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How Does Network Media Affect the Efficiency of Emergency Response During Natural Disaster Process?

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Review Article

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Abstract

This paper delves into the influence of network media on the efficacy of emergency response during natural disasters. Given the frequent occurrence of disasters that pose significant risks to urban areas, effective emergency response mechanisms are paramount. Leveraging the Data Envelopment Analysis (DEA) model, this study assesses disaster response efficiency by analyzing network information. It explores the distinct characteristics of disaster response across different types of natural disasters and their various occurrence stages. To this end, three emblematic disasters are chosen for empirical analysis: the 2021 Zhengzhou heavy rainstorm, the 2022 Super Typhoon Chaba, and the 2022 Luding earthquake. Our findings reveal disparities in response efficiency among these disaster types, with Zhengzhou's rainstorm response demonstrating the highest efficiency, followed by the Super Typhoon Chaba, and the Luding earthquake yielding the lowest efficiency. Furthermore, this study meticulously discusses the pivotal factors that shape response efficiency, encompassing government decision-making, emergency rescue operations, and social assistance. By pinpointing optimal response strategies tailored to distinct disaster stages, this paper underscores its contribution toward augmenting disaster response efficiency and fostering urban safety and disaster preparedness.

Network media refers to the media corresponding to traditional media, supported by digital compression and wireless network technology, and using its characteristics of large capacity, real-time, interactivity and diversified publishing subjects, which can cross geographical boundaries and finally achieve globalization.[1] With the continuous progress of information technology, network media information plays an important role in the process of disaster occurrence.[1,2] On the one hand, the popularization of informatization and big data has improved public participation and provided convenient efficiency for disaster analysis and response, and the informatization methods represented by network media have gradually become the basis for measuring the behavioral characteristics of public disasters at different stages and are important tools for government, organizations, and the public to coordinate governance.[3] This phenomenon is particularly evident in the handling of emergencies, such as the disappearance of MH370 in 2014, the super typhoon "Likima" in 2019, the COVID-19 that began in 2019, and the Haiti earthquake in 2021. These events quickly became hot topics in society after their outbreaks. Network media platforms like X (formerly known as Twitter) and Weibo even became the earliest channels for many to receive updates on these emergencies. On the other hand, network media can also cause some negative effects. For example, during a disaster, a large amount of false information may appear on these platforms, misleading the public and interfering with emergency response work. Additionally, information on network media can trigger social panic and affect social stability.[4]

Therefore, in the context of frequent disaster risks, the popularization of information technologies such as the Internet and big data holds significant analytical and research value for disaster studies, disaster response, and post-disaster reconstruction. These technologies can directly extract disaster information from public opinion, assess disaster losses, and help form early warning mechanisms based on public opinion,[5,6] response, and resilience mechanisms.[6,7] During a disaster, the large influx of diverse relief materials, personnel, and information can lead to communication imbalances. This imbalance, along with the waste of personnel and resources, greatly affects the efficiency of disaster response. Therefore, improving the coordination among multiple stakeholders, ensuring orderly communication and integration during different phases of disaster relief, and achieving efficient disaster rescue operations are essential.[8] This article mainly offers three contributions. First, this paper innovatively uses the Data Envelopment Analysis (DEA) model to evaluate the efficiency of natural disaster emergency response through network media information, offering a new perspective and method for disaster management. Second, it subdivides the emergency response process into outbreak, duration, and subsidence periods, analyzing the efficiency of each stage and revealing response characteristics across different disaster types and stages. Finally, it deeply discusses the factors affecting response efficiency from the perspectives of government decision-making, emergency rescue, and social assistance, providing theoretical support and practical guidance for enhancing capabilities.

The rest of the paper is organized as follows. Section 2 reviews key disaster response research and efficiency methods. Section 3 outlines three disasters studied, data sources, and DEA-based assessment models. Section 4 computes and analyzes disaster response efficiency across cycles and stages. Section 5 examines efficiency factors. Section 6 summarizes main conclusions.

Literature Review

Research on the Application of Network Media in Disasters

The research on disasters by scholars has developed with the advancement of the media[9], and the analysis of network media reports has always been the theme of disaster management,[10–12] reflecting the socioeconomic situation of disaster occurrence, and is most likely to affect disaster-related policies and practices.[13,14] In recent years, network media has evolved from mere information collection tools into essential disaster management tools.[15,16] They serve multiple functions including disaster response, real-time information dissemination, and early warning. Numerous scholars have discussed the application of X (formerly known as Twitter) and other network media in various types of natural disasters.[17] They have summarized their roles during and after disasters, providing timely information for emergency responses and enabling both government agencies and the public to participate in disaster response efforts. Previous studies focused on the following aspects:

1) Differences in communication on network media during disasters. Influentials and followers adopted different communicative functions on network media during the disaster. Influentials participated in information exchange and support exchange, whereas followers participated in opinion expression and emotional coping. Influentials and followers also adopted specific frames and styles to achieve these communicative functions.[18] Some scholars also recognized that the disaster stressor may be a risk factor that amplifies the deleterious impact of network media use on depression. Excess exposure to disaster on network media can trigger negative effects, which in turn may contribute to mental health problems. Future interventions to improve mental health should consider elements of both disaster stressors and negative affect.[19]
2) Communication and trust on network media in post-disaster reconstruction. To enhance post-disaster reconstruction efforts, it is crucial to learn how to effectively communicate with audiences on network media and gain their trust. Some studies have found that improving disaster communication through network media, including dedicated staff and resources, assessments, symmetry, and the use of ethical communications, can better quell rumors or misinformation during a disaster.[20] A lack of trust in the information exchanged through network media can significantly hinder decision-making by community members and emergency services during disasters. Therefore, the use of network media in disaster management, information collection, and quasi-news verification is related to trust monitoring and requires a verification process that highlights content and sources to determine the role of power and responsibility in post-disaster reconstruction.[21,22] These also indicate the need to incorporate information generated by users from network media sources into disaster response efforts.
3) Study on Network Media During Disasters in China. Initially, Chinese scholars' research delved into disaster attention and response by quantifying the information disseminated through traditional media avenues—notably newspapers.[23] With the development of network media, scholars have found that it is crucial to make full use of network media as an important consulting platform in natural disasters. For network media, the research of Chinese scholars is mainly based on Weibo and big social data[24] for a disaster analysis or Baidu index for different disasters and comparative research on social responses.[25] With the advent of the network media era, there has been a gradual integration between traditional media and network media. Relevant scholars analyzed disaster information according to the characteristics of the network media era and believed that the government's ability to disseminate disaster information and the ability to control crises have been significantly improved.[26] The gradual maturity of the development of network media and social networks has promoted the gradual establishment of information systems using information technology, and in the increasingly severe natural disaster situation, the top-level design of information management systems using clearer and more scientific means for disaster protection has been gradually established. China's disaster relief adopts a government-led top-down disaster relief model, which has highlighted its advantages while improving its pre-disaster prevention and post-disaster recovery capabilities.[27]

In recent years, the term "resilience" has appeared more frequently in network media.[28] In the field of disaster management, although the importance of resilience and interdisciplinary research is increasing, its implementation and evaluation are still not fully grasped. Network media, as an important part of disaster management activities,[29] not only plays a role in information transmission but also carries the societal value of resilience. Studies have shown that studying the role of information means, including the media, in disaster recovery can help promote social construction[30]. The research on disasters by network media represented by network media can promote academic research on resilience, and this new research field can better promote the research of disaster resilience, help to find the common theme of the gap between theory and practice, and lay the foundation for innovative disaster research mechanisms.

Research on Emergency Response to Disasters

Emergency response was first proposed at the 2005 International Disaster Reduction Conference and then gradually became the focus of scholars. Disaster response is a response system composed of government, social organizations, and multi-agents of citizens, which emphasizes the coordinated interaction and resource sharing of multiple entities in the disaster relief process.[31] Efficiency reflects the allocation of resources and the effect of interaction. Only rationally allocating resources and maximizing the use of input factors can meet the efficient operation of society and improve the level of disaster management.[32,33] The research on natural disaster response efficiency is still in its infancy, and the research results are relatively lacking. In terms of disaster response, scholars focus on the research of disaster development trends and disasters response capabilities.

