaluation Indicators | yes | static (as in electrostatic force) |
| Seraji et al. [23] | Heuristic algorithm | pre-disaster | Operations, distributional inequities and grievance costs | yes | static (as in electrostatic force) |
| Zhang et al. [24] | Multilevel siting model on the topic of mobile emergency response | pre-disaster | Safety stock costs | no | dynamic (science) |
| Li et al. [25] | Basic efficacy factor method and unit cost utility method | pre-disaster | Balancing time, cost and equity | no | dynamic (science) |
| Liu et al. [26] | Novel fuzzy multicriteria decision-making approach | pre-disaster | Minimizing the expected cost of providing materials | no | static (as in electrostatic force) |
| Zeng et al. [27] | Novel weighted Mahalanobis distance-gray relational analysis-TOPSIS | pre-disaster | Overall cost, unsatisfied demand | no | static (as in electrostatic force) |
| Condeixa et al. [28] | Conditional value-at-risk metrics | pre-disaster | Minimum relief supply shortfall | yes | static (as in electrostatic force) |
| Nyimbili and Erden [29] | Fuzzy hierarchical analysis (FHA) | pre-disaster | Density of hazardous materials facilities, high population density and proximity to major roadways | no | static (as in electrostatic force) |

Site selection of emergency supplies is the basis for guaranteeing the supply of all kinds of materials required for rescue work, and reasonable site selection can effectively improve the supply efficiency of emergency supplies. Researchers and scholars have carried out a lot of research on the siting of emergency supplies and have developed a variety of models and algorithms to solve this problem. In the study of the emergency relief supplies siting problem, it is necessary to use the appropriate model algorithms for solving it. In recent years, the research on the emergency supplies reserve siting has continued to increase, and a variety of different algorithm models have also appeared, optimizing different indicators. These models and algorithms target different optimization metrics, such as cost, response time, coverage, etc., including evaluation methods, mathematical algorithms, and heuristic algorithms. In practical applications, both single algorithms and methods that combine different algorithms to compensate for their respective shortcomings are used. In practical applications, the location of emergency stockpile depots also needs to take into account the effects of cost, natural conditions, and the social environment. The Chinese government has also issued relevant policies to optimize the layout of emergency material stockpiles, promote local governments at all levels to optimize the spatial layout of emergency material stockpiles in their administrative areas in the light of the characteristics of disasters and accidents in their regions, and strengthen the social synergy of emergency material stockpiles. With the depth of research and the development of technology, more methods and models have been developed to improve the efficiency and effectiveness of emergency material reserve depot siting. Specific analyses are shown in Table 1.

From Table 1 it can be observed that the hierarchical analysis method has been widely used in numerous studies. However, in the research field of emergency stockpile center siting, the hierarchical analysis method, as an assessment tool, has the limitation that the calculation process is complicated and prone to producing inconsistent results. Some studies have explored the emergency supplies siting model by adopting a modified hierarchical analysis method. For example, Zhang and Huang [21] used data envelopment analysis to evaluate the reasonableness of different siting alternatives for the new centralized stockpile. In addition, researchers have designed various computer programs to optimize the siting algorithms, including genetic algorithms, basic utility coefficient methods, unit cost utility methods, heuristic algorithms, hierarchical cluster analysis-improved center of gravity methods, non-dominated sequential genetic algorithms with elite strategy (NSGA-II), multi-objective decision-making methods, immune nonlinear algorithms, particle swarm optimization algorithms, two-stage bending decomposition-based stochastic planning methods, multi-objective mixed integer planning algorithms, etc. These algorithms can be broadly categorized into three main groups: evaluation methods, mathematical algorithms, and heuristic algorithms. Hierarchical analysis and data envelopment analysis belong to evaluation methods, while hierarchical cluster analysis, multi-objective planning algorithms, Dijkstra's algorithm, etc. belong to mathematical algorithms, and genetic algorithms, particle swarm optimization algorithms, etc. belong to heuristic algorithms. Evaluation methods were the more used methods in the early days, but due to their strong subjectivity, researchers later shifted more to the use of mathematical algorithms and heuristic algorithms. With the advent of the big data era, the development of algorithms has been further integrated with big data and intelligent technology, but most of the current research uses a single algorithm to solve the problem and has not considered algorithms that combine different algorithms to make up for their respective shortcomings. Many models are highly dependent on accurate and comprehensive data input. The difficulty and incompleteness of data collection can affect the accuracy of the models. Most existing models have not fully adapted to rapidly changing environments, such as the immediate demand changes following natural disasters. When addressing multiple objectives (cost, time, coverage, etc.), there is still a need for improvement in finding the optimal balance. In response to these issues, future research can develop new algorithmic models to integrate and process data from more sources and types, improving the accuracy and robustness of the models; design models that can quickly respond to environmental changes, such as using real-time data analysis and forecasting technologies; and research new multi-objective optimization techniques to better balance different objectives and find the optimal solution.

