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Research article

Government's public panic emergency capacity assessment and response strategies under sudden epidemics: A fuzzy Petri net-based approach

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ABSTRACT

In the post-epidemic era, public panic has emerged as a highly significant secondary disaster, necessitating an urgent enhancement of emergency management capabilities by governments at all levels. In order to ensure a robust assessment of the government's ability to manage public panic, it is crucial to effectively address the influence of uncertain and ambiguous factors associated with such scenarios. This paper proposes a governmental public panic emergency management capability assessment method based on fuzzy Petri nets. By analyzing the factors influencing public panic across the four evolutionary stages, namely gestation, outbreak, diffusion, and fading, we establish a hierarchical evaluation index system for assessing emergency management capabilities. Additionally, we develop a range of multi-scenario emergency management strategies. To address the challenges posed by uncertainty, randomness, fuzziness, and insufficient statistical data within the assessment index system, we introduce fuzzy Petri nets and fuzzy reasoning rules to evaluate the emergency management capability of the assessment system and derive the optimal emergency management strategy. According to example simulations, the effectiveness and practicality of models and rules constructed using fuzzy Petri nets are demonstrated, highlighting their superiority over traditional assessment methods. This comprehensive approach equips the government with a versatile toolkit for effectively managing public panic emergencies.

1. Introduction

The outbreak of the COVID-19 pandemic in 2019 had a significant impact on the lives of people worldwide. Nowadays, although the impact of the pandemic has gradually diminished, local outbreaks of the virus still occur frequently due to its continuously produced variants. In addition, outbreaks of acute hepatitis of unknown origin in children, monkeypox, and dengue fever have appeared in various regions, and we can predict that humans may experience more viral and microbial effects in the future. Therefore, public panic during an epidemic outbreak is a common reaction, and its most significant features are a loss of individual emotional self-control and the heightened tendency to engage in irrational behavior. In the era of traditional media, individual panic had limited channels of

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transmission and did not easily become widespread public panic, so the negative impact on society was not prominent [1–3]. However, in the era of social media, the traditional limitations of spatial and temporal risk communication have been shattered. The dissemination of panic is no longer confined to one-way or one-to-many offline communication; instead, it has evolved into a multidimensional communication paradigm, characterized by multiple focal points and intersecting vertical and horizontal channels [4]. This new communication landscape facilitates the rapid proliferation of countless communication pathways within a short span of time, amplifying the potential for unpredictable mutations and intensification of public panic [5]. Concurrently, the incorporation of numerous interest algorithms and associative relationships within social media platforms renders individual members of the public highly susceptible to becoming ensnared in echo chambers of similar information. Consequently, this phenomenon engenders cognitive imbalances, weakens social rationality, and reinforces biased perceptions, potentially culminating in confrontations with outbreak prevention and control measures and the erosion of societal norms, among other extreme behaviors [6]. This has a significant impact on the spiritual order, economic order, and even political order [7].

It can be seen that public panic is characterized by mutability, interactivity, high propagation, high risk, etc. Furthermore, panic, as an emotional state, remains largely imperceptible until the outbreak of irrational behaviors, posing significant challenges to the government's emergency management efforts. However, in the post-epidemic era, characterized by frequent disease outbreaks, public panic and the subsequent emergence of irrational behaviors have evolved into a crucial secondary disaster that accompanies sudden epidemics and disasters. Consequently, the development of emergency management capabilities specifically tailored to address public panic has emerged as a pressing issue within the government's emergency management system, demanding urgent attention [8]. Within this context, our study undertakes a comprehensive examination of the diverse factors that impact public panic during sudden outbreaks. We establish a hierarchical evaluation index system for emergency management capability and develop a set of multi-scenario emergency management strategies. Furthermore, we employ a problem-specific evaluation methodology to address these factors. The overarching objective of our research is to mitigate public panic through scientific and effective measures, enhance the government's emergency management capability, and safeguard social harmony and stability.

The remainder of this essay is organized as follows: Section 2 is a literature review, which describes the current state of research on public panic as well as emergency management capacity assessment; Section 3 is a methodology, which constructs the FPN assessment model and reasoning rules; Section 4 is a case study, which calculates for a typical case; Section 5 is a discussion, primarily dedicated to discussing the computational results and the research's value; Section 6 is a conclusion, which mainly summarizes the study.

2. Literature review

Reviewing existing studies, scholars have accumulated findings on public panic. They have explored various aspects, such as the measurement of public panic, the analysis of its causes and evolution, and intervention initiatives. In terms of measurement, traditional psychologists have developed measurement tools for public panic based on the structural dimension of panic response identification measurement [9,10]. Additionally, as social media has grown, some researchers have mined public panic data using computer crawler technology and developed emotion calculation models to measure public panic [11–13]. Causal, evolutionary and intervention analyses have considered the influences on individual panic perceptions [14,15] and environmental resource conditions [16]. Furthermore, many scholars have analyzed public panic by constructing mathematical models from the perspectives of machine learning [17], disaster chains [18], and action decision making [19] to explore effective intervention methods and emergency decision-making systems. Studies have been conducted from different theoretical perspectives that have provided understanding and management of public panic. However, the governance of public panic during sudden outbreaks is a complex project in which the government is the most critical subject [20–22]. The level of contemporary governance is reflected in part by the government's emergency management capability with regard to sudden disasters and secondary disasters. However, the majority of research on governments' emergency management capabilities has centered on production safety accidents and natural disasters, particularly on the emergency response capability for sudden disasters [23,24]. After the COVID-19 pandemic outbreak, academics paid attention to the emergency management of public health events, but there has been less research on the secondary disasters of the epidemic. However, public panic, as the primary secondary disaster of the sudden epidemic, plays a catalytic and escalating role in the development of epidemic events and has a significant impact that cannot be ignored. For instance, several researchers have found that widespread panic may lead to irrational actions such as hoarding foods and medical squeezes [25,26] as well as unfavorable outcomes such as a "stranger society" and racism [27,28]. Therefore, a focused evaluation of the government's emergency management capabilities is required for secondary disasters caused by epidemics, i.e., widespread panic.

Numerous academics domestically and internationally have carried out pertinent research in emergency management capacity assessment in an effort to strengthen the government's emergency management capabilities. Establishing an evaluation index system for emergency management capacity is a necessary step before developing emergency management capacity and has combined expert scoring, key element verification, hierarchical analysis [29,30], and fuzzy comprehensive evaluation based on the indicator system [31]. Additionally, different improvements have been made by experts and scholars to further strengthen the applicability of the method. To address the impact of variations in expert experience and linguistic descriptions, Xu Shuo et al. proposed a method for evaluating emergency management capabilities in emergencies based on D-number preference relations that improved hierarchical analysis and the approximate ideal solution ranking method [32]. By improving the hierarchical analysis method, Tan Xiaoqun et al. proposed a multilevel fuzzy comprehensive evaluation method for the comprehensive assessment of cross-regional government emergency management capabilities [33]. However, these assessment methods are difficult to effectively eliminate subjectivity and randomness in the process of evaluating emergency management capabilities and lack the ability to present them graphically in a concise and intuitive manner. Especially when dealing with complex evaluation issues such as public panic, the applicability of these traditional assessment methods is somewhat limited due to the ambiguity and complexity of the information, the strong correlation of influencing factors, and the large number of subjects of interest involved.