1) Study on the development trend of disasters. After the disaster, different organizations gradually participate in the rescue and disaster recovery operations, and the multi-subjects start to become an important part of the disaster response. Previous studies showed that the participation of government, social organizations, and individuals constitutes a response network in disasters and promotes inter-agency through the design of information systems.[34–36] In addition, for different types of natural disasters such as earthquakes, geological disasters, landslides, typhoons, and other weather, Chinese scholars explored and summarized their temporal and spatial distribution rules, providing an important basis for disaster response and recovery.[37] With the deepening of disaster response research, some scholars studied the characteristics of community disaster response,[38] supply and demand capacity,[39] and resource utilization that relied on the community's disaster response,[40] and summarized the strengths and weaknesses of communities in disaster response.[38]

2) Emergency response capabilities. Disaster response is related to resilience and vulnerability, which is a phased dynamic response process. Disaster response research has evolved along with media advances, and network media reports reflect the socioeconomic conditions of disasters or related policies and practices. Some scholars use newspapers, journals, and other information to explore the response process and characteristics of social organizations and victims.[41,42] The media participation during the disaster and after the disaster was discussed and studied by many scholars in China. Relevant scholars believe that the government's disaster information dissemination ability and crisis control ability has been significantly improved in the network media era.[43,44] The gradual maturity of network media has promoted the establishment of information management systems in various places and laid the foundation for innovative disaster research mechanisms.[32,45]

In the event of a disaster, the time and reasons for the outbreak of the incident are complex and diverse. During the outbreak of the disaster, the influx of various relief materials, relief personnel, and disaster relief information has caused an unbalanced state of information communication, which has greatly affected the efficiency of natural disaster response. It is essential to improve the synergy of multi-subjects after disasters to achieve efficient linkage of disaster relief. In this paper, the relative efficiency refers to how to achieve the maximum synergy of government decision-making, emergency rescue, and social assistance for different types and scales of disaster events without the public response. This paper studies the response efficiency of different natural disasters, provides the response measures for different stages, and guides the response efficiency of multiple subjects, which has strong practical significance for the disaster prevention and mitigation.

Methods and Materials

Overview of the Study Cases and Data Source

Natural disasters refer to natural phenomena that cause harm to human existence or damage the living environment of humans. Due to the different formation times, occurrence process, and scope of impact, different natural disasters show different characteristics. Different types of disaster have different impacts, durations, and losses, and there are differences in post-disaster response characteristics and response efficiencies. In this paper, the Luding earthquake in 2022, the Zhengzhou heavy rainstorm disaster in 2021, and the Super Typhoon Chaba in 2022 are selected as study cases (Table 1). These disasters are typical and representative, clearly reflecting the characteristics of earthquakes, heavy rainstorms, and typhoons.

Baidu is the world's largest Chinese search site and the most comprehensive website with Chinese information. In this article, we use disaster information from network media on Baidu News to

Table 1. Basic situation of three types of natural disasters

Type (year)	Number of casualties	Direct economic loss	Scope of influence	Infrastructure situation
Zhengzhou Heavy Rainstorm (2021)	398 (dead) 50 (missing)	120 billion CNY	• Heavy precipitation was mainly concentrated in the western, northern and central regions, affecting 10 cities. • It affected 150 counties (cities and districts) in 16 cities in Henan Province. • 14.786 million people were affected.	• Three-day rainfall totaled 617.1mm. • The metro network suspended. • 376 000 people evacuated; 256 000 urgently resettled in Henan. • Crops affected: 215.2 thousand hectares. • Housing damage: 18 000 collapsed, 57 600 severely damaged, 164 400 and 135 400 generally damaged, totaling 618 800 affected.
Super Typhoon Chaba (2022)	25 (dead) 1 (missing)	3.11 billion CNY	• Heavy rainfall or extremely heavy rainfall occurred in 5 provinces, causing power outages in a certain area. • A total of 1.862 million people were affected. • Some trains between Guangzhou and Haikou were suspended. • Many flights were cancelled.	• Typhoon suspended several trains in Guangzhou-Haikou area. • A total of 112 flights were canceled at the airport. • Power facilities were damaged, causing outages for 232 128 users.
Luding Earthquake (2022)	82(dead) 35 (missing)	15.48 billion CNY	• Earthquake affected 545 000 people in Ya'an, Kardze, and Liangshan. • 80 000 people were urgently evacuated and resettled.	• Many houses and infrastructure were damaged. • Lifelines like roads, communications, water, and power supply were interrupted. • Secondary geological disasters were triggered. • Approximately 2 000 hectares of crops were affected. • About 281 000 houses were damaged.

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reflect the number of disaster-related news items and the Baidu search index to gauge public response. Specific data sources:

1) The government disaster response efficiency data come from Baidu News (http://news.baidu.com/). by screening and sorting the content of network media news headlines.
2) The public response characteristic data come from Baidu search index (http://index.baidu.com/). When searching for information, we searched with the keywords "Luding earthquake," "Zhengzhou heavy rainstorm," and "Typhoon Chaba" to obtain the number and information of relevant network media news.

Construction of Evaluation Methods for Disaster Response Efficiency

The essence of efficiency is the degree of realization of resources or labor value, reflecting the final resource allocation and interaction effects. The disaster response efficiency involved in this paper is relative efficiency, which refers to how to achieve the maximum degree of synergy between government decision-making, emergency rescue, and social assistance under the condition that the public response remains unchanged for different types and scales of disaster events.

The characteristics of network media in natural disaster response

Response to sudden disaster events is often referred to as emergency response, which mainly refers to the emergency plan formulated according to the scale and impact of the disaster and the response measures taken in response. In a broad sense, response refers to the emergency rescue and management activities provided to organizations and individuals affected by disasters. This includes emergency plans, rescue operations, information dissemination, and communication, all utilizing modern techniques and methods to ensure the safety of life and property.[25] Efficient disaster emergency management is crucial due to the complex and varied timing and causes of disaster events.[27] Therefore, the operational mechanism of emergency management in the context of network media should be different from the traditional way. The main impact of the emergence of network media on emergency management is as follows:[23,24]

1) It will be difficult for the subject of the incident to cover up the incident in front of the public, so the subject of the incident must respond quickly and be honest with the public.
2) The roles of the subject, the government, and the public have undergone tremendous changes, and the public is no longer an audience that can only passively receive information, but has become the transmitter, supervisor, and questioner of the event information (Figure 1). At this point, the flow management process for responding to emergencies can be clearly divided into the following three stages:
   a) The first stage: In the realm of network media, with its multiple news channels, vast information, and rapid transmission speeds, it is crucial for the involved parties to promptly conduct a preliminary investigation following an incident.
   b) The second stage: Due to the role of network media, the public's access to information is not limited to official incident reports, but also includes widespread gossip and other sources. In such situations, the involved parties must promptly conduct a thorough and comprehensive investigation of the incident.
   c) The third stage: After the incident subsides, the involved parties continue their investigation under government supervision, detailing the causes, effects, and specific losses of the incident before releasing them to the public.

Based on the characteristics of disaster response, disaster-related information in network media typically remains stable for about a week after the event. Most scholars have studied the stages of disaster events based on life cycle theory and found that after disasters take into account the different degrees of response of multiple subjects to disasters during disasters, the disaster response process can be divided into disaster outbreak periods, duration

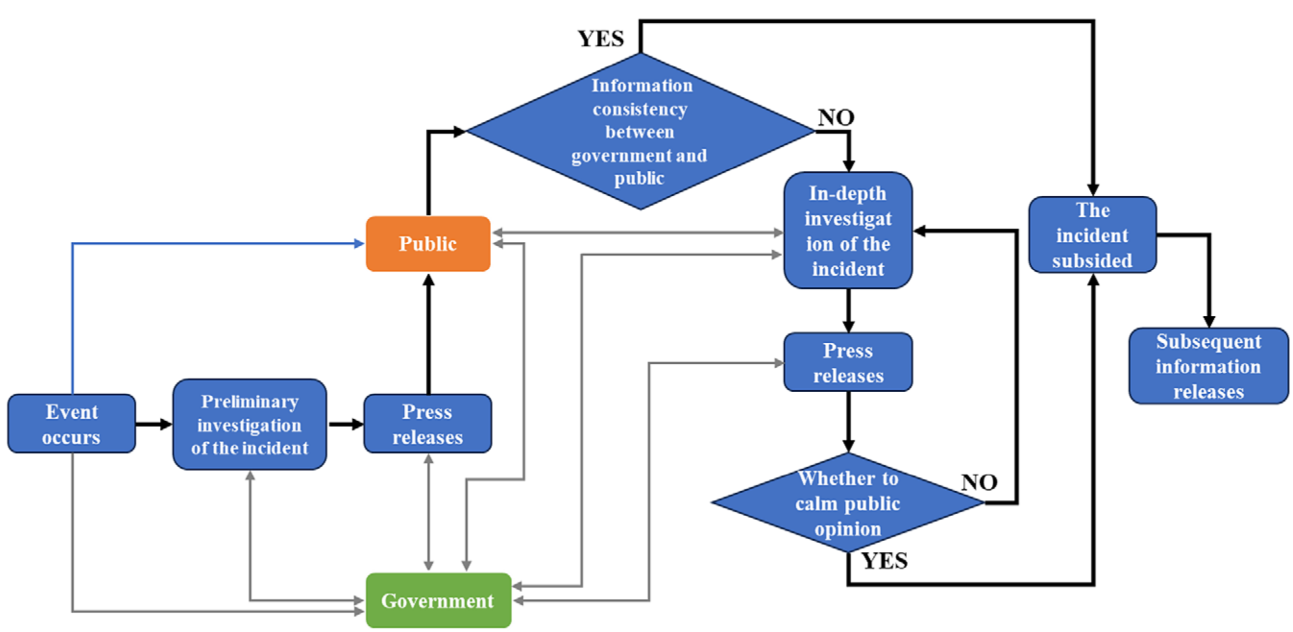

Figure 1. Disaster emergency response process and characteristics under the background of Network media.