### 2.3 Factors Affecting the Siting of Emergency Supplies

Selecting the location of an emergency stockpile is a complex decision-making process involving many parties. In order to achieve systematic and rational planning, various factors affecting site selection must be considered in depth. Researchers have explored the factors affecting the location of reserve depots from multiple dimensions, including population, economy, environment, and transportation, as shown in Table 2.

By combing and summarizing the literature, it can be seen that, in the study of siting emergency stockpile depots, Table 2 outlines nine key factors to be considered in siting emergency stockpile bases, each of which is critical to ensuring rescue efficiency and effectiveness. The rescue target range emphasizes that the rescue base should cover a wide area and follow the proximity response principle. Disaster response range focuses on meeting the rescue needs of major emergency disasters, even if the probability of these events is extremely low. Transportation accessibility points out that rescue bases should be located in areas with well-developed transportation networks to ensure rapid transportation of supplies. Hydrography requires that relief supplies be stored in a suitable environment to maintain their quality and availability. Rescue transportation distance is the main influencing factor, which is inversely proportional to the number of rescue bases and affects rescue efficiency. Rescue transportation mode selects the appropriate transportation mode, such as air, rail, or road transportation, according to the transportation distance and demand. Regional balance focuses on the rescue needs of economically developed and geologically disaster-prone areas. The scope of material reserve is affected by the shelf life of materials and local reserve situations to ensure that the initial period can meet the needs of the disaster area. The number of bases constructed, on the other hand, should be in reasonable proportion to the number of national base facilities to optimize resource allocation. Together, these factors constitute a comprehensive framework of considerations to guide the scientific siting of emergency reserve bases, with a view to improving the efficiency and effectiveness of rescue operations.

**Table 2.** Factors affecting the siting of emergency supplies and their analysis

| Serial Number | Site Selection Influences | Analysis of Influencing Factors |
|---|---|---|
| 1 | Rescue target range | Covering a vast continental area of a country, emergency relief follows the principle of “regional management, proximity response”. |
| 2 | Scope of disaster response | For very low probability and national level cannot meet the needs of major emergency disaster relief. Materials are used with the lowest probability from the most recent. |
| 3 | Transportation accessibility | Surrounding transportation roads are connected to the surrounding areas and the outside world, with a large number of transportation routes, high quality of transportation, a large number of main roads, and high road capacity. |
| 4 | Hydrographic condition | Rescue supplies usually need to be stored for long periods of time in a clean, dry, open area with good air circulation. |
| 5 | Rescue transportation distance | Main influencing factors. There is an inverse relationship between the number of national emergency stockpile bases and the maximum relief transportation distance. |
| 6 | Rescue traffic patterns | There is an inherent relationship between the mode of transportation and the distance traveled. Air transport: time-critical, small supply; rail transport: good security, speed, large capacity; road transport: short distances, flexibility, moderate capacity. |
| 7 | Regional balance | Focus on economically developed areas and areas prone to geologic hazards. |
| 8 | Scope of material reserves | Mainly affected by the shelf life of the materials, it can be used in conjunction with local stockpiles to meet the demand for emergency supplies in disaster areas at the beginning of a disaster emergency. |
| 9 | Number of bases constructed | The ratio of the number of national emergency stockpile bases to the number of national base facilities should be reasonable. |