In addition, from the innovation of evaluation methods, the fuzzy Petri net (FPN) is a new modeling and analysis tool that has been proposed in recent years. On one hand, this approach is derived from Petri nets, inheriting numerous advantages associated with this modeling technique, such as clear and flexible rules for generating models, modular design principles, strong generality, and the ability to intuitively depict the relationships that trigger changes in knowledge [34]. Notably, by utilizing matrix-based reasoning operations, it overcomes the limitations of traditional knowledge representation methods, which struggle to handle parallel reasoning, ultimately leading to improved reasoning efficiency [35]. On the other hand, fuzzy Petri nets (FPNs) enhance the representation and processing capabilities of fuzzy knowledge within the framework of traditional Petri nets. This extension allows for a more comprehensive representation and utilization of fuzzy knowledge that aligns with human thinking and cognition. Consequently, fuzzy reasoning can be effectively applied, particularly in addressing research problems characterized by high levels of uncertainty, ambiguity, and randomness [36,37]. Therefore, it is widely used in transportation [38,39], robotics [40,41], and electric power [42], showing its advantages in risk assessment. Specially, some scholars have expanded and innovated on the basis of evaluating models. They established certain reasoning rules to infer and explore reasonable action plans based on the evaluation results, providing new ideas for problem solving in high ambiguity and uncertainty scenarios [43–45]. For example, Zhou et al. conducted safety risk assessment in the chemical industry using fuzzy Petri nets and proposed a safety risk inference method based on matrix operations. This method helps enterprises take targeted measures to reduce safety risks [46]. Guo et al. developed a comprehensive risk evaluation method using the FPN model for long-distance oil and gas transportation pipelines. Meanwhile, they used fuzzy inference rules to provide decision support for risk management of oil and gas pipelines, aiming to reduce risks [47]. Due to the characteristics of the epidemic-induced public panic, such as its invisibility, mutability, interactivity, high propagation, and high risk, the evaluation of emergency management capability concerning public panic necessitates a reasoning and evaluation approach that aligns more closely with human thinking and cognition. Particularly in scenarios characterized by high levels of uncertainty, vagueness, and stochasticity, the advantages offered by fuzzy Petri nets (FPNs) become evident [48]. Fuzzy Petri nets leverage expert knowledge and experience to establish inference rules that are clear, simple, easy to comprehend, and amenable to simulation. Furthermore, they can overcome the limitations posed by the lack of statistical data in public panic research. Considering these factors, this study selects FPN as the preferred method for investigating the capacity of governmental emergency response to public panic, aiming to develop a valuable and reliable tool.

In conclusion, the research on the emergency management capacity of secondary disasters, particularly public panic, faces several challenges. Firstly, existing studies primarily focus on the emergency response capacity for general emergencies, while paying little attention to evaluating the emergency management capacity specifically for public panic within the emergency response context. However, in the current social media communication environment, public panic has emerged as an essential secondary disaster, necessitating an urgent need for governments at all levels to enhance their emergency management capacity for public panic.

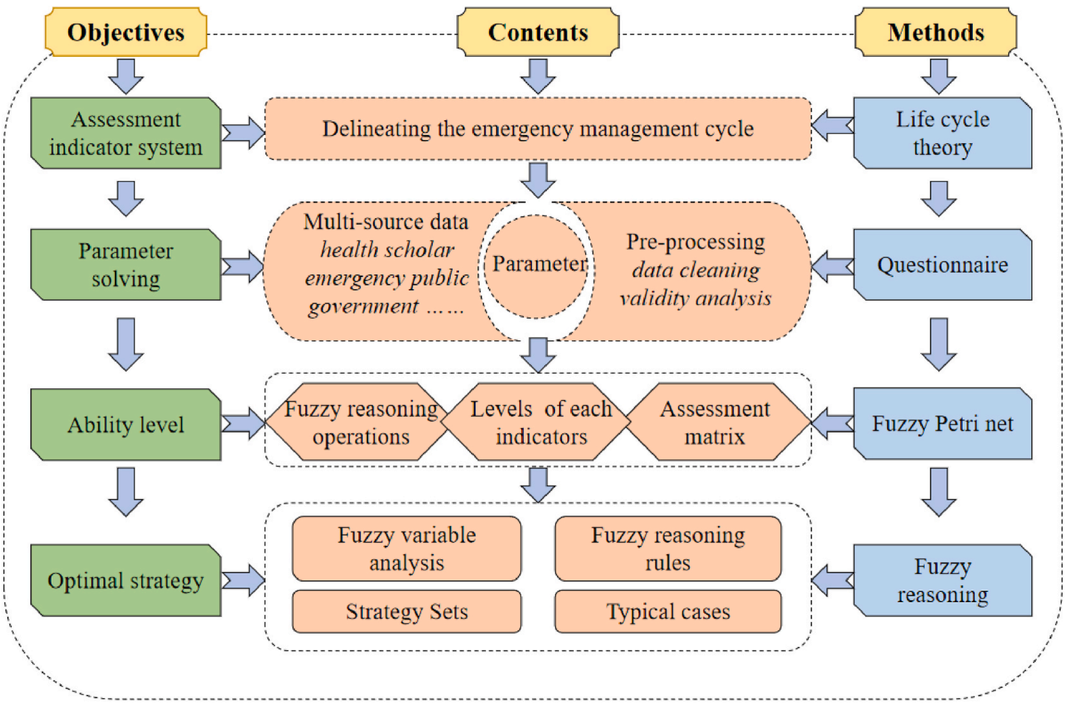


Fig. 1. Specific scheme and related flow chart.

Secondly, as a secondary disaster rooted in psychological perceptions, public panic possesses unique characteristics. The existing evaluation methods fail to effectively address the uncertainties, randomness, fuzziness, and insufficient statistical data associated with the influencing factors of public panic. Consequently, the conventional methods used in general disaster emergency management capacity research cannot be directly applied to the evaluation of public panic.

To solve the above problems. Based on life cycle theory, this paper divides the evolution of public panic into several stages, establishes a hierarchical assessment index system from multiple perspectives, uses the parallel computing capability of fuzzy Petri nets to address the relationships among influencing factors, evolution stages and different subjects, and establishes a systematic FPN assessment model and reasoning rules (the logic block diagram is shown in Fig. 1) to realize a comprehensive assessment and analysis of multiple subjects and the process of governmental public panic emergency management to provide powerful support for emergency management decision-making. At the same time, it provides a new research idea for the prevention and management of public panic.

3. Construction of the model

3.1. Establishment of the index system

The government's emergency management of public panic during a sudden epidemic involves a multistage and complex integrated emergency network system, and similar life-cycle partitioning can also be applied. The theory suggests that each element has different characteristics throughout the process, from the creation to the end of the crisis; that there are differences in their characteristics at each stage of the development of the crisis; and that there are differences in the evolutionary stages of the life cycle that are not completely linear [49,50]. Furthermore, the earlier crisis factors are discovered, the easier it is to do away with them and prevent or lessen the negative effects of the crisis [51]. In summary, this study divides the development of public panic into four stages, the gestation period, outbreak period, diffusion period, and fading period, based on Stephen Fink's division of crisis communication of emergencies [52], as shown in Fig. 2.

Based on this, this study uses the public panic life cycle in an outbreak as a data dimension, perceives the fluctuation of event content and emotion in each stage of the life cycle and divides the public panic evaluation index system into six subsystems: a risk perception system, a pre-security system, a monitoring and warning system, an emergency response system, an emotional guidance and reconstruction system, and an emergency review system. Each of these subsystems plays a crucial role in the government's ability to respond to emergencies when they occur. The analysis of the influencing factors of the urban emergency response system and related literature [53–55], as shown in Table 1, led to the establishment of a governmental public panic emergency response capability assessment index system based on life cycle theory, which includes 6 secondary indicators and 36 tertiary indicators.

3.2. FPN assessment model

3.2.1. Construction of the FPN assessment model

The evaluation index system (Table 1) is transformed into an FPN assessment model through the basic fuzzy rule logic relationship [56,57], as shown in Fig. 3.