periods, and regression periods.[46–48] It basically takes 12 days as the basic unit of disaster response.[49] Considering the factors such as scale and influence of the disaster, the 12-day disaster analysis was carried out for decision-making units (DMUs).[49]

Evaluation the disaster response efficiency based on DEA model

Data Envelopment Analysis (DEA) is an effective method for evaluating the efficiency of decision-making units (DMUs).[50,51] Based on the concept of relative efficiency, it evaluates the scale and technical effectiveness of decision-making unit with multiple inputs and outputs and gets the most effective solution that can reflect the information and characteristics of the evaluation object. From the perspective of the disaster occurrence process, it can be used as an "input-output" system. The public response (output factor) caused by the disaster is the result of government decision-making, emergency rescue, and social assistance (input factors). From the perspective of "input-output," the effects of different input factors and output results can reflect the situation of disaster response at different times, thus assessing the level of natural disaster response efficiency. The efficiency of natural disaster response improves with effective disaster response decision-making, program organization, and coordination by disaster management authorities. Higher response levels indicate stronger disaster response efficiency, whereas weaker system organization and cooperation among organizations lead to lower natural disaster response efficiency. This paper attempts to use the DEA model to measure the natural disaster response efficiency of natural disasters (Figure 2).

By comparing the efficiency of the natural disaster response for each day, we explore the factors influencing the disaster response and provide suggestions for the response and management of the disasters of different natural disasters. The calculation formulas of the DEA model are as follows:

$$min\left[\theta-\varepsilon\left(\sum_{j=1}^{m}s^{-}+\sum_{j=1}^{r}s^{+}\right)\right]=v_d(\varepsilon) \tag{1}$$

$$\text{s.t.}\sum_{j=1}^{n}x_j\lambda_j+s^{-}=\theta x_0 \tag{2}$$

$$\sum_{j=1}^{n}y_j\lambda_j-s^{+}=y_0 \tag{3}$$

$$\lambda_j\geq 0 \tag{4}$$

$$s^{+}\geq 0, s^{-}\geq 0 \tag{5}$$

Where, x is the input value, y is the output value, v is the weight coefficient of input and output, m is the input type, n is the decision unit, θ is the natural disaster response efficiency, λ is the optimal solution, s- is the output insufficient value, and s+ is the input redundancy value.

Natural disaster response efficiency reflects when public response information (i.e., output indicators) is constant,the commitment level of government command and decision-making ability, emergency rescue capability, and social assistance response (i.e., input indicators).[51]

1) If θ^*=1, the efficiency of disaster response is equal to 1, then the government decision-making, emergency rescue, and social assistance response inputs just meet the public response information; that is, multi-agent cooperation and resource allocation is optimal, and natural disaster response efficiency is the highest.
2) If θ^*<1 (that is, the efficiency of disaster response is less than 1), then the investment in government decision-making, emergency rescue, and social assistance is insufficient, the natural disaster response efficiency is not optimal, and some investments need to be strengthened.
3) There is no θ>1 in this model.

Indicator system of the natural disaster response efficiency

After the disaster, different subjects have different characteristics of disaster response behavior. Therefore, the following principles should be followed when selecting the main behavior characteristics of the disaster occurrence as the index to evaluate the efficiency of the response to natural disasters.

Scientific

The choice of indicators should be based on the scientific basis of sufficient research on existing data. The indicators must clearly indicate the theme of the news and the characteristics of the response variable response and can be subsequently implemented by subsequent policies.

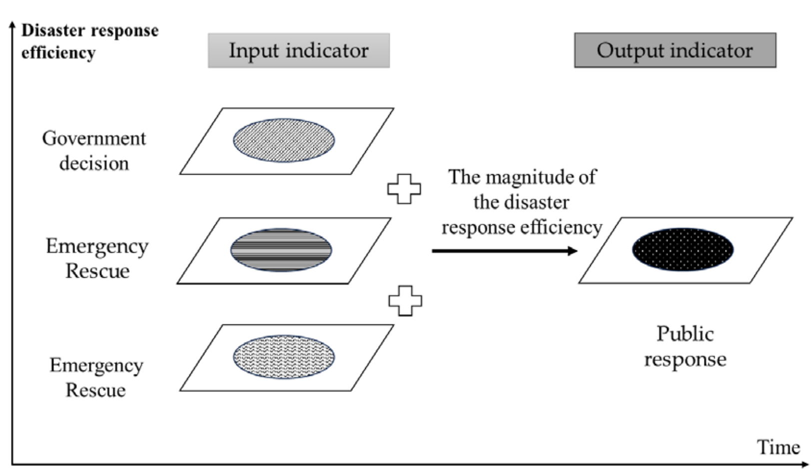

Figure 2. Evaluation idea of natural disaster response efficiency based on DEA model.

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Comprehensive

Evaluation indicators should reflect the characteristics of disaster response at different stages-before, during, and after the disaster. They should encompass the basic content needed to assess disaster response efficiency.

Independence

Evaluation indicators should avoid overlapping index information to improve the accuracy and rationality of the evaluation.

Operability

The selection of evaluation indicators should be based on existing data and statistical information. Quantifying the indicators can objectively reflect the overall picture of the variable response process and assess the efficiency of risk response.

Disaster events are complex and influenced by numerous factors.[51] Based on life cycle theory, this paper considers the different responses of multiple entities to disasters during various phases. According to the characteristics of different natural disasters, the disasters are divided into the outbreak period, the duration period, and the regression period, and the 12 days is the basic unit of disaster response. The main targets of disaster response are government command and decision-making capabilities, emergency rescue capabilities, and social assistance. The results of these aspects are reflected in the public response. According to the principle of index selection and an understanding of different natural disasters, this paper constructs the input indicators of the DEA model from three aspects: government decision-making, emergency rescue, and social assistance, using the public response index as the output indicator of the DEA model. Specific indicators (Table 2) are constructed and described as follows:

Table 2. DEA model input-output indicator system

Indicator type		Description
Input indicator	Government decision	Reflecting the formulation and decision-making of the government's command and rescue capabilities, departmental action, information disclosure capabilities, and related disaster relief programs.
	Emergency rescue	Reflecting the organization of rescue, medical assistance, materials and infrastructure, and disaster information after the disaster.
	Social assistance (SA)	Reflecting the research on disasters by experts and research institutions after disasters, the mobility of enterprises, social organizations and volunteers, social donations, insurance claims, and post-disaster relief.
Output indicator	Public response	The search index based on Baidu index, which reflects the degree of public response to the characteristics of different stages of disasters after the disaster.

Methods for analyzing the impact of disaster response efficiency

Based on the introductory analysis of disaster response, in order to understand the impact of different variables on disaster response efficiency, it is necessary to further analyze how each input variable changes (increases or decreases) to achieve the target efficiency. Therefore, it is necessary to analyze the input redundancy rate and the output shortage rate. The specific calculation formulas are as follows:

The input redundancy rate is mainly used to analyze how much input needs to be reduced for each variable to achieve the target efficiency, which is defined as

$$\eta_j = s_j^- / x_j \tag{6}$$

Where, η_j is the j-th input redundancy rate of the decision unit.

The output shortage rate is mainly used to analyze how much output needs to be increased by each variable to achieve the target efficiency, which is defined as

$$\rho_j = s_j^+ / y_j \tag{7}$$

Where, ρ_j is the j-th output shortage rate of the decision unit.

Results and Analysis

Comparative Analysis of Response Characteristics of Natural Disasters at Different Stages

Network media combines the common advantages of traditional media and network media. Analyzing the number of news reports from online media effectively shows the progress of pre-disaster and post-disaster events and the participation of multiple subjects. Based on the number of online media news of three different types of natural disasters, this paper finds that the number of network media reports of the three types of disasters varies differently in different periods of disasters (Figure 3). There were three peaks in the amount of news about the Luding earthquake. The news on the Zhengzhou heavy rainstorm disaster subsided after a small spike after the peak. Due to the rapid occurrence of typhoon disasters, the number of news reports on the Super Typhoon Chaba subsided quickly. Overall, the number of early reports on the Zhengzhou heavy rainstorm disaster increased rapidly, whereas the number on news reports on the Luding earthquake decreased slowly due to the severity and duration of the disaster.

Regarding the stage characteristics of disaster response, government decision-making, emergency rescue, and social assistance constitute the main response characteristics of various types of post-disaster responses. With the passage of time, the types and frequency of various characteristics during the outbreak period of disasters have gradually become more and more common. Among the three types of disasters, the government's command and decision-making occupies an absolute position in both the outbreak and duration of the disaster and is the main body of disaster relief. Emergency rescue efforts weaken over time, whereas social assistance responses gradually increase.