To summarize, the siting of emergency stockpiles, whether at the central, provincial, municipal, or county level, requires consideration of key factors such as demographics, economics, cost, transportation, and the natural environment. The core objective is to ensure that the materials can be distributed quickly and effectively to the affected areas under limited material resources and tight time constraints. Although existing research has focused mainly on certain specific influencing factors in the process of emergency material storage and transportation, only a comprehensive and integrated analysis of the various factors can lead to a more scientific and reasonable site selection plan. Existing research is moving towards data-driven methods, utilizing big data and artificial intelligence to analyze and predict demand models. Additionally, multi-criteria decision analysis is being used to balance multiple objectives such as cost, time, and coverage. Moreover, the integration of environmental and social impact assessments ensures the sustainability and social acceptability of site selection decisions. Future advancements can focus on improving the quality of site selection decisions by addressing enhancements in supply chain management, consideration of policy and regulatory factors, strengthening risk and vulnerability analysis, enhancing community engagement and communication, integrating technology, and the use of simulation and scenario analysis.

## 3 Challenges to the Siting of Emergency Stockpiles

The siting of emergency stockpiles is a complex decision-making process involving multiple factors, which requires decision-makers to deal with the uncertainty of demand and a dynamically changing environment while taking into account a number of dimensions, such as cost, efficiency, response time, and environmental impact. In practice, this means that it is necessary to anticipate and prepare for a variety of emergencies that may occur in the future, which may include natural disasters, public health events, or other emergencies. Because of the unpredictable nature of the location, timing, and magnitude of these events, siting models need to be able to flexibly adapt to these changes to ensure a rapid and effective response in all circumstances.

At the same time, siting decisions also need to balance multiple objectives, such as minimizing cost, minimizing emergency response time, and maximizing coverage, which may conflict with each other and need to be coordinated through complex multi-objective optimization models. In addition, factors such as environment, demand, service cost, and efficiency change over time, requiring that siting decisions be adaptable to these dynamic changes, which may require adjustments over multiple time periods.

In solving these optimization problems, traditional exact algorithms often have difficulty in giving solutions within a reasonable time due to their computational complexity and therefore need to rely on intelligent optimization algorithms to find near-optimal solutions. These algorithms are able to provide effective solutions within limited computational time and help decision-makers to make the best choices under complex real-world conditions.

Environmental and social impacts are also important factors that must be taken into account in site selection. The construction of material warehouses may have an impact on the local economy, transportation, and ecological environment, so these factors need to be taken into account comprehensively in planning in order to achieve optimal allocation of resources and sustainable environmental development.

In addition, inventory management at grassroots emergency stockpile points is also a challenge, as there are difficulties in managing the wide variety of materials and large stockpiles, making it easy for materials to be wasted or under-supplied. At the same time, in the face of emergencies, the inventory of materials at grassroots stockpile points is often difficult to meet demand, and there is a lack of effective stockpile plans and response measures, which affects the effectiveness and efficiency of rescue and response efforts.

Finally, the lack of a scientific basis for site selection is also a problem. At present, the location of emergency stockpile sites at the grassroots level relies mainly on government planning and enterprise volunteering, with a lack of scientific and comprehensive assessment and analysis, which has led to a lack of rigor and precision in the basis for site selection. Therefore, there is a need to develop and apply more scientific methods to guide the selection of emergency stockpile sites in order to improve their efficiency and effectiveness.

## 4 Conclusions

The siting of emergency stockpiles plays a crucial role in responding to natural disasters and public safety crises. As societal progress and economic development continue, the frequency and intensity of such events have escalated, posing significant challenges to emergency management systems. The unpredictability and severity of these emergencies necessitate the rapid and efficient delivery of relief supplies, making effective response strategies an urgent global priority.