3.2.2. Reasoning steps

To more clearly express the assessment model of government emergency management capabilities [58–60], it is defined as a 7-tuple:

$$\mathrm{FPN} = (P\ ,\ T\ ,\ I\ ,\ O\ ,\ U\ ,\ \lambda\ ,\ M) \tag{1}$$

As shown in **Equation (1)**, where.

$P = (p_1, p_2, \ldots\ldots, p_n)$ is a finite set of places. P is defined as a set of influential factors that impose constraints on the government's emergency management;

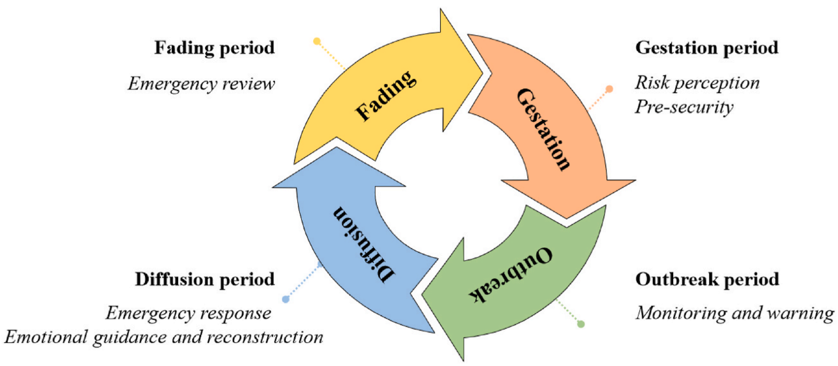


Fig. 2. The life cycle of public panic in sudden outbreaks.

Table 1
Emergency management capability assessment indicator system.

Primary indicators	Secondary indicators	Tertiary indicators
Emergency management capacity of public panic during an unexpected epidemic P_{43}	Risk perception capability P_{37}	Awareness of panic P_1
		Completeness of knowledge P_2
		Degree of involvement of relevant experts P_3
		Public awareness of the scientific management of the pandemic and emotions P_4
	Pre-security capability P_{38}	Division of responsibilities of relevant units P_5
		Ability to manage social opinion P_6
		Development and implementation of relevant standards P_7
		Overall quality of the personnel involved P_8
		Advanced degree of technical equipment P_9
		Completeness of the database P_{10}
		Degree of protection of dedicated funds P_{11}
		Preparation of emergency plans P_{12}
	Monitoring and warning capability P_{39}	Data collection capability P_{13}
		Information processing capability P_{14}
		Analysis of the possibility of panic events P_{15}
		Information feedback capability P_{16}
		Advanced monitoring technology P_{17}
		Technical competence of relevant personnel P_{18}
		Degree of classification of the early warning level P_{19}
	Emergency response capability P_{40}	Government interdepartmental coordination capacity P_{20}
		The case of social linkage P_{21}
		Status of experience in handling panic incidents P_{22}
		Speed of response from relevant departments P_{23}
		Command and decision-making capabilities P_{24}
		Orderliness of graded response P_{25}
	Emotional guidance and reconstruction capability P_{41}	Information distribution channel selection P_{26}
		Degree of publicly relevant information P_{27}
		Timeliness of information delivery P_{28}
		Regulation of media coverage (including self-media) P_{29}
		Public awareness and education P_{30}
		Public informed feedback P_{31}
		Assessment of social impact P_{32}
	Emergency review capability P_{42}	Investigation of the cause of the incident P_{33}
		Accountability for incidents P_{34}
		Public opinion survey on panic governance P_{35}
		Feedback improvement status P_{36}

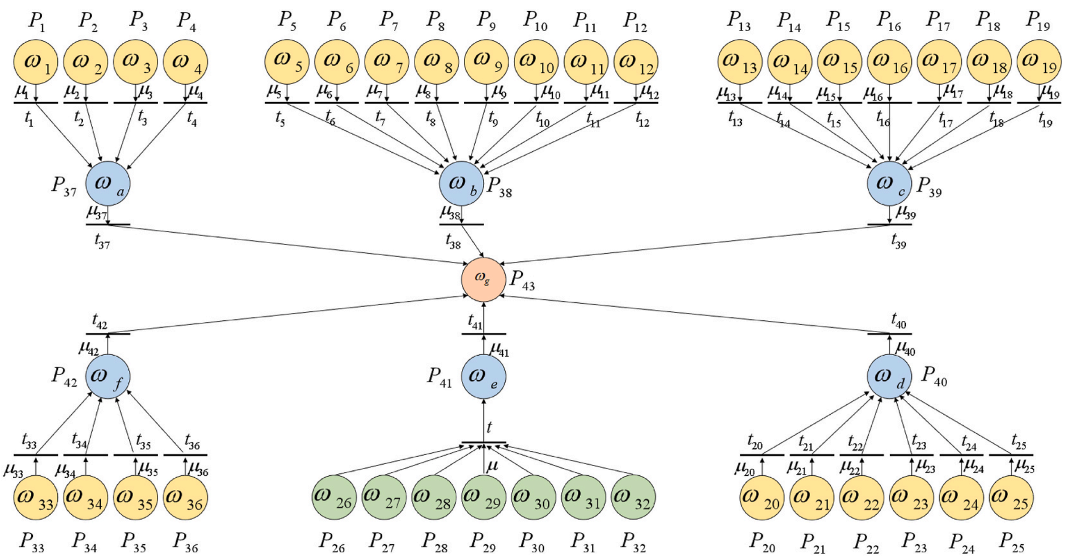


Fig. 3. FPN assessment model.

$T = (t_1, t_2, \ldots\ldots, t_n)$ is a finite set of transitions. T denotes the set of behaviors that encompass the occurrence process of factors affecting the emergency management capability;

$I = (w_{ij})$ is the $n \times m$ input matrix, where I indicates the presence or absence of a directed arc from p_i to t_j ($i = 1,2,3\ldots\ldots,n; j = 1,2,3,\ldots\ldots,m$). When p_i is an input to t_j, $w_{ij} = 1$; otherwise, $w_{ij} = 0$. Herein, I denotes the importance of behaviors that affect emergency management capabilities;

$O = (r_{ij})$ is the $n \times m$ output matrix, where O records existence or non-existence of a directed arc from p_i to t_j ($i = 1,2,3\ldots\ldots,n; j = 1,2,3,\ldots\ldots,m$). When p_i is the output of t_j, $r_{ij} = 1$; otherwise, $r_{ij} = 0$. In this paper, O is the output relationship between contingency capacity behavior t_j and contingency capacity influencing factors p_i;

U: $T \rightarrow [0,1]$ denotes the confidence function, $F(t_j) = \mu_j (j = 1,2,3,\ldots\ldots,m)$. μ_j indicates the confidence level of the emergency management capability behavior (t_j);

λ: $P \rightarrow [0,1]$ is the threshold value for the occurrence of behavior t_j. The behavior occurs when the confidence level of its influencing factor p_i is greater than the threshold value (λ);

$M(0)$ is the initial state matrix of order $n \times q$. In this paper whose element $M_{ij}^0 = [0,1]$ represents the initial state value of the emergency management capability influencing factor p_i at level j, representing its credibility, and $n \times q$ is the state of n emergency management capability influencing factor in q levels. $M(k)$ is the state matrix after change k has occurred.

