Review

Knowledge System Analysis on Emergency Management of Public Health Emergencies

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Abstract: The Coronavirus Disease 2019 (COVID-19) infectious pneumonia pandemic highlights the importance of emergency management of public health emergencies (EMPHE). This paper addresses the challenge of building a knowledge system for EMPHE research that may contribute to understand the spatial and temporal characteristics of knowledge distribution, research status, cutting-edge research and development trends, and helps to identify promising research topics and guide research and practice of EMPHE. Based on the Web of Science, this paper retrieves 1467 articles about EMPHE published from 2010 to date. Then, based on high-frequency keywords, we use CiteSpace to analyze their knowledge co-occurrence network, clustering network and knowledge evolution. Furthermore, we summarize the features and gaps in EMPHE research, providing references for future research directions. Based on the above analysis, this work constructs a knowledge system about EMPHE research, providing a comprehensive visual summary of the existing research in the field of EMPHE, with the aim to guide future research and practice.

Keywords: emergency management; public health emergencies; knowledge system; CiteSpace

1. Introduction

The COVID-19 infectious pneumonia pandemic has been sweeping the globe, bringing the term “public health emergency” into the public eye again. Public health emergency (PHE) means "sudden occurrence of major infectious disease that causes serious damage to public health, disease of unknown cause in groups, major food or occupational poisoning, or other events that seriously affect public health, which has the characteristics of suddenness, publicity, urgency, and seriousness, and also has high requirements for the timeliness, publicity and interaction of relevant information dissemination" [1]. In the past 10 years, the World Health Organization (WHO) has announced a total of six major PHEs of International Concern (PHEIC) [2]. These outbreaks have the characteristics of emergent viruses, long virus incubation periods, complex transmission routes, serious infection consequences, wider affected countries, and long pandemic cycles, having a great negative impact on the economy, society and public health of the affected areas (e.g., [3,4]).

The International Health Regulations define PHEIC as "unusual events that pose public health risks to other countries through the international spread of disease and that may require a coordinated international response”. This definition means “serious, sudden, unusual or unexpected pandemics;
the public health impact extends beyond the borders of the affected country and may require immediate international action” [5]. PHEIC may result in serious harmful consequences, leading to a series of chain reactions, such as a shortage of medical materials, public anxiety, regional closure, and economic recession [6,7].

EMPHE means quickly obtaining and effectively using relevant information and resources to improve the effectiveness and efficiency of emergency response in order to minimize the harm and negative impact of a PHE [8]. EMPHE involves many research fields, and more and more scholars from different disciplines have conducted relevant studies. Various research methods and research tools have been applied, making the research on EMPHE have interdisciplinary characteristics. Thus, the related research topics are very rich, and research hotspots emerge frequently (e.g., [9,10]), which may make it difficult for readers to grasp the research focus and trend [11]. It is necessary to use a scientific metrology method to analyze the relevant system of knowledge [12].

A literature review is considered to be an effective way to deeply understand a field of research [13]. Systematical analysis of existing research contributes to clarify the current research status and development trends, and provides directions for future research [14,15]. Understandably, the development of knowledge is a dynamic process. With the continuous updating of the literature, scholars may not have enough time or energy to only rely on non-visualization techniques to track knowledge evolution [16]. With the continuous development of scientometrics tools, software such as Pajek, NetMiner, and CiteSpace have gradually become emerging options for literature review. CiteSpace, compared with other software, has more comprehensive functions and simpler operation. First, CiteSpace is a diversified, time-sharing dynamic analysis tool. With the development of scientometrics as well as data and information visualization technology, it is used to visualize citations and then analyze the basic knowledge contained in scientific literature [17]. In addition, CiteSpace provides functions of literature co-citation analysis and keyword co-occurrence analysis, supports quantitative and objective analysis of related fields, and reveals quantitative relationships between various studies [18]. Then, by combining quantification and visualization, scholars can find implicit connections and trends in related literature. Specifically, it can help scholars to clarify the spatial and temporal distribution characteristics of research, current research status, cutting-edge research and future development directions [16]. It can also highlight some important documents in the development of a field [19]. Given its comprehensive bibliometric capabilities and high reliability, CiteSpace has been widely used in the past two years (e.g., [20–22]).