1) Disaster outbreak period. The outbreak period is the golden rescue period after a disaster, requiring coordinated responses from multiple actors (Figure 4). In the Luding earthquake, experts and related institutions research, resettlement of victims, and government assistance accounted for a large proportion, and the participation in departmental actions and prayer and mourning activities were weak. In the Zhengzhou heavy rainstorm disaster, leadership attention, government assistance, and insurance disaster assistance

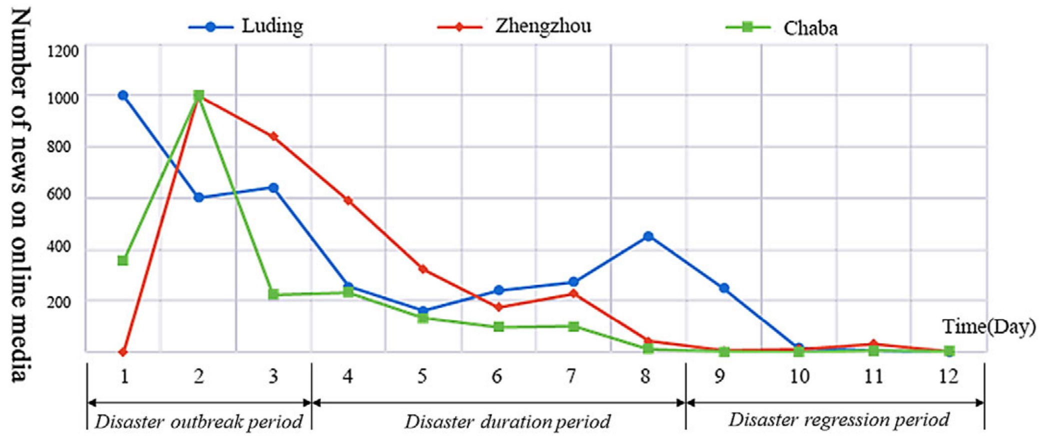

Figure 3. Change in the number of news reports for different disasters.

accounted for a large proportion, whereas volunteer action, disaster early warning, disaster knowledge popularization, expert and related institution research, prayer and mourning, and other actions were relatively lacking. The Super Typhoon Chaba focused on prayer and mourning, disaster warning, disaster knowledge popularization, and departmental actions, with less government assistance and victim resettlement.

2) Disaster duration period. The Luding earthquake was mainly characterized by leadership attention, infrastructure conditions, and volunteer actions, and the resettlement of victims and social organization activities were weak (Figure 5). The Zhengzhou heavy rainstorm disaster was mainly characterized by organization of rescue, resettlement of disaster victims, and social donations, whereas government assistance, infrastructure conditions, expert analysis, and social organization assistance were weak. The Super Typhoon Chaba was mainly characterized by disaster early warning and social organization assistance (the leadership attaches great importance to it), and the government departments were relatively weak in disseminating disaster information.

3) Disaster regression period (Figure 6). During the disaster regression period, the Luding earthquake focused on early warning, expert analysis, and prayer, with weak government information release. The Zhengzhou heavy rainstorm disaster was mainly characterized by the resettlement of disaster victims and was relatively weak in the response of government departments, related disaster research, information release, and insurance. The Super Typhoon Chaba was mainly characterized by the release of disaster information by government departments, followed by the rescue of social organizations and the popularization of disaster knowledge, and was relatively lacking in the release of rescue information of relevant organizations, disaster early warning and resettlement of disaster victims, and expert research.

Results of the Disaster Response Efficiency Assessment

Results of the disaster response efficiency analysis

According to the results of the disaster response calculation, the average natural disaster response efficiency can be obtained

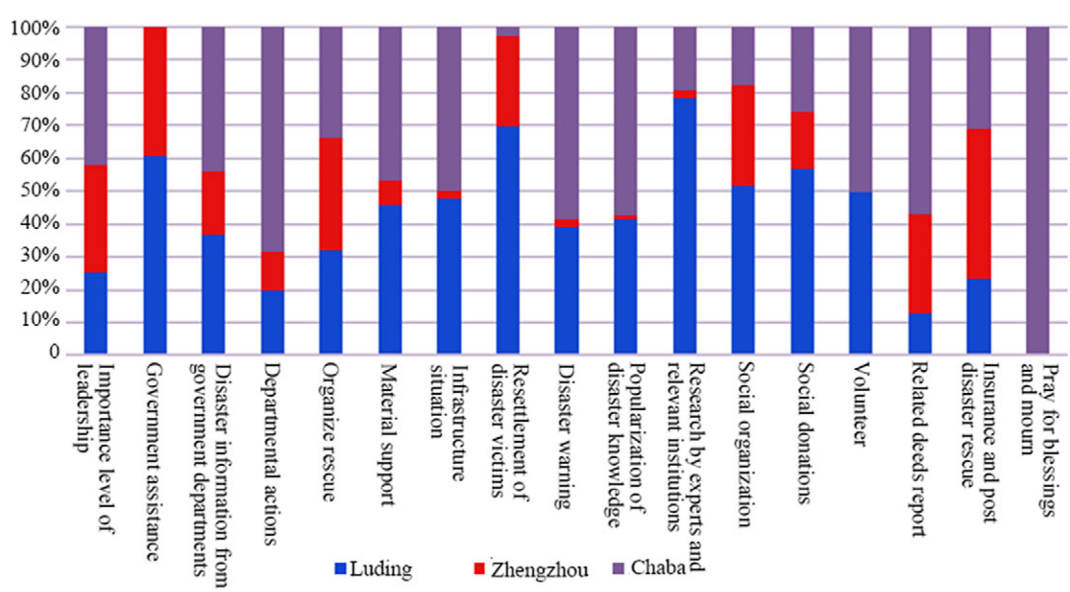

Figure 4. Comparison of the characteristics of different types of disasters during the outbreak period of disasters.

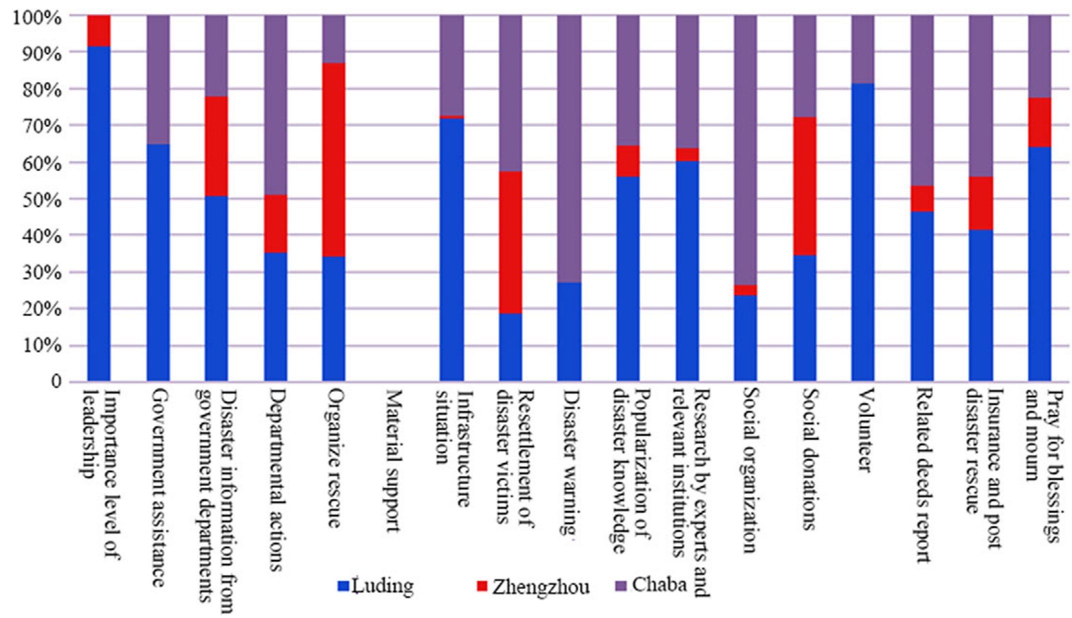

Figure 5. Comparison of the characteristics of different types of disasters during the duration of disasters.