Following the definition of FPNs, input matrix I and output matrix O are obtained, where $|P| = n, |T| = m$. their corresponding matrix forms are $I = (w_{ij})$, $O = (r_{ij})$. The initial state matrix $M(0)$ is obtained by analyzing the results of the questionnaire. The fuzzy variation confidence vector V is calculated from the weight matrix ω_i of the evaluation indicators. The specific fuzzy reasoning steps are shown below:

Step 1: Make initial state $k = 0$ when the behavior occurs and obtain the credibility of the initial influencing factors by calculating $I^T M(k)$, i.e., the credibility with which the variation can be fired.
Step 2: The plausibility of the occurrence of the behavior is calculated by $V \otimes O$, i.e., the credibility of the output influences after the variation has occurred.
Step 3: Calculate the next state after the behavior occurs, where the confidence level of the influencing factor becomes $M(k+1) = M(k) \oplus \{[V \otimes O][I^T M(k)]\}$, i.e., the next state after the variation has occurred.
Step 4: Determine whether $M(k+1)$ and $M(k)$ are equal. When $M(k+1) \neq M(k)$ is triggered after a change, it means that there is still a variation action that has not been triggered, then set $k = k+1$ and go to step 3 to continue the iteration; when triggering the variation makes $M(k+1) = M(k)$, it indicates that the variation is completed, and the final state matrix is obtained.
Step 5: The emergency management capability level F is obtained by calculating $M(k)Q^T$. F is a matrix of order $n \times 1$. It represents the level values of n influencing factors, where the last element indicates the grade value of the government's comprehensive emergency management capability. $Q = (10, 8, 6, 4, 2)$ is the evaluation matrix, and its evaluation criteria are shown in Table 2.

3.3. Reasoning rules of the FPN

3.3.1. Fuzzy variable analysis

Based on the calculation results of the FPN assessment model, risk perception capability, pre-security capability, monitoring and warning capability, emergency response capability, emotional guidance and reconstruction capability, and emergency review capability are defined as $P_1 - P_6$, where P_1, P_3, P_4, P_5 take the values of L and H (low and high) and P_2, P_6 take the values of L, M, H (low, medium, high). The specific variable assignments are shown in Table 3.

3.3.2. Fuzzy reasoning rules

For the decision-making characteristics of governmental public panic emergency management during a sudden epidemic, the fuzziness of rules is more applicable to the reasoning of strategies. Therefore, uses a fuzzy Petri net as a tool, takes the above index system as the basis, takes the abilities of risk perception, pre-security, monitoring and warning, emergency response, emotional guidance and reconstruction, and emergency review as the main body of strategies, extends them to the governmental emergency management process, and establishes fuzzy reasoning rules of public panic multiprogram preference. In fuzzy systems, the reasoning rule employed is the "if-then" rule. This rule constitutes a sequence of conditional statements and result statements, serving to map the input variable state to the output variable state. Thus, in the context of this paper, each reasoning rule is represented in the form of a fuzzy "if-then" statement [43,44]. The specific fuzzy reasoning rules are shown below:

Table 2
Emergency management capability assessment matrix.

Ability levels	Evaluation values
High	8–10
Relatively high	$6 \leq 8$
Medium	$4 \leq 6$
Relatively low	$2 \leq 4$
Low	$0 \leq 2$

Table 3
Assignment table of secondary index variables.

Secondary indicators	Variable symbols	Fuzzy language variables
Risk perception capability	P_1	*L*
		H
Pre-security capability	P_2	*L*
		M
		H
Monitoring and warning capability	P_3	*L*
		H
Emergency response capability	P_4	*L*
		H
Emotional guidance and reconstruction capability	P_5	*L*
		H
Emergency review capability	P_6	*L*
		M
		H

$$R1: \text{IF } (P_{37} \rightarrow L) \text{ and } (P_{38} \rightarrow L) \text{ and } (P_{39} \rightarrow L) \text{ and } (P_{41} \rightarrow H) \text{ and } (P_{42} \rightarrow H) \text{ THEN Strategy is 1;}$$

$$R2: \text{IF } (P_{39} \rightarrow H) \text{ and } (P_{40} \rightarrow L) \text{ and } (P_{41} \rightarrow L) \text{ and } (P_{42} \rightarrow H) \text{ THEN Strategy is 2;}$$

$$R3: \text{IF } (P_{37} \rightarrow H) \text{ and } (P_{38} \rightarrow H) \text{ and } (P_{41} \rightarrow H) \text{ and } (P_{42} \rightarrow L) \text{ THEN Strategy is 3;}$$

$$R4: \text{IF } (P_{38} \rightarrow H) \text{ and } (P_{39} \rightarrow H) \text{ and } (P_{40} \rightarrow L) \text{ and } (P_{41} \rightarrow L) \text{ and } (P_{42} \rightarrow M) \text{ THEN Strategy is 4;}$$

$$R5: \text{IF } (P_{37} \rightarrow L) \text{ and } (P_{38} \rightarrow L) \text{ and } (P_{40} \rightarrow H) \text{ and } (P_{42} \rightarrow L) \text{ THEN Strategy is 5;}$$

$$R6: \text{IF } (P_{39} \rightarrow L) \text{ and } (P_{41} \rightarrow L) \text{ and } (P_{42} \rightarrow M) \text{ THEN Strategy is 6;}$$

$$R7: \text{IF } (P_{38} \rightarrow M) \text{ and } (P_{41} \rightarrow L) \text{ and } (P_{42} \rightarrow L) \text{ THEN Strategy is 7;}$$

3.3.3. Strategy sets

According to the abovementioned FPN assessment model, the content of government emergency management decisions should focus on one or more aspects [61,62], such as risk perception, pre-security, monitoring and warning, emergency response, and emergency review. Therefore, to achieve the goal of the best governance effect, the content of public panic emergency management concerns should have primary and secondary importance and be selective. For the various scenarios faced by governmental public panic emergency management during an outbreak, the solution that best matches them should be chosen. For this purpose, this study constructs the following strategy sets with typical cases.

Str 1: The government strengthens the crisis ideology

The government should pay more attention to public panic. While disclosing information, it is also important to interpret and explain relevant policies and systems and to invite government personnel or experts and scholars to conduct web-based thematic interpretations. At the same time, through the media, internet, television and other information channels, it is important to answer questions and solve issues of public concern. Finally, the construction of a comprehensive and interactive integrated information management platform for big data networks provides technical support for government staff to conduct risk monitoring and early warning while allowing free discussion between staff and the public to reach consensus and alleviate panic in a timely manner.

Str 2: Vertical linkage, hierarchical response, a sound information sharing system, and controlling the direction of public opinion

When an emergency occurs, it is important to first establish a strong, efficient emergency command center with sufficient authority to break the limitations of various departments and regions and achieve unified leadership, unified command and unified dispatch. Second, a three-dimensional and effective information dissemination and feedback mechanism should be created to improve information communication among various departments, realize information sharing, and improve the speed with which the government responds to emergencies. Finally, relevant network information topics are set based on public opinion development trends, and the direction of public opinion can be controlled in a targeted manner to reduce unnecessary panic while avoiding network resource waste.

Str 3: Establishing a review body for emergencies to improve government credibility

It is important to apply scientific and standardized management methods and tools, conduct investigations, act in accordance with laws and regulations, and develop and implement specific accountability mechanisms. The formation of public participation mechanisms and public oversight to report legal violations should be encouraged. The government should publicize the process and outcomes of dealing with emergencies as early as possible to address the public's right to know while also collecting public feedback. Additionally, it should also take the crisis as an opportunity to learn from past mistakes, plug gaps, and promote the improvement and perfection of emergency plans, related policies, and management systems in a targeted manner to improve emergency prevention and control capabilities and governance capacity.

Str 4: Guiding the direction of public opinion and conducting mental health counseling to realize positive interactions between the government and society

After the incident, it is important to expand social participation avenues through radio, television, microblogging, and other media and create a situation of national mobilization, collective participation, and common confrontation to further prevent panic. Meanwhile, it is also necessary to achieve timely and effective information release, strengthen information supervision, smooth information transmission channels, avoid panic to the greatest extent possible, reduce control costs, and improve control efficiency during the event handling process. Finally, relevant experts should be organized to provide public mental health counseling and follow-up work, which can improve the public's ability to protect themselves and their psychological tolerance as well as the government's credibility and transparency.