This study uses CiteSpace software as a bibliometric tool to conduct a review of the related studies on EMPHE in the past 10 years. Modeling and visualization are combined to build a knowledge base, which helps readers to more systematically understand relevant knowledge in the field of EMPHE, and provides support and guidance for future research. Moreover, as a strategic resource, the knowledge base has important value in the current era of big data. The relevant research conclusions can provide a reference for government departments to formulate guidance strategies. It has important implications for academics and practitioners.

2. Methodology

2.1. Data Sources and Processing

This work uses the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to select bibliographic data. The method is divided into four stages: identification, screening, qualification and inclusion, to ensure the accuracy of bibliographic data selection and the quality of systematic review, and it has been widely used in many literature [23]. The main purpose of this work is to construct the EMPHE knowledge system, to present the efforts and results of relevant research on EMPHE in the past ten years and present the latest progress to identify research opportunities.

This work selects the Science Citation Index Expanded (SCI-E) and Social Science Citation Index (SSCI) databases in the Web of Science (WoS) core database as the sources for the literature search
and collection. The database has two key characteristics: authoritativeness and a massive amount of data [24]. Archambault et al. [25] considers WoS’s core database to be a suitable data source for scientometric analysis. Hou et al. [26] further elaborates that, based on the WoS core database, researchers can identify the knowledge map and knowledge domain of a specific field, and can perform knowledge evolution analyses. The selection of the WoS core database as the source for the literature search has been widely recognized by previous studies (e.g., [27,28]). What needs to be explained here is that, because EMPHE involves science, technology and social science, the SCI-E and SSCI databases are commensurate with this research area. However, the Art and Humanities Citation Index (A&HCI) in the WoS core database is different from this research area. In fact, some articles in A&HCI database are also included in SSCI if their subject areas are related to social sciences. Therefore, this work uses the SCI and SSCI databases in the WoS core database as the search basis, and sets the time span as 2010–present, selecting “public health emergency” and “emergency management” in the subject bar to search.

In order to make the analysis results more accurate, this work excluded some irrelevant materials, such as publication advertisements, letters, and submission guidelines. At the same time, because a paper may cover different topics, some articles may cover topics other than EMPHE, which may bring noise interference to the findings. Therefore, this work adopts a dual expert discussion method to individually review the selected articles. Thus, two researchers with experience independently read and checked the selected papers according to the standards and discussed any differences until they reached a consensus. In the end, this work saves 1467 selected EMPHE-themed papers in the form of full records, and standardizes them. Therefore, the full record of each article in WoS contains the following basic information: author, title, abstract, keywords, publication period and references. Similarly, each retrieved reference includes the name of the first author, year of publication, type of source, journal number, volume number, and DOI. The specific search criteria are shown in Table 1.

| Database  | Database Source | Subject 1         | Subject 2          | Type  | Condition | Time Limit | Result |
|-----------|-----------------|-------------------|--------------------|-------|-----------|------------|--------|
| WoS       | SCI-E/SSCI      | Public health emergency | Emergency management | Article | Topic     | 2010–present | 1467   |

2.2. Main Methods

EMPHE’s bibliographic map can be presented through various networks established by CiteSpace. This work mainly analyzes the following aspects: keyword co-occurrence network based on high-frequency keywords, clustering network and knowledge evolution.

Co-word analysis is a method of content analysis, and is very similar to co-occurrence analysis [29]. By analyzing the professional terms that can express the subject or direction of the subject research, co-occurrence of the terms can show the relationship between the subjects [30,31]. Co-word analysis is mainly based on the following two assumptions: if two keywords appear at the same time, it means that they have relationship [12], and keywords are considered to be fully descriptive and best at summarizing a paper’s main components [32]. Many scholars use co-word analysis to analyze research advances in their respective disciplines (e.g., [33]).

Clustering analysis is used to aggregate variables with large similarities into one category, and other variables with high similarity into another category; thereby aggregating all variables to form a classification system from small to large, using a pedigree chart, network view or density view to show the relationship between all variables [34]. If two articles are often cited at the same time, it may imply that they contain similar concepts and have a close connection. Clustering analysis can help identify articles with intrinsic connections.

CiteSpace can help aggregate keywords into clusters based on their interconnectivities. Different clusters represent different research paradigms [35]. The connection between different clusters reflects their correlation [17,32].
In order to examine the trend of the subject change in the literature, this work also draws the time zone view of keyword changes based on the keyword map. The map uses the year in which the keywords appear as marked points and the frequency of occurrence as a cumulative amount, which can better reflect the theme change and evolution. Based on this, this paper introduces a keyword knowledge map and analyzes the research hotspots at each progress stage.