Existing research on emergency stockpile siting has been systematically reviewed, revealing the complexity of this decision-making process. It is clear that site selection must consider a wide range of factors, including transportation logistics, hydrographic conditions, regional balance, and the scope of disaster response. Various models and methodologies have been proposed to address these challenges, including the integration of algorithms such as hierarchical analysis and binary mixed ordered weighting methods, leading to advancements in model development and optimization techniques.

Research in areas such as inventory management, material deployment, information technology application, risk control, and transnational cooperation has contributed significantly to the practical understanding of emergency stockpile siting. These studies offer valuable insights for the development of efficient, reliable emergency supply systems, with notable progress being made in countries such as China, where research in this area has accelerated in recent years.

The application of mathematical and heuristic algorithms has gained prominence in the field, with recent trends indicating the use of hybrid models to mitigate the limitations of individual approaches. These models enable precise calculations for determining optimal locations for stockpiles, ensuring quick and cost-effective relief delivery. By optimizing resource allocation and reducing logistics costs, such models enhance the flexibility of supply chains during emergencies, providing data-supported decision-making tools for policymakers and fostering collaboration among rescue agencies. Furthermore, the integration of advanced technologies in these models improves decision-making efficiency, supporting the development of robust and sustainable emergency response systems.

A comprehensive framework for site selection is presented, encompassing factors such as the scope of rescue operations, transportation ease, and environmental considerations. This holistic approach ensures that site selection decisions are based on a thorough understanding of the needs and constraints, enabling the reduction of transportation and storage costs while improving budget efficiency. It also helps identify potential supply chain vulnerabilities and mitigates risks by enhancing the resilience of the system.

However, several challenges remain in the field, including the need for effective multi-objective balancing, adaptation to dynamic environments, consideration of social and environmental impacts, and the lack of standardized methodologies for site selection. Furthermore, issues related to grassroots stockpile management and the integration of scientific approaches in site selection need to be addressed in future research.

In conclusion, while significant progress has been made, further refinement of site selection models, particularly in integrating emerging technologies and addressing dynamic challenges, will be essential for improving the effectiveness and efficiency of emergency stockpile systems.

## 5 Future Directions

The future development of emergency stockpile siting will focus on creating a more scientific, systematic, and intelligent emergency supply protection system. This system aims to enhance material management and response capabilities through the optimization of reserve networks, improved deployment efficiency, and stronger technological support. As information technology continues to advance, future stockpiling will increasingly rely on technologies such as big data, cloud computing, and artificial intelligence to enhance transparency and responsiveness in supply management.

A key future direction is strengthening the coordination between central and local authorities, ensuring a seamless integration of government and social reserves. This includes optimizing existing resources and strategically locating new depots in areas with high population density, elevated disaster risks, and remote or hard-to-reach regions.

In addition, social synergy will become a priority, encouraging public participation in material stockpiling and guiding household emergency preparedness through policy measures. This approach will contribute to a more diversified and flexible material security network, improving overall societal emergency response capabilities.

To enhance decision-making support for emergency supplies, the integration of the Internet of Things (IoT), big data, and cloud computing will facilitate real-time tracking, monitoring, and dynamic control of emergency stockpiles. Leveraging artificial intelligence and data analytics will improve the accuracy of demand forecasting, optimize supply routes, and better match supply with demand.

Finally, upgrading information technology infrastructure for emergency supply systems will be critical. The automation, networking, and digitization of storage and logistics facilities—such as stockpiles and distribution centers—will enhance the efficiency and intelligence of emergency supply management. These advancements will ensure that future stockpile siting is more efficient, flexible, and responsive, better equipping systems to handle a wide range of emergencies.

By exploring these future research directions, significant progress can be made in improving disaster response speed, reducing costs, strengthening supply chain resilience, and driving technological innovation. These efforts will contribute to the development of more efficient, economical, and sustainable emergency material management systems, capable of addressing the growing and evolving global risks.

**Funding**

This work was supported by the Guangdong Planning Office of Philosophy and Social Science (Grant No.: GD24CGL37).

**Data Availability**

Not applicable.

**Conflicts of Interest**

The authors declare no conflict of interest.

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