Str 5: Transforming public panic prevention and control thinking and establishing a regular management model

The government should rely on the network platform to create an intelligent database of emergencies, incorporating experts in emergency management to provide more scientific and reasonable suggestions for public panic source management. Moreover, it should also collaborate with relevant universities, businesses, and research institutions to develop emergency management software, systems, and related equipment that are urgently needed in the source management process to provide preliminary technical support for panic management. Meanwhile, the prevention and control of public panic should be incorporated into routine management. It is important to conduct extensive public awareness and education on epidemic prevention and control as well as scientific emotion management and raise public risk awareness. The government should focus on improving staff members' crisis management, public opinion guidance, and social management skills as well as developing efficient government working mechanisms and strengthening effective government system oversight.

Str 6: Improving the early warning system and strengthening the information construction of government functions

The government should improve the emergency plan by clarifying and organizing the various resources, collaboration mechanisms, connectivity, graded response, and security measures required for emergency response so that individuals can "follow the map" after an incident. Artificial intelligence, big data, and other emergency technologies are being used to improve the quality and efficiency of early warning by informing and intelligently monitoring pandemic spread trends, network opinion, information dissemination, and data statistics. Furthermore, to seize the opportunity to prevent and control, meet the public's right to know, and alleviate public panic, it is important to build a network information exchange platform, clarify the authority and scope of information release, and release timely and comprehensive information.

Str 7: Comprehensive enhancement, building a comprehensive emergency management mechanism

It is important for the government to improve its monitoring and early warning capabilities as well as emergency response capabilities by collaborating on emergency response plans, clarifying emergency response coordination mechanisms, command mechanisms, resource guarantees, and disposal procedures and conducting regular emergency drills. On the one hand, big data should be utilized to create a centralized network information management platform that includes a network monitoring platform, an information dissemination platform, and a resource deployment platform to simplify resource deployment and information dissemination while avoiding the spread of false information that could cause social panic. On the other hand, through information media, the latest developments of the incident are released in real time to continuously strengthen the public's awareness of prevention and control, while work is reviewed and analyzed to compensate for the shortcomings of technical prevention and control and public opinion guidance.

Conclusively, in a practical application, the FPN assessment model can analyze the weak areas that affect the government's emergency management capability through the content and path of control variables. The reasoning rules of FPN can then be used to reason the appropriate decision scheme for the government to manage and significantly enhance its comprehensive emergency management capability.

4. Case study

4.1. Background

The end of 2021 saw the covert arrival of the coronavirus disease in the historic city of X. Unexpectedly, the epidemic spread quickly. In just 21 days, the number of new confirmed cases increased from 0 to over 1000. After December 26, the number of new cases exceeded 150 for 7 consecutive days, reaching a peak of 175 on the 27th [63]. Intense debates on social media platforms about this epidemic, which was dubbed "the most serious one after the closure of Wuhan" resulted from the clash of various public opinions. Led to the public experienced significant anxiety and panic, and the situation was very serious. Despite the chaos and disorder of the initial prevention and control measures, it was a true manifestation of governance's ability to handle the situation with decisive and efficient measures, strong leadership in deploying emergency treatment and improvement measures, and responding with sincerity to social concerns in a timely manner [64]. Therefore, considering the above factors, this paper examines the emergency management of public panic in cities and verifies the feasibility of the FPN assessment model and reasoning rules.

4.2. Fuzzy reasoning algorithms

4.2.1. Parameter solving

Step 1: According to the definition of an FPN, the input matrix I and output matrix O of the FPN model can be obtained:

$I = (w_{ij})$. When $i = j$, $w_{ij} = 1$; otherwise, $w_{ij} = 0$.

$O = (r_{ij})$. When the relationship between i and j is as shown in Table 4 below, $r_{ij} = 1$; otherwise, $r_{ij} = 0$.

Step 2: Calculation of indicator weight values.

This study defines the same weight values for the tertiary indicators under each secondary indicator. As shown in Table 5, for example, risk perception ability includes awareness of panic, completeness of knowledge, degree of involvement of relevant experts, and public awareness of the scientific management of the pandemic and emotions. The four indicators are equally weighted at 0.250, which leads to a weight matrix V.

Step 3: Use the questionnaire to conduct the survey and obtain the data needed for the empirical analysis.

The final form of the questionnaire consisted of three sections. The first section briefly explained the objectives of the study. The second section aimed to collect basic information of the respondents, e.g., the years of work and nature of work. The third section investigated the relative importance of the 36 tertiary indicators from the respondents' point of view according to a 5-point Likert scale [65], where 5 means "extremely important", 4 means "important", 3 means "neutral", 2 means "less important", and 1 means "unimportant". A sample of the third section of the questionnaire is presented in **Appendix** Table A1.

The investigation was approved by the Ethics Committee of the Institute of Disaster Prevention. Based on theoretical foundations and indicator systems, a questionnaire was designed and distributed via email. A total of 100 questionnaires were sent out. Out of these, 93 valid questionnaires were collected, resulting in an effective response rate of 93 %. This sample size fulfills the requirements for studying the influencing factors of government emergency management capabilities. The majority of the respondents to the questionnaire were representatives of the emergency system, health system, local government, relevant academics, and the general public. Because, these respondents could intuitively and thoroughly reflect the cognitive circumstances of various groups regarding the government's public panic management during the epidemic and ensure its rationality. Among the valid questionnaires recovered, there were 5 emergency system workers, accounting for 5.38 % of the total number of valid questionnaires; 21 health system workers, accounting for 22.58 % of the total number of valid questionnaires; 41 local government workers, accounting for 44.09 % of the total number of valid questionnaires; 4 related scholars, accounting for 4.3 % of the total number of valid questionnaires; and 22 members of the general public, accounting for 23.66 % of the total number of valid questionnaires. The data collected by the questionnaire survey are summarized in **Appendix** Table A2. The evaluation vector of each three-level indicator, i.e., the initial state matrix, was derived through comprehensive analysis of questionnaire $M(0)$, as shown in **Equation (2)**.

Table 4
Output matrix correspondence.

i	37	38	39	40	41	42	43
j	1–4	5–12	13–19	20–25	26–32	33–36	37–42

Table 5
Weights of the tertiary indicators.

Indicators	$P_1 - P_4$	$P_5 - P_{12}$	$P_{13} - P_{19}$	$P_{20} - P_{25}$	$P_{26} - P_{32}$	$P_{33} - P_{36}$
Weights	0.250	0.125	0.143	0.167	0.143	0.250