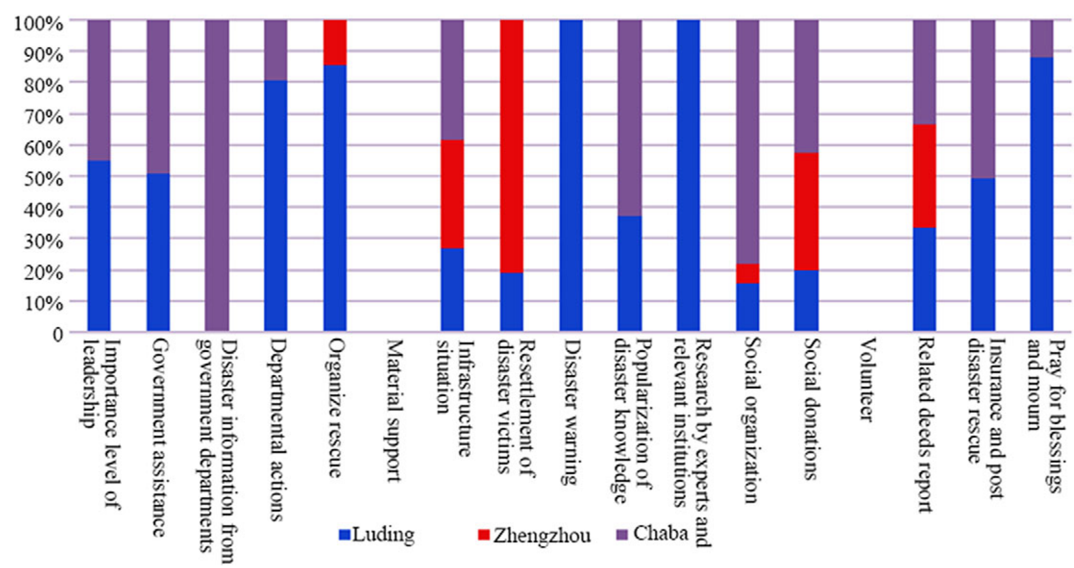

Figure 6. Comparison of the characteristics of different types of disasters during the disaster subsidence period.

(Table 3). The Zhengzhou heavy rainstorm has the fastest effect efficiency after the disaster, followed by Super Typhoon Chaba. Luding Earthquake has the slowest effect efficiency after the disaster. The Luding earthquake showed the best response efficiency twice; the Zhengzhou heavy rainstorm disaster showed the best response efficiency four times; the typhoon disaster showed the best response efficiency three times. The optimal response value of the three types of disaster is the 12th day. The days and the frequency of the optimal values for the other different days vary. The closer the value of the natural disaster response efficiency to 1, the higher the value of the natural disaster response efficiency, the lower the opposite.

- Results of Luding earthquake disaster response efficiency
  1) The DMU unit with a disaster response efficiency of 1 totals 2 days, and the sample distribution is 16.67%, whereas the number of invalid days for disaster response efficiency is 10 days, accounting for 83.33%. This shows that in the 12 days after the disaster, the disaster response efficiency was invalid for most time; that is, the utilization of resources and personnel was not maximized.
  2) The disaster response efficiency value reaches 0.685 on the 8th day, and the DMU unit is 1 day, indicating that the disaster resources and response on the 8th day after the disaster are relatively effective relative to other days, and there is still a certain gap from the effective value 1.
  3) There are 9 days with efficiency values between 0 and 0.6. These days have not reached the best state of disaster response efficiency, and all are lower than the average value of disaster response efficiency of 0.427. The lowest disaster response efficiency is 0.091 on the 3rd day, and

Table 3. Three types of natural disaster response efficiency results

Time(day)	Luding earthquake	Zhengzhou heavy rainstorm	Super Typhoon Chaba
1	0.163	–	1
2	0.224	1	0.303
3	0.091	0.389	0.758
4	0.219	0.237	0.269
5	0.419	0.265	0.276
6	0.172	0.167	0.43
7	0.382	0.156	0.303
8	0.685	0.608	0.545
9	0.391	1	0.641
10	1	1	0.691
11	0.378	0.916	1
12	1	1	1
Mean	0.427	0.613	0.601

multiple indicators of input and output need to be adjusted to make the disaster response efficiency value effective and resource allocation optimal.

- Results of Zhengzhou heavy rainstorm disaster response efficiency
  1) The number of days with a disaster response efficiency value of 1 is 4 days, and the sample distribution ratio reaches 33.33%. That is, one third of the days are effective for disaster response efficiency. It shows that after the Zhengzhou heavy rainstorm disaster occurred, there were 4 days of disaster response input and output to achieve the most effective allocation.
  2) The disaster response efficiency values between 0.6 and 1 occur on 2 days, of which 0.916 is on the 11th day, and the disaster response efficiency value is close to 1; that is, the fine adjustment of the response input index can be effective. The disaster response efficiency value on the 8th day is 0.608, and there is still a certain gap from the effective value of 1.
  3) The number of disaster response efficiencies between 0 and 0.6 is 6 days, accounting for one-half of the total number of DMU units. These days the disaster response efficiencies are less than the average value of 0.613, and the minimum value is on the 7th day, which is 0.156. From the perspective of time distribution, the basic distribution is within 7 days after the disaster. This reflects the poor allocation of disaster response input and output indicators during this period. Adjust the input and output of the indicator to maximize the efficiency of the disaster response.
- Results of Super Typhoon Chaba disaster response efficiency
  1) There are 3 units with a disaster response efficiency of 1, accounting for 25% of the total number of units. That is, 3 days have reached the optimal value of disaster response efficiency, and the best resource allocation and main body response in these 3 days during the disaster. There are a total of 9 units in 1, indicating that the disaster response efficiency of these 9 days is invalid, and the resource allocation is not optimal.
  2) There are 3 days with disaster response efficiency values between 0.6 and 1and occur on the 3rd day, the 9th day, and the 10th day after the disaster. The relative efficiency value of these areas is relatively effective compared with other days less than 0.6. However, there is still a certain gap from the optimal value of 1, and the input and output indicators need to be adjusted.
  3) The disaster response efficiency value is in 6 days with a range of 0 to 0.6, representing 50% of the total number of units. The efficiency is less than the average value 0.601. The minimum number of disaster response efficiency days is 0.269 on the 4th day. During these time periods, disaster response efficiency is invalid, and more adjustments to input and output indicators are needed to make resource allocation reach the optimal value, thus increasing disaster response efficiency.

Analysis of the disaster input redundancy rate and the output shortage rate

According to the results of the natural disaster response analysis, the overall natural disaster response efficiency is low, and the main factors that affect the effectiveness of the DEA evaluation unit must be explained by the rate of input redundancy and the rate of output shortage (Table 4).

The redundancy rate of the disasters gradually increased during the disaster outbreak period, and the redundancy rate of the duration investment was the highest, which means the organization resource allocation and the main subject coordination degree were the lowest, and the work still needs to be managed. During the regression period, there are still small fluctuations, and various tasks after the disaster still need to be strengthened:

1) Luding earthquake. Judging by the trend of changes in the 12 days after the disaster, the Luding earthquake is a large-scale earthquake disaster in terms of both economic loss and casualties. During the 1st through 9th days of the disaster, the redundancy rate of the rescue information response remained high. As the disaster began to enter the continuation period, the efficiency of the disaster response gradually increased, and the redundancy rate of the rescue information response still represented a large proportion. Redundant input from government departments' response and social assistance gradually decreased as the disaster receded.
2) Zhengzhou heavy rainstorm. The disaster response efficiency of the heavy rainstorm of Zhengzhou is obviously better than that of the Luding earthquake. From the overall trend of change of the input redundancy rate value, the rescue information input redundancy rate and the social assistance response redundancy rate are the largest, followed by the government department response redundancy rate. The impact of rescue information and social assistance response on the efficiency of the response to heavy rainstorm disaster in Zhengzhou is basically the same. It begins to decrease on the 7th day after the disaster, and the government's response input redundancy rate begins to decrease on the 6th day, gradually approaching the optimal value.
3) Super Typhoon Chaba. Judging from the overall change in the value of the input redundancy rate of the Super Typhoon Chaba, the input redundancy rate for the social assistance response is the highest, followed by the input redundancy rate for the rescue information, and the response redundancy rate

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Table 4. Analysis of the input redundancy rate and output shortage rate of disaster response in three types of disaster events

Time/day	Luding earthquake				Zhengzhou heavy rainstorm				Super Typhoon Chaba			
	Input redundancy rate/%			Output shortage rate/%	Input redundancy rate/%			Output shortage rate/%	Input redundancy rate/%			Output shortage rate/%
	GD	ER	SA	PR	GD	ER	SA	PR	GD	ER	SA	PR
1	86.29	99.98	83.66	0	–	–	–	0	0	0	0	0
2	80.84	99.98	77.64	0	0	0	0	0	69.73	76.78	69.73	0
3	90.91	99.01	90.91	0	61.14	61.14	61.14	0	24.23	51.29	24.23	0
4	86.35	99.97	78.11	0	76.27	76.27	76.27	0	73.11	77.95	73.11	0
5	85.86	99.96	58.14	0	73.51	73.51	73.51	0	72.41	77.01	72.41	0
6	84.25	99.96	82.78	0	83.3	83.31	83.31	0	57.05	57.05	72.82	0
7	66.16	99.83	61.8	0	84.4	84.39	84.39	0	69.71	69.71	94.52	0
8	38.33	99.89	31.47	0	40	99.28	99.28	0	45.48	45.48	73.74	0
9	60.88	88.72	60.87	0	0	0	0	0	36.24	35.85	35.86	0
10	0	0	0	0	0	0	0	0	44.73	30.9	30.88	0
11	73.79	99.95	62.22	0	10	97.3	86.91	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0

Note: GD is short for Government Decision. ER is short for Emergency Rescue. SA is short for Social Assistance. PR is short for Public Response.

for the government department is the lowest. On the 7th day after the disaster, the value of the input redundancy rate of each response began to decline, and the disaster response efficiency gradually reached the optimal.