3. Results Analysis

Descriptive statistical results on the number of EMPHE articles published each year in the past ten years indicate (see Figure 1) that research in related fields has maintained a trend of volatile growth. Because this work is finished before the second quarter of 2020, only a few papers were collected for the year 2020, which should not be counted in the trend analysis. However, since the outbreak of the COVID-19 infectious pneumonia pandemic has attracted great attention from all over the world, the number of relevant papers should increase in the future for the whole year of 2020.

![Figure 1. Yearly number of published papers on emergency management of public health emergencies (EMPHE).](image)

3.1. High-Frequency Keywords

Because the keywords of an article can summarize the main content of the article well [32], the analysis of the frequency of keywords can help to identify the hotspots of EMPHE research. With CiteSpace, one can analyze the frequency of keywords in the literature and standardize the keywords. Through merging keywords with similar meanings and unifying the singular and plural forms of keywords, as well as upper and lower case, we obtained a total of 279 effective keywords.

Then, we needed to determine the threshold for high-frequency keywords. At present, the academic community has not reached a consensus on how to determine the threshold of a topic in co-word analysis [36,37]. After calculations, this work sets the high-frequency keyword threshold as 10 times and obtains 33 keywords. If the threshold is set higher than 10, it will miss many critical studies. If the frequency of keywords is set lower than 10, the number of studies and keywords included will be too large to perform a concise and effective co-word analysis. This work summarizes the high-frequency keywords of EMPHE, as shown in Table 2.
High-frequency keywords in the field of EMPHE (frequency ≥ 10).

| Rank | Keyword                              | Frequency | Rank | Keyword                           | Frequency |
|------|--------------------------------------|-----------|------|-----------------------------------|-----------|
| 1    | public health                        | 105       | 18   | public health emergency           | 15        |
| 2    | disaster                             | 56        | 19   | hospital                          | 14        |
| 3    | emergency management                 | 48        | 20   | disaster management               | 14        |
| 4    | emergency preparedness               | 48        | 21   | emergency planning                | 14        |
| 5    | emergency department                 | 42        | 22   | stroke                            | 13        |
| 6    | emergency                            | 34        | 23   | prevention                        | 13        |
| 7    | epidemiology                         | 31        | 24   | health care                       | 13        |
| 8    | preparedness                         | 24        | 25   | disaster medicine                 | 13        |
| 9    | education                            | 22        | 26   | public health preparedness        | 12        |
| 10   | emergency medical service            | 21        | 27   | disaster preparedness             | 12        |
| 11   | disaster planning                    | 21        | 28   | health policy                     | 12        |
| 12   | emergency medicine                   | 20        | 29   | primary care                      | 11        |
| 13   | emergency response                   | 19        | 30   | climate change                    | 11        |
| 14   | risk communication                   | 17        | 31   | health system                     | 10        |
| 15   | children                             | 17        | 32   | infectious disease                | 10        |
| 16   | Ebola                                | 16        | 33   | asthma                            | 10        |
| 17   | response                             | 16        |      |                                   |           |

These keywords are an important basis for understanding EMPHE research. From Table 2, it can be seen that the most commonly used keywords are as follows: public health (105 times), disaster (56 times), emergency management (48 times); emergency preparedness (48 times), emergency department (42 times). These keywords imply that the EMPHE research is closely related to these topics.

3.2. Keyword Co-Occurrence Network

High-frequency keywords reflect the foundation of EMPHE research to some extent. However, the frequency analysis of keywords appearing in the literature alone cannot reveal the relationship between the keywords, nor can it explore the inherent structure of the current literature on EMPHE topics. Thus, we needed to conduct a further co-occurrence analysis on the keywords in the literature to produce a co-occurrence network of keywords to show the knowledge map in the field of EMPHE research.

Figure 2 is a keyword co-occurrence network generated by CiteSpace software based on high-frequency keywords with a frequency of 10 or greater in Table 3. There are 278 nodes and 795 connections in Figure 2, where nodes represent keywords, and links represent the connections of keywords. The font size of the keywords in the figure is directly proportional to the co-occurrence frequency of the keywords [38], which helps us understand the current focus of EMPHE research.