$$M(0)=\begin{bmatrix} 0.38 & 0.43 & 0.15 & 0.03 & 0.01 \\ 0.34 & 0.41 & 0.19 & 0.06 & 0 \\ 0.36 & 0.34 & 0.27 & 0.03 & 0 \\ 0.48 & 0.28 & 0.23 & 0.01 & 0 \\ 0.47 & 0.31 & 0.19 & 0.02 & 0.01 \\ 0.46 & 0.31 & 0.16 & 0.06 & 0.01 \\ 0.44 & 0.36 & 0.16 & 0.04 & 0 \\ 0.44 & 0.36 & 0.16 & 0.04 & 0 \\ 0.31 & 0.42 & 0.22 & 0.05 & 0 \\ 0.37 & 0.36 & 0.18 & 0.09 & 0 \\ 0.43 & 0.38 & 0.15 & 0.04 & 0 \\ 0.45 & 0.37 & 0.12 & 0.05 & 0.01 \\ 0.45 & 0.39 & 0.12 & 0.03 & 0.01 \\ 0.42 & 0.41 & 0.15 & 0.02 & 0 \\ 0.40 & 0.37 & 0.19 & 0.04 & 0 \\ 0.43 & 0.37 & 0.17 & 0.02 & 0.01 \\ 0.41 & 0.43 & 0.12 & 0.03 & 0.01 \\ 0.36 & 0.48 & 0.13 & 0.03 & 0 \\ 0.40 & 0.46 & 0.10 & 0.03 & 0.01 \\ 0.39 & 0.46 & 0.12 & 0.02 & 0.01 \\ 0.44 & 0.41 & 0.13 & 0.02 & 0 \\ 0.37 & 0.43 & 0.16 & 0.04 & 0 \\ 0.46 & 0.42 & 0.09 & 0.03 & 0 \\ 0.42 & 0.42 & 0.14 & 0.02 & 0 \\ 0.45 & 0.42 & 0.10 & 0.03 & 0 \\ 0.46 & 0.41 & 0.10 & 0.02 & 0.01 \\ 0.43 & 0.43 & 0.11 & 0.02 & 0.01 \\ 0.48 & 0.41 & 0.08 & 0.02 & 0.01 \\ 0.44 & 0.45 & 0.07 & 0.03 & 0.01 \\ 0.42 & 0.42 & 0.12 & 0.04 & 0 \\ 0.44 & 0.40 & 0.13 & 0.02 & 0.01 \\ 0.41 & 0.44 & 0.11 & 0.04 & 0 \\ 0.43 & 0.44 & 0.10 & 0.03 & 0 \\ 0.42 & 0.38 & 0.13 & 0.04 & 0.03 \\ 0.40 & 0.39 & 0.14 & 0.06 & 0.01 \\ 0.44 & 0.32 & 0.20 & 0.04 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (2)$$

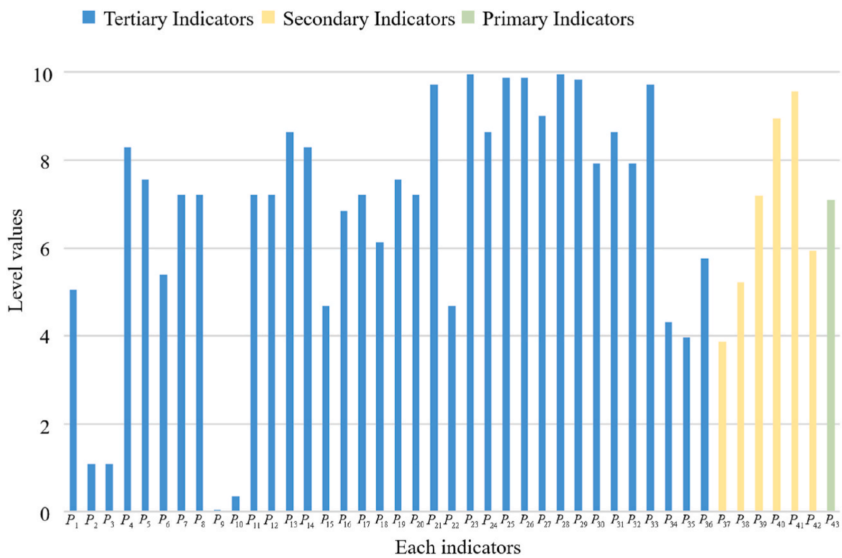


Fig. 4. Level values of each indicators.

$$M(2) = M(3) = \begin{bmatrix} 0.38 & 0.43 & 0.15 & 0.03 & 0.01 \\ 0.34 & 0.41 & 0.19 & 0.06 & 0 \\ 0.36 & 0.34 & 0.27 & 0.03 & 0 \\ 0.48 & 0.28 & 0.23 & 0.01 & 0 \\ 0.47 & 0.31 & 0.19 & 0.02 & 0.01 \\ 0.46 & 0.31 & 0.16 & 0.06 & 0.01 \\ 0.44 & 0.36 & 0.16 & 0.04 & 0 \\ 0.44 & 0.36 & 0.16 & 0.04 & 0 \\ 0.31 & 0.42 & 0.22 & 0.05 & 0 \\ 0.37 & 0.36 & 0.18 & 0.09 & 0 \\ 0.43 & 0.38 & 0.15 & 0.04 & 0 \\ 0.45 & 0.37 & 0.12 & 0.05 & 0.01 \\ 0.45 & 0.39 & 0.12 & 0.03 & 0.01 \\ 0.42 & 0.41 & 0.15 & 0.02 & 0 \\ 0.40 & 0.37 & 0.19 & 0.04 & 0 \\ 0.43 & 0.37 & 0.17 & 0.02 & 0.01 \\ 0.41 & 0.43 & 0.12 & 0.03 & 0.01 \\ 0.36 & 0.48 & 0.13 & 0.03 & 0 \\ 0.40 & 0.46 & 0.10 & 0.03 & 0.01 \\ 0.39 & 0.46 & 0.12 & 0.02 & 0.01 \\ 0.44 & 0.41 & 0.13 & 0.02 & 0 \\ 0.37 & 0.43 & 0.16 & 0.04 & 0 \\ 0.46 & 0.42 & 0.09 & 0.03 & 0 \\ 0.42 & 0.42 & 0.14 & 0.02 & 0 \\ 0.45 & 0.42 & 0.10 & 0.03 & 0 \\ 0.46 & 0.41 & 0.10 & 0.02 & 0.01 \\ 0.43 & 0.43 & 0.11 & 0.02 & 0.01 \\ 0.48 & 0.41 & 0.08 & 0.02 & 0.01 \\ 0.44 & 0.45 & 0.07 & 0.03 & 0.01 \\ 0.42 & 0.42 & 0.12 & 0.04 & 0 \\ 0.44 & 0.40 & 0.13 & 0.02 & 0.01 \\ 0.41 & 0.44 & 0.11 & 0.04 & 0 \\ 0.43 & 0.44 & 0.10 & 0.03 & 0 \\ 0.42 & 0.38 & 0.13 & 0.04 & 0.03 \\ 0.40 & 0.39 & 0.14 & 0.06 & 0.01 \\ 0.44 & 0.32 & 0.20 & 0.04 & 0 \\ 0.3900 & 0.3650 & 0.2100 & 0.0325 & 0.0025 \\ 0.4213 & 0.3587 & 0.1675 & 0.0488 & 0.0037 \\ 0.4104 & 0.4161 & 0.1401 & 0.0286 & 0.0057 \\ 0.4225 & 0.4275 & 0.1236 & 0.0267 & 0.0017 \\ 0.4404 & 0.4233 & 0.1030 & 0.0272 & 0.0071 \\ 0.4225 & 0.3825 & 0.1425 & 0.0425 & 0.0100 \\ 0.4187 & 0.3963 & 0.1481 & 0.0345 & 0.0051 \end{bmatrix} \tag{3}$$

4.2.2. Operations of the FPN assessment model

According to the fuzzy reasoning steps of the FPN assessment model, the above derived parameters were substituted into $M(k+1) = M(k) \oplus \{[V \otimes O][I^T M(k)]\}$ for the fuzzy reasoning operation using MATLAB software. Conclusively, $M(2) = M(3)$ was determined, as shown in **Equation (3)**. $M(2)$ was then substituted into Equation $F = M(k)Q^T$, and the calculation results were normalized. Finally, the emergency management capability level values for each indicator in the FPN evaluation model are obtained, as shown in Fig. 4. The larger the value is, the stronger the government's emergency management capability under that indicator.