The output shortage rate reflects the rate at which the output needs to increase, whereas the level of the input remains the same. It can be seen from the table that the output response rate of the three types of disaster is 0; that is, the output reaches the optimal value when the input is unchanged.

Analysis of the trends of natural disaster response efficiency

- Overall trend analysis of natural disaster response efficiency

In general, the Zhengzhou heavy rainstorm and the Super Typhoon Chaba achieved a natural disaster response efficiency of 1 on the 1st day after the disaster. The natural disaster response efficiency (Figure 7) of the three types of disasters was generally low from the 3rd day to the 8th day. The polynomial trend of the three types of disasters indicates that the response efficiency of the three types of disasters showed a 12-day cycle trend. The Zhengzhou heavy rainstorm and the Super Typhoon Chaba disaster all showed a U-shaped structure with a natural disaster response efficiency that first decreased and then increased. The Zhengzhou heavy rainstorm period was shorter than that of Super Typhoon Chaba, and the Luding earthquake showed a gradual upward trend. The main reasons are as follows:

1) From the perspective of the impact of the disaster. Due to multiple reasons such as the remote location of the disaster, inconvenient transportation, and economic backwardness, the number of casualties and economic losses caused by the Luding earthquake was relatively large. The scale of disasters in the Zhengzhou heavy rainstorm and the Chaba super-typhoon was relatively small. At the same time, being located in areas with better economies and facilities allows for a relatively smooth disaster relief response, achieving optimal efficiency values when disaster relief begins.
2) From the perspective of disaster management. How to respond quickly to the underdeveloped system after disasters occurred? It is inevitable that waste of resources and personnel imbalances will occur in disaster relief. Consequently, disaster response efficiency is low in the early stage of the disaster, and the value of disaster response efficiency is gradually optimized after the disaster gradually transitions to a stable stage in the later period. When the Zhengzhou heavy rainstorm and Super Typhoon Chaba occurred, disaster management gradually changed from risk management to governance stage, and resilient city construction has also been put on the agenda, so it is relatively calm and orderly to deal with disasters.

- Efficiency comparative disaster response stages

According to the overall trend of natural disaster response efficiency (Figure 8), when discussing the disaster response characteristics of three types of natural disasters, we divide the whole process into three stages: 1) disaster outbreak period, within 1st to 3rd day after the disaster; 2) Disaster duration period, from the 3rd to the 8th day after the disaster; and 3) Disaster receding period, from the 8th to the 12th day after the disaster.

1) During the period of the disaster outbreak. The efficiency of the response to natural disasters of the three types of disasters generally showed a trend of decreasing. Among them, the Zhengzhou heavy rainstorm and the Super Typhoon Chaba achieved the best efficiency on the 1st day of the response. However, the Zhengzhou heavy rainstorm had no response information due to the late 1st day of the event, and the optimal Luding earthquake on the 2nd day had a very inefficient response.
2) During the duration period of the disaster. All three types of disasters showed a low period of disaster response, and the efficiency of natural disaster response was less than 0.5, explaining that the government's decision-making, emergency

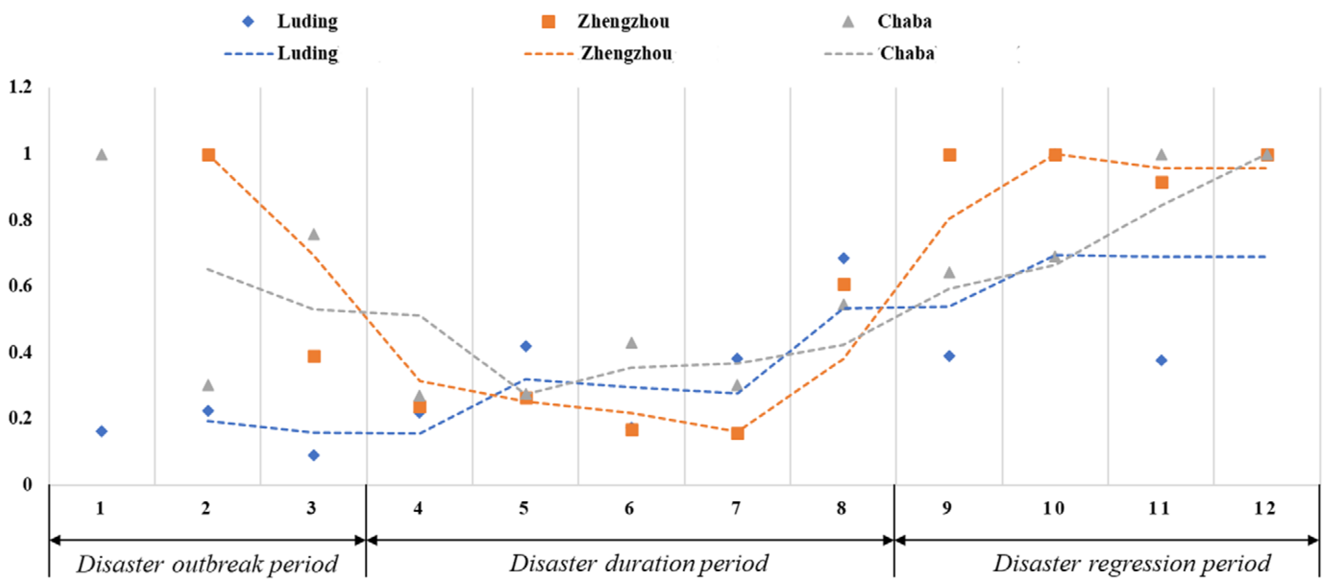

Figure 7. Trend analysis of natural disaster response efficiency.

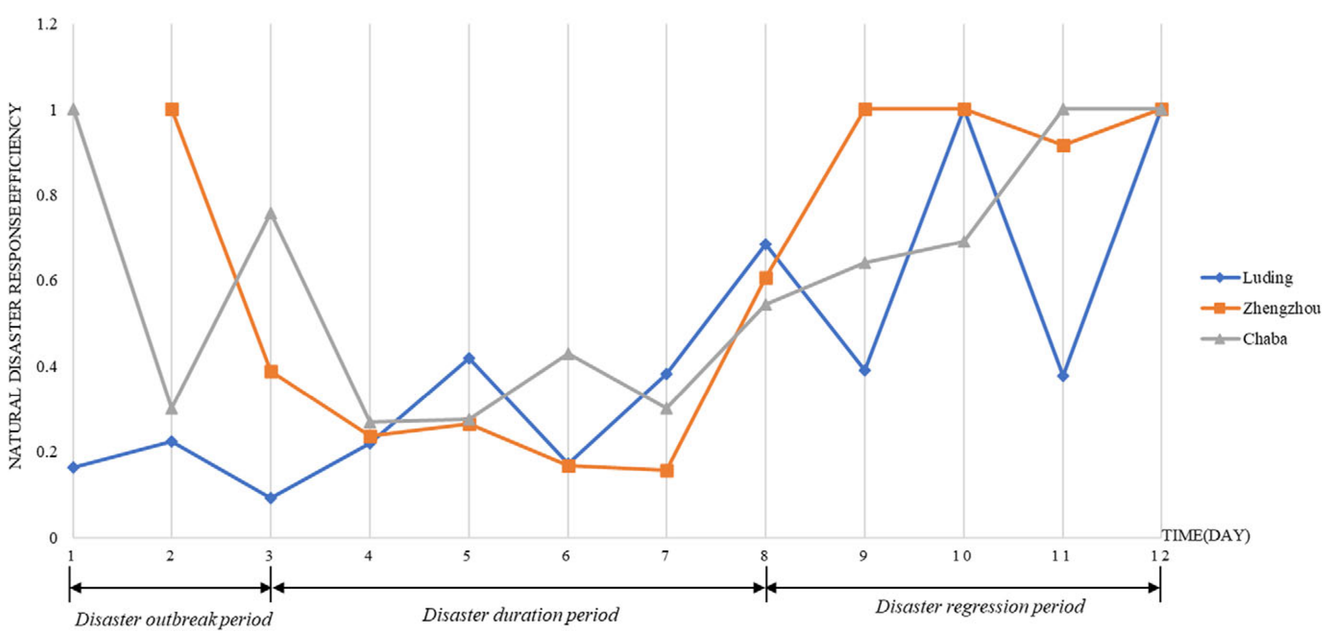

Figure 8. Efficiency Comparative disaster response stages.

rescue, and social assistance were poor at this stage. The Zhengzhou heavy rainstorm showed a trend of decreasing the response value and reached its lowest on the 7th day. Both the Luding earthquake and the Super Typhoon Chaba showed a trend of increasing first and then decreasing, and the corresponding efficiency was the lowest on the 6th and 4th day, respectively.