Figure 2. Keywords co-occurrence network of EMPHE (knowledge map).
In the analysis of the keyword co-occurrence network, centrality is one of the main indicators to measure the power, influence or individual properties of a keyword [14]. In particular, the centrality degree indicates the degree to which a keyword is directly related to other keywords. If a keyword (node) has more links to other keywords, then that keyword is likely to be the core of a popular topic. As can be seen from Figure 2, public health is located at the focus of the figure. It is at the core of EMPHE research and has received extensive attention in related fields.

3.3. Cluster Identification and Analysis

Identifying highly cited articles through literature co-citation analysis is the first step in building a knowledge domain, and the second step is analyzing the literature to identify key research areas. By selecting a cluster label for each cluster from its noun phrase, we extracted noun phrases from the titles, keywords and the abstracts from the literature. The highest ranked phrase can be selected as the clustering label [32]. CiteSpace provides three different types of cluster tag extraction algorithms, including Log-Likelihood Ratio (LLR) testing, Term Frequency–Inverse Document Frequency (TF–IDF), and Mutual Information (MI) testing. This article uses CiteSpace’s default algorithm LLR test to extract cluster labels, using the CiteSpace keyword path calculation method, setting the Node Types to “Keyword”, setting the time slice to one and performing time zone division on the sample data to extract the top 50 keywords that appear in each time slice, then selecting Cosine to calculate the strength of the association. In order to ensure the integrity of the knowledge graph, this work does not use any network pruning algorithm to generate the keyword co-occurrence knowledge graph (see Figure 2). In the map, the keywords with high connections reflect research hotspots, and the degree of centrality indicates the degree of dominance in the network. After network clustering, we use LLR to name the clusters. There are 278 nodes and 795 connections in the graph, the network density is 0.0206, the module value is Q = 0.5033 (>0.3), and the average contour value S = 0.3185 (>0.3), which shows that the clustering structure is significant and the clustering is reasonable [16]. It should be noted that the network density values, module values, and average contour values in the cluster analysis network are consistent with the keyword network analysis, which further illustrates the effectiveness of the cluster analysis.

The six clusters obtained by CiteSpace are shown in Figure 3. Sorted by size: cluster #0 disaster, cluster #1 public health, cluster #2 response cluster #3 hospitals, cluster #4 polio eradication initiative, and cluster #5 emergencies. They are the main keyword categories of EMPHE research.

![Figure 3. Clusters of knowledge domain within EMPHE.](image-url)
This work further summarizes the number of articles, contour values, citation years, and LLR likelihood values included in each cluster, as shown in Table 3.

Table 3. Top-ranked clusters and the terms within the clusters. Log-likelihood ratio (LLR).

| Cluster ID | Size | Silhouette | Mean (Cited Year) | Labe (LLR) (p-Value) |
|------------|------|------------|------------------|----------------------|
| 0          | 42   | 0.642      | 2014             | 11.97, 0.001         |
| 1          | 42   | 0.847      | 2015             | 22.33, 0.001         |
| 2          | 42   | 0.823      | 2015             | 28.30, 0.001         |
| 3          | 31   | 0.86       | 2014             | 18.31, 0.001         |
| 4          | 31   | 0.846      | 2014             | 14.29, 0.001         |
| 5          | 25   | 0.829      | 2014             | 15.04, 0.001         |

The initial cluster of EMPHE research is “disaster”, which contains 42 articles. In the context of modern urban system, the subsystems of critical infrastructures are coupled and embedded with each other, and there is a close interaction and linkage relationship, meaning that once PHE occurs in cities the “chain effect” and “magnification effect” of the disastrous consequences will be very significant. Major PHEs were described as “black swan” emergencies [39], meaning an unpredictable and unusual phenomenon that often causes a chain of negative reactions or even a disruptive disaster. Disasters caused by PHE have become a major issue, affecting the national economy and people’s livelihoods, while traditional emergency management modes have gradually shown structural obstacles, leading to inefficient responses at a high price. It is important to incorporate the community in PHE response, and to educate people about public health prevention standards, which can improve the ability of coping with pandemics [40].