The level values of each indicators, obtained by matching the arithmetic results of the above FPN assessment model with the emergency capability evaluation matrix, are shown in Table 6. The level values for the primary and secondary indicators are F = [3.8700, 5.2236, 7.1856, 8.9424, 9.5652, 5.9400, 7.0956], and the risk perception capability is 3.8700, which indicates that the emergency management capability level of this indicator is relatively low. The pre-security capability is 5.2236, which indicates that the emergency management capability level of this indicator is medium. The monitoring and warning capability is 7.1856, which indicates that the emergency management capability level of this indicator is relatively high. The emergency response capability is 8.9424, which indicates that the emergency management capacity of this indicator is high. The emotional guidance and reconstruction capacity is 9.5652, indicating that the emergency management capacity of this indicator is high. The emergency review capacity is 5.9400, indicating that the emergency management capacity of this indicator is medium.

In conclusion, the overall emergency management capability of the X City government is rated as medium. The main factors contributing to the moderate level of emergency management capability in X City are risk perception capability, pre-security capability, and emergency review capability. Similarly, based on the level values of the tertiary indicators, the main factors constraining the level of secondary indicators can be identified.

4.2.3. Operations of the reasoning rules

The above index levels are introduced into MATLAB for operation in accordance with the reasoning rules of FPN, and the final decision results are displayed in Fig. 5. Therefore, based on the characteristics of the crisis event, the government should choose strategy number five, which has the smallest deviation in results, as the response strategy. This strategy involves transforming public panic prevention and control and establishing a regular management model. The X city government should focus on enhancing resource security for panic events, public panic awareness levels, and a timely and efficient review and summary following such events.

5. Discussion

5.1. Results discussion

The purpose of this study is to explore and understand the government's emergency management capability in addressing public panic during the governance process of COVID-19, as well as how to alleviate public panic. We conducted an analysis on the emergency management situation of the government in City X. The results revealed management issues in risk perception, resource provision, and post-recovery aspects. The following sections will provide a detailed discussion on these issues.

(1) Since the notification of the first confirmed case, the city of X has focused on the flow of people and nucleic acid screening. Given the handling of the unfortunate situation of being unable to seek medical attention during the prevention and control of the epidemic, the panic of individuals did not attract the attention of the government and relevant departments [66,67]. Therefore, there were issues with the overall emergency management process of the X city government, including low risk awareness, poor monitoring and early warning procedures, and insufficient information research and judgment skills, which meant that the event's triggering factors could not be quickly screened [68]. This led to insufficient follow-up monitoring skills and a lack of precision in research and judgment for effective early warning, which is consistent with the insufficient risk perception ability calculated by the model.

(2) X city experienced closed management with the emergence of food hoarding, distribution difficulties, "a code through" paralysis [69,70], inability to access medical care and a number of public opinion events that continued to ferment. This social phenomenon reflected the inadequacies of the government's ability to protect resources in this incident, but it was also the main cause of the spread of public fear. Therefore, the X municipal government and related departments in the emergency management of panic, the emergency plan and policy measures were not implemented effectively, the organizational synergy and policy convergence were not sufficient, and the technical and material security capacity were not sufficient [68], consistent with the model calculation of insufficient pre-security capability.

(3) The X city government only focused on the prevention and control of the epidemic itself and ignored its social effects, such as the psychological effects of heightened public tension, anxiety, and even panic. The investigation did not locate the source of the panic spread in a timely manner, and those responsible were not held accountable in a timely fashion, seriously undermining the government's credibility. Therefore, the X municipal government's understanding of normalized prevention and control in the process of managing public panic emergencies was insufficient, and the responsibility supervision mechanism was weak [68], which is consistent with the model's estimate of insufficient emergency review capacity.

Table 6
The ability levels of each indicators.

Sndicators	Results	Ability levels	Sndicators	Results	Ability levels
P_1	5.0400	Medium	P_{23}	9.9400	High
P_2	1.0800	Low	P_{24}	8.6400	High
P_3	1.0800	Low	P_{25}	9.8800	High
P_4	8.2800	High	P_{26}	9.8800	High
P_5	7.5600	Relatively high	P_{27}	9.0000	High
P_6	5.4000	Medium	P_{28}	9.9400	High
P_7	7.2000	Relatively high	P_{29}	9.8400	High
P_8	7.2000	Relatively high	P_{30}	7.9200	Relatively high
P_9	0.0400	Low	P_{31}	8.6400	High
P_{10}	0.3600	Low	P_{32}	7.9200	Relatively high
P_{11}	7.2000	Relatively high	P_{33}	9.7200	High
P_{12}	7.2000	Relatively high	P_{34}	4.3200	Medium
P_{13}	8.6400	High	P_{35}	3.9600	Relatively low
P_{14}	8.2800	High	P_{36}	5.7600	Medium
P_{15}	4.6800	Medium	P_{37}	3.8700	Relatively low
P_{16}	6.8400	Relatively high	P_{38}	5.2236	Medium
{P		\nolimits_ {17}}	7.2000		Relatively high
P_{39}	7.1856	Relatively high			
P_{18}	6.1200	Relatively high	P_{40}	8.9424	High
P_{19}	7.5600	Relatively high	P_{41}	9.5652	High

(continued on next page)

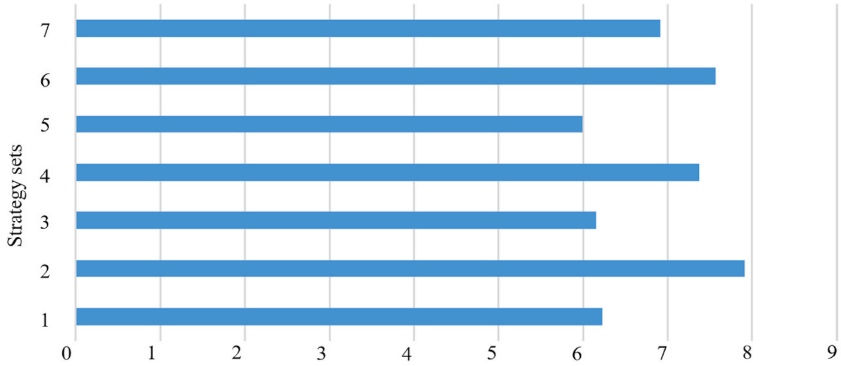
The government quickly realized that whenever there is a local increase in cases and emergency measures are taken, the general public inevitably experiences tension, anxiety, and even panic [71]. Hence, while reducing and controlling the current and future COVID-19 epidemic, it is necessary to pay attention to other decisions to prevent and alleviate the accompanying psychological crisis. Existing research has shown that to prevent the harmful effects of panic on public mental health, the government should first strengthen information dissemination [72,73] based on the overall emergency plan for emergencies [74], provide policy interpretations, involve expert groups to guide the work, meet the public's right to know, improve public psychological resilience [75], and reduce their panic, as well as other depressive symptoms and stress conditions, for example, through cognitive behavioral therapy (CBT) via online platforms [76,77]. Meanwhile, information management platforms should be established to collect and process relevant information, introduce advanced technological devices, effectively enhance the level of resource provision and monitoring and early warning capabilities, and control the spread of misleading information through social media platforms [78,79]. Finally, it is necessary to increase supervision, improve accountability mechanisms, investigate and punish relevant personnel, accurately account for them, and expose them in a timely manner to curb the spread of panic and effectively protect public safety and physical health [80]. By comparing the results of the FPN assessment model and reasoning rules with the development process of public panic events in reality and the governance status investigated in the current study, it was found that the case studied in this paper aligns well with the driving factors and management strategies of real-life public panic events, providing a solid basis for the assessment and enhancement of the government's emergency management capability in addressing public panic during sudden epidemics, demonstrating a certain level of feasibility.