3) During the disaster regression period. The three types of natural disaster response efficiency values all tend to be at a stable stage of 1. Resource allocation after the disaster has gradually become optimal, and all work has gradually recovered. The Luding earthquake natural disaster response efficiency value was in a fluctuating state and generally tends to be optimal. The heavy rainstorm in Zhengzhou was characterized by a stable trend in the response efficiency to natural disasters in the regression period. The basic value of natural disaster response efficiency was 1 or close to 1, and the tornado natural disaster response efficiency was increasing. On the 11th day, the optimal response efficiency was at a stable value.

In general, the efficiency of various types of disaster response is short in duration, and attention should be paid on the 3rd to 8th day after the disaster.

Factors Affecting Natural Disaster Response Efficiency

The redundancy rate for various types of natural disasters in the disaster relief process is generally too high. On the one hand, the

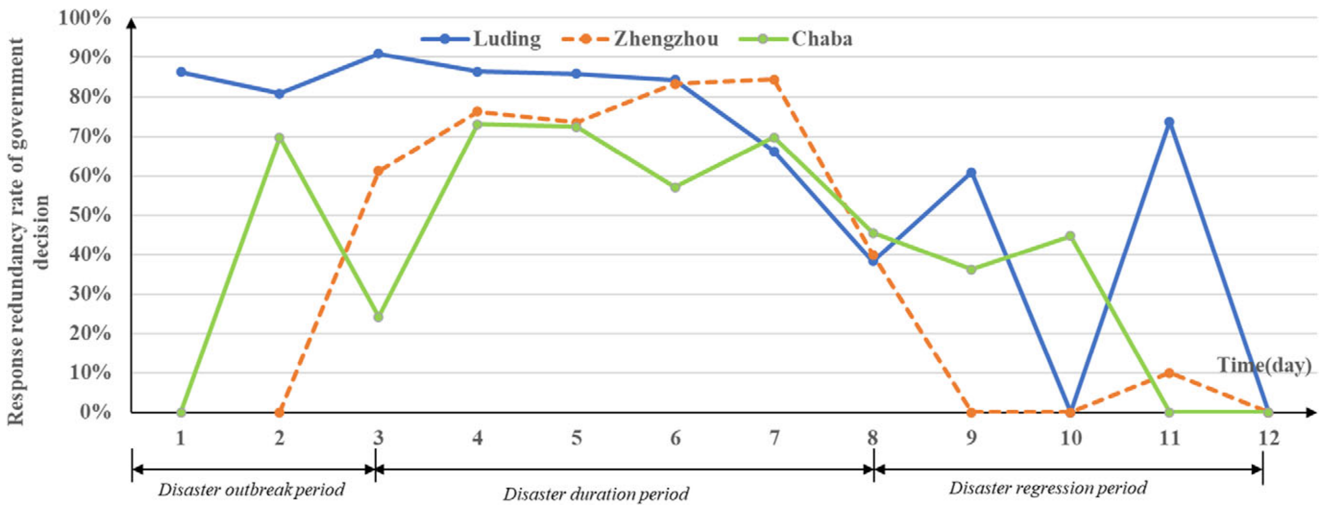

Figure 9. Analysis of response redundancy rate of government decision.

redundancy rate of disaster inputs can reflect the large investment and the high degree of attention to disaster relief for natural disasters. On the other hand, the redundancy rate of disaster relief is higher. It also reflects the low efficiency of disaster relief resources utilization and the need to improve coordination. The redundancy rate of various input indicators during different periods of disasters can reflect the impact of different disaster response information. This article discusses the factors that influence natural disaster response efficiency from three aspects: government decision-making, emergency rescue, and social assistance.[51]

Government decision-making factors

After the disaster, the disaster response capability of the government is a key factor affecting the success of disaster relief. Different types of disaster have different requirements for government crisis response measures. Many measures such as the formulation of government disaster relief plans, rescue work, information release, and post-disaster relief affect the government's disaster response capability and influence the direction of public opinion.

From the perspective of government department response (Figure 9), the three types of disaster government decision-making redundancy rate values were higher. In the case of the Luding earthquake, government decision-making response spanned all stages of the disaster, with the input redundancy rate gradually declining. The Zhengzhou heavy rainstorm was concentrated mainly on the 3rd to 9th days, and the Chaba super-typhoon was concentrated mainly for 2nd through 11th day. Government decision-making response exhibited a higher input redundancy rate compared to the Luding earthquake, indicating further improvement in the government's disaster relief efficiency.

From the perspective of the occurrence of three types of disasters (Table 5), compared with the Luding earthquake, the Zhengzhou heavy rainstorm and the Super Typhoon Chaba arranged for rescue, claims, and government assistance at the same time in the disaster outbreak. Government departments have gradually optimized and improved their information release, departmental collaboration, and leadership emphasis. This has led to an increase in the level of disaster management, with a shift toward a service-oriented government model that progresses from leadership to cooperation.

Table 5. Government and departmental disaster response analysis table for three types of events

Government response	Outbreak period	Duration period	Regression period
Luding earthquake	National emergency response; Organizing rescue work; National leaders sympathize with the people in the disaster area and guide the work.	Organize the remains of the body; release a rescue plan; National President's condolences; Organizing post-disaster reconstruction work.	Leaders emphasize organizational disaster assessment.
Zhengzhou heavy rainstorm	Emergency response at two levels in urban areas; Organizing rescue; Carry out insurance claims work.	Rescue work continues.	Do a good job in resettlement work and insurance claims; Troubleshoot hidden points.
Super Typhoon Chaba	The national, provincial, city, and county governments respectively launched emergency response, and relevant leaders rushed to the disaster area; Organize rescue; Disaster grants for post-disaster resettlement subsidies.	Rescue work is carried out in an orderly manner; Municipal leaders and NGOs to discuss disaster relief programs and the post-disaster public;The first seven mournings.	Leadership condolences; Post-disaster placement.

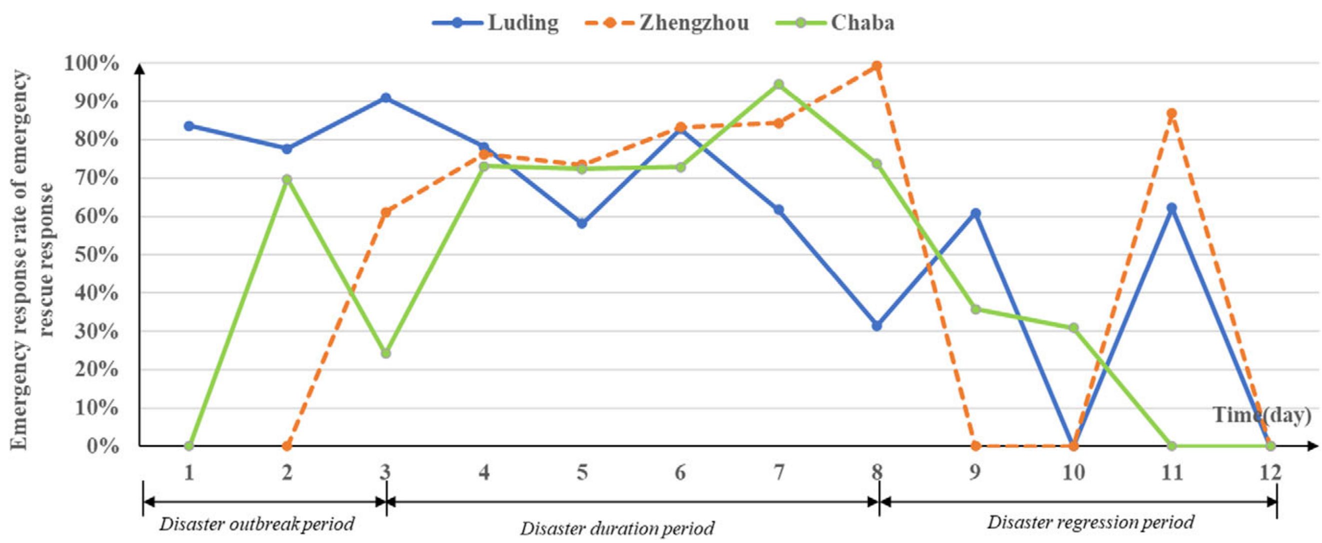

Figure 10. Analysis of emergency response rate of emergency rescue response.

Emergency response factors

Judging from the rate of emergency response (Figure 10), the input redundancy rate is large at all stages of disaster occurrence. The redundancy rate of the Luding earthquake emergency rescue investment remained high and began to stabilize during the regression period, largely influenced by the scale of the disaster. The other two types of disasters showed U-shaped and inverted V-shaped structures in a certain period.