5.2. Validity discussion

The effectiveness of the FPN assessment model and reasoning rules depends not only on the feasibility of individual cases but also on the overall empirical performance. To further validate the model and reasoning rules' effectiveness, this study employed two approaches: Firstly, two representative cases of panic management were selected for comprehensive analysis and discussion. Secondly, a comparison was conducted with commonly used methods for evaluating emergency management. Through these two avenues, the validity and reliability of the model and reasoning rules were thoroughly examined.

The Wuhan city government was not aware of the potential for panic during the early stages of the 2019 coronavirus outbreak, which allowed for the growth of online rumors and subsequent widespread public panic. The results of this study's small-scale investigation of actual government management suggest that strategy 6 is the best option for such circumstances. In fact, the government efficiently carried out its obligations after the "city closure" measures were announced, did a good job of organization and coordination, and paid close attention to how the relevant policies were publicized and covered by the media. Meanwhile, it also strengthened its control over the media's informational dissemination and revision of the applicable emergency response plans [81]. The Wuhan government's actual response strategies were consistent with strategy 6 when the government's measures were extracted and compared to the strategy set developed in this study. In addition, since the coronavirus outbreak, Shanghai has been a model for various local governments to learn from because of its advanced emergency management capabilities and precise panic prevention and control model. This study also conducted a small-scale examination of the situation during the new coronavirus epidemic in Shanghai in March 2022, and the results suggest that the government should choose strategy 2 for this scenario. The government established pertinent topics and investigated them in response to issues such as "overpriced vegetables" and panic about medical resources and introduced corresponding policy measures [82,83] to allay public panic. Moreover, the government also strengthened information communication between various departments, realized information sharing, improved social linkage mechanisms, and sped up response times based on the "one network unified management" [84] network platform. Given the measures taken by the government and the comparison analysis with the strategy set constructed in this study, strategy 2 is consistent with the coping strategies adopted by the Shanghai government.

Aside from qualitative-based analytical methods, traditional quantitative evaluation methods for emergency management capabilities include fuzzy comprehensive evaluation, BP neural networks, and projection pursuit models. Among these, the fuzzy comprehensive evaluation method can handle fuzzy uncertainty information and consider the mutual influence of multiple evaluation indices. However, it is heavily influenced by subjective factors in determining the membership function, resulting in the loss of fuzziness and a weakness in randomness, thereby impacting the evaluation results to some extent [85]. On the other hand, while BP neural networks possess strong nonlinear processing capabilities and fault tolerance, they exhibit slow convergence speeds and rely heavily on the training sample set. Training the model also requires a significant amount of data [86]. The projection pursuit model, driven directly by sample data without formal or mathematical limitations, is suitable for high-dimensional nonlinear evaluation problems. However, it may be computationally intensive and prone to information loss, overfitting, and sensitivity to data distribution. It is also less effective in analyzing highly nonlinear data [87]. Furthermore, none of these methods have the ability to visually present results in a concise and intuitive manner. In comparison to the aforementioned traditional evaluation methods, the formalized evaluation method proposed in this paper, which is based on fuzzy Petri nets, overcomes the limitations of these methods. It effectively addresses the challenges posed by uncertainty, randomness, fuzziness, and insufficient statistical data in evaluating the emergency management capability of public panic. As a result, the evaluation outcomes become more reliable, the presentation of results becomes more intuitive, and the overall process becomes simpler. Additionally, it is worth noting that the evaluation results obtained using fuzzy Petri nets align with the actual government's emergency management measures, as demonstrated by the previous case study. This further validates the feasibility of the proposed method.



Strategy sets	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7
Results	6.2323	7.9083	6.1497	7.3714	5.9940	7.5636	6.9096

Fig. 5. Preferred case of public panic emergency management program.

5.3. Values discussion

Based on the results of theoretical research and empirical analysis, this study not only provides new insights for scholars' theoretical research and policymakers' improvement measures but also holds significant reference value and practical significance for the effective evaluation of the government's emergency management capacity in addressing public panic during sudden events.

5.3.1. Theoretical values

Two aspects of this study's theoretical value are as follows. First, a mass panic emergency management capacity evaluation index system is suggested based on life cycle theory. This system corrects for the original static cognition of emergency management capacity and offers a more in-depth understanding of the content and structure of emergency management capacity from a dynamic perspective. Second, the group panic governance strategy set formed based on the fuzzy Petri net fully embodies the idea of cooperative governance theory with multiple subjects and scenarios, which complements the research findings of public panic governance, expands the application scenarios of fuzzy Petri, and further verifies its feasibility value in the field of public panic research.

5.3.2. Practical values

The following three aspects of this study's practical value are evident. First, the government is given suggestions for how to carry out public panic monitoring and early warning in a comprehensive and efficient manner by the multistage evaluation index system that was created on the basis of a systematic analysis of the influencing factors and evolution characteristics of mass panic. Second, the government deals with crises in the social, political, and economic spheres in addition to those in the health sector. The study of public panic's capacity for emergency management is helpful in encouraging the government to prioritize social goals over economic ones to better carry out its civic duties. Third, the government must gradually transition from opaque administrative governance to transparent administrative governance to address the secondary crisis of public panic brought on by public health emergencies. The study's findings offer government-specific recommendations on how to control public anxiety in an open and transparent manner.

6. Conclusion

Fuzzy Petri nets have excellent knowledge expression, reasoning and decision-making capabilities, and can graphically show the logical relationship between conditions and conclusions, and have been widely used in assessment and fuzzy reasoning. Based on these advantages, this study suggests a fuzzy Petri net-based emergency management capacity assessment model and reasoning rules based on life cycle theory to analyze the influencing factors of public panic and propose governance decisions for various scenarios to provide guidance for the governance of public panic. The study's conclusions primarily focus on the following elements.

First, based on life cycle theory, this paper systematically examines the influencing factors that limit the government's public panic governance and develops an assessment index system that can adequately address the government's public panic emergency management capability status. This system overcomes some of the ambiguity and uncertainty of assessment indices and offers a framework for the government to conduct public panic emergency capability assessments.

Second, by using the parallel processing capability of fuzzy Petri nets, this paper analyzes the development process of public panic in a set scenario and reproduces the process of a panic event from its emergence to its end. This not only reveals the influencing factors that limit the government's emergency response capability but also provides the best decision solution for the government's public panic management.

Finally, the example analysis led to the conclusion that the X city government's public panic emergency response capability level is at a medium level, and the necessary improvement measures are highly consistent with the actual emergency response performance. This demonstrates the viability of fuzzy Petri nets in the assessment of public panic emergency response capability.

Nevertheless, this paper has some limitations. First, some of the quantified tertiary indicators are fuzzy data based on questionnaire results, and the quantified results have some subjective bias. Second, the model reasoning process is complicated, which is not conducive to data analysis and processing. In subsequent research, in addition to considering more data resources, extracting more correlated indicator elements, and continuously optimizing the assessment model, we should study in depth how to induce the government to shift from administrative governance that prioritizes economic goals and obscurity to administrative governance that prioritizes social goals and transparency. In addition, the endogeneity problem embodied by the model is an extremely complex social phenomenon that merits in-depth study, and the two-way relationship between government public panic governance and public panic mentioned in this paper is only one of its many effects.

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Ethics declarations

This study was reviewed and approved by the Ethics Committee of the Institute of Disaster Prevention, with the approval number: 2022991008.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Cui Li: Writing – review & editing, Project administration, Investigation, Conceptualization. **Yiming Zhao:** Writing – original draft, Visualization, Methodology, Formal analysis. **Lei Gao:** Writing – review & editing. **Yuan Ni:** Methodology, Funding acquisition. **Xiaoxue Liu:** Writing – review & editing, Resources.

Declaration of competing interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work, there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e30316.

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