From a temporal perspective, the disaster redundancy rate of Luding earthquake emergency rescue was higher than that of Zhengzhou heavy rainstorm and Super Typhoon Chaba, and the disaster redundancy rate of the three types of emergency rescue was gradually reduced. In relative terms, emergency rescue is the dominant factor that affects the efficiency of the three types of disaster response and remains high during the outbreak period and duration. The reason is that the organization of rescue is more powerful, related to the degree of disaster impact. Additionally, it may be derived from the dissemination of media information such as disaster information and disaster relief knowledge. During the period of heavy rainstorms from Super Typhoon Chaba and Zhengzhou, media information was more developed, information was more transparent, the efficiency of organizing rescue work was correspondingly improved, and the disaster rescue capability was gradually improved.

Social assistance factors

In recent years, the proportion of social assistance in disasters has gradually increased, highlighting the increasingly prominent role of coordinated multi-subject management. The participation of experts, various nonprofit organizations, civil organizations, and volunteers in disaster relief has effectively compensated for the government's functions and played a good comforting role in the rescue of the public.

Compared with the government's decision-making response and emergency response, the pattern of social assistance response has changed significantly. The redundancy rate of the social assistance (Figure 11) response input from Super Typhoon Chaba and the heavy rainstorm of Zhengzhou was significantly better than the Luding earthquake. In the Luding earthquake, there was not a

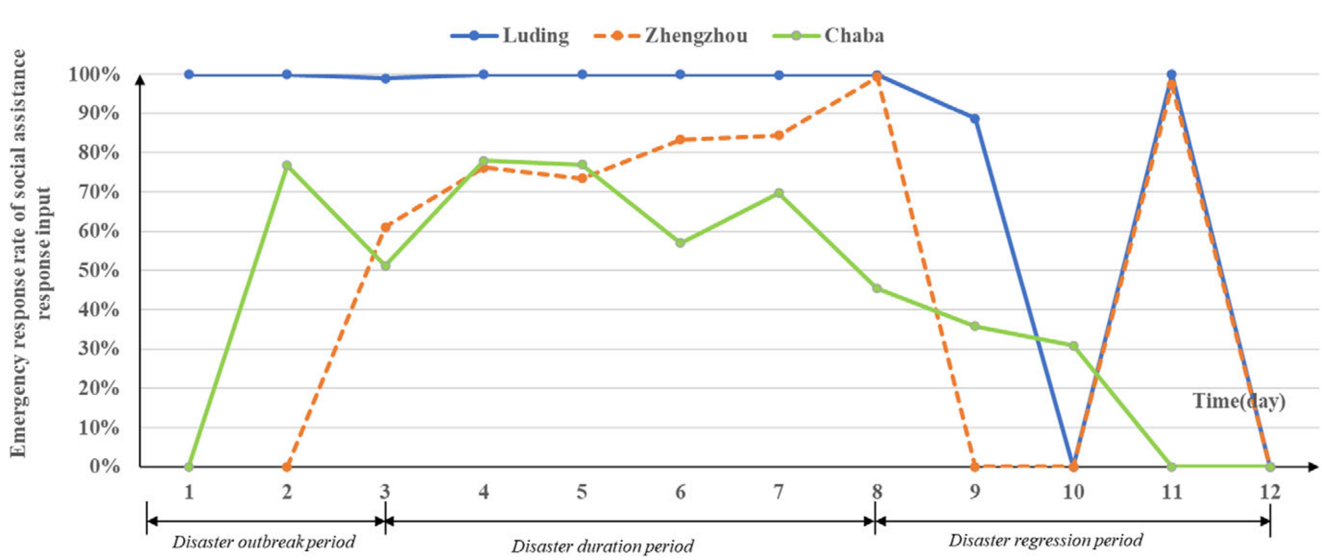

Figure 11. Analysis of emergency response rate of social assistance response input.

complementary relationship among the government, social organizations, and the public, and the purpose and mode of action of most social organizations were relatively lacking. In contrast, social organizations during the Zhengzhou heavy rainstorm demonstrated effective disaster relief capabilities. Similarly, social organizations responded quickly during Super Typhoon Chaba, demonstrating well-ordered coordination and increasingly diverse organizational forms. Overall, China's nonprofit organizations and other civilian rescue forces have begun to mature in terms of emergency response, disaster relief professional literacy, and general coordination.

Conclusion and Discussion

The frequent occurrence of disasters makes cities in a high-risk society. How to use scientific means to improve the efficiency of natural disaster response in social subjects and improve the performance and resilience of urban safety is the basis for promoting urban development. This study explores the role of network media in the efficiency of natural disaster emergency response. First, the study introduces the importance of network media in the process of disaster occurrence, including the positive effects of improving public participation and facilitating disaster analysis and response, but also points out the possible negative effects of network media, such as the spread of disinformation and social panic. Then, this paper uses the Data Envelopment Analysis (DEA) model to evaluate the emergency response efficiency of different types of natural disasters (such as earthquakes, heavy rains and typhoons) at different stages and analyzes the main factors affecting the emergency response efficiency, including government decision-making, emergency rescue, and social assistance. The specific conclusions are as follows:

1) There are notable disparities in the efficiency of emergency responses to various types of natural disasters. Utilizing the Data Envelopment Analysis (DEA) model, we evaluated the emergency response efficiency across different natural disasters, specifically earthquakes, heavy rains, and typhoons. Our findings indicate that heavy rain disasters exhibit the highest response efficiency, followed by typhoon disasters, whereas earthquake disasters demonstrate the lowest. Across these three disaster types, the optimal response efficiency is achieved on the 12th day. However, the effectiveness of disaster response varies in terms of days and frequency for other time periods. In terms of trends, the response efficiency for heavy rain and typhoon disasters initially decreases and then increases, whereas earthquake response efficiency shows a gradual upward trend. These differences may be attributed to a multitude of factors, including the scale of the disaster, its impact extent, and the level of economic and social development.
2) The phased characteristics of the disaster emergency response process. This paper subdivides the emergency response process of natural disasters into three periods: the outbreak period, the duration period, and the subsidence period. It further analyzes the emergency response efficiency during each stage. The findings reveal that the emergency response efficiency is high for heavy rain and typhoon disasters during the outbreak period. However, the emergency response efficiency for all three types of disasters is generally low during the duration period, which is identified as the key stage for improving emergency response efficiency. During the subsidence period, the efficiency of emergency response gradually stabilizes. Therefore, in the process of a disaster, the duration period immediately follows the post-disaster golden rescue phase as the first response stage. During this period, it is crucial to focus on and integrate disaster relief efforts, personnel, resources, and information in order to enhance disaster response efficiency and shorten the overall response cycle.
3) The factors that affect the response efficiency of different types of disasters are different. In the process of disaster emergency response, the effectiveness of government decision-making plays a crucial role in enhancing the efficiency of the response. Therefore, it is imperative for the government to make decisions swiftly and accurately, while also strengthening collaboration with relevant departments to improve the overall efficiency of emergency response. Emergency rescue holds a dominant position in the response to earthquake disasters, and the timeliness and effectiveness of rescue operations directly impact the efficiency of the response. Similarly, in the case of heavy rain and typhoon disasters, emergency rescue is also one of the key factors in improving the efficiency of the response. With the growing participation of social organizations, volunteers, and the public, the role of social assistance in emergency response to natural disasters has become increasingly prominent. This paper finds that, in particular, the contribution of social assistance to improving the efficiency of emergency response is especially significant in the context of typhoon disasters.

This paper measures the disaster response efficiency of three different types of natural disasters based on the DEA model. Through the disaster response efficiency model, we analyze and discuss the main factors that affect the stage model. However, there are still some limitations in the study:

1) Disaster response is a dynamic, staged process influenced not only by the characteristics of each stage but also by the level of economic and social development. However, due to the difficulty of obtaining relevant daily data after the disaster, this article does not currently consider the impact of the city's internal systems, assuming that the relevant indicators remain unchanged.
2) Exploring different natural disaster response efficiency should draw conclusions through a comparative study of multiple similar disasters. However, subject to time and space constraints, this article only compares and studies three major natural disasters affecting Chinese cities: typhoons, extreme rainfall, and earthquakes. The universality of the research conclusions needs further exploration. Subsequent research will consider expanding the scope to examine the differences in disaster response characteristics between China and regions in Europe, America, and Africa.
3) Due to the varying timing of disasters and multiple influencing factors in the comparative process, as well as differences in the development level of network media, there have been difficulties in acquiring research data. Therefore, it is necessary to further improve the accuracy of disaster response efficiency research. In the follow-up research, we will also try to explore the introduction of big data technology to achieve refined research on the characteristics of disaster response in the whole cycle of disasters.
4) This study primarily focuses on the Chinese region for both the research area and data acquisition platforms. As a result, there are certain differences in data openness, acquisition methods, government types, disaster emergency response characteristics, and influencing factors compared to regions

in Europe and America. Therefore, the conclusions drawn from this study mainly have reference value for disaster management in Chinese cities. However, the methods developed in this study also provide some reference value for global scholars studying disaster response efficiency. In future research, we will consider expanding the research area and data acquisition platforms and explore the differences in disaster response efficiency under different government types to provide valuable guidance for research conclusions.

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