The second cluster is “public health”, which contains 42 articles. There is no doubt that EMPHE is closely related to public health. One of its aims is to take timely and effective treatments to reduce the threat to public health from PHE—for example, Reeder and Turner [41] use a scheme-based design approach to involve public health practitioners in the creation and verification of information designs to respond to PHE, and quickly and accurately assess the availability of labor in adverse and changing circumstances to support routine and emergency public health activities. In view of the infeasibility of establishing mathematical models or performing physical experiments on PHE in the real world, Duan et al. [42] applied artificial society, computational experiments and parallel execution (ACP) methods to EMPHE research, in order to achieve the fastest optimization of resource allocation for protection and treatment. In addition, some scholars have also paid attention to the public’s psychological health problems and pointed out that community intervention is the best way to solve psychological problems in PHE. It is understandable that, due to the characteristics of the suddenness, seriousness, and urgency of PHE, the public will generally experience panic, anxiety and other psychological problems. Since community workers know more about local residents, they can easily gain trust in their work, potentially making them the main force to solve residents’ psychological problems in a timely manner during PHE [43]. Community frontline staff play an important role in pandemic investigations [44] and psychological appeasement.

The third category is “response”, which contains 42 articles. Many scholars consider this as an emergency response. For example, Hu et al. [45] developed a preliminary framework for measuring PHE response capabilities to provide scientific guidance to most countries. Lurie et al. [46] recalled the challenges in behavior research for PHE to identify the key elements to improve the emergency preparedness and response capabilities of government agencies, hospitals, clinics and public health agencies. Response can be also considered, in a sense, as the governmental response to public issues through information disclosure. For PHE, governmental information disclosure will have a direct impact on public perception and behavior choices. Improper information disclosure may cause the public to overreact, which may lead to irrational behavior [47].
The fourth category is “hospitals”, which contains 31 articles. This type of research is mainly related to protective measures. First, from the perspective of clinical medicine, we must analyze the causes, transmission routes, and diagnostic drugs, and eradicate the root causes of the emergencies medically (e.g., [48–50]). In addition, there are also studies on medical staff’s psychological state and willingness to participate so as to increase the efficiency of treatment. For example, Hope [51] surveyed frontline health workers working in large regional health departments in Australia to determine their willingness to work in a PHE, and analyzes the potential obstacles to their participation.

The fifth category is the “polio eradication initiative”, covering 31 articles. The first case of wild-type polio virus occurred in Nigeria in 2014, and the pandemic quickly spread. The virus causes irreversible paralysis in the body within hours. The pandemic has had a huge impact on three intercontinental regions: Central Asia (from Pakistan to Afghanistan), the Middle East (from the Syrian Arab Republic to Iraq) and Central Africa (Cameroon to Equatorial Guinea). It was identified as a PHEIC twice by the United Nations Health Organization. Scholars have carried out a series of studies on how to control the pandemic. For example, Cochi et al. [52] summarized the 10 main lessons for the polio eradication initiative. Humayun et al. [33] summarized the status of environmental monitoring (ES) used in the Global Polio Eradication Initiative, provided the principles of ES, examples of ES methods and discoveries, and summarized how to use these data to achieve poliovirus eradication.

The sixth category is “emergencies”, which includes 25 articles. Combined with the keyword co-occurrence analysis in Section 3.2, it can be found that the related topics include emergency department, emergency medicine service, public health emergencies, emergency preparedness, emergency response, as well as many other topics.

### 3.4. Research Frontier Analysis

Over a short period of time, the studies with strong internal connections are clustered together to form research hotspots [17,54,55]. Keywords are the concentration and generalization of the core content of the literature. This work chooses a time zone map to reflect the evolution of research hotspots based on the time dimension [56], and to track research hotspots at different stages through high-frequency keywords. In order to ensure the integrity of the map, this work does not use any network trimming algorithm, keeps other settings unchanged, and selects “Time Zone” in the visual interface. In order to effectively display the key nodes, this work only shows the nodes with frequency ≥ 10, and the graph is shown in Figure 4.

![Figure 4. The time zone map of keywords co-occurrence in EMPHE research field.](image-url)
According to the time zone, it can be found that many major keywords in the EMPHE field have maintained a high level of attention over time, such as emergency department, public health, emergency management, emergency preparedness, disaster, hospital, etc. These keywords basically coincide with the keywords in the cluster analysis. This shows that disaster, public health, hospital, and emergency in cluster analysis have been the focus of EMPHE research since 2010. This is understandable because the purpose of EMPHE is to urgently allocate necessary resources through medical means and medical departments to effectively treat patients and protect public health. Emergency responses to PHE have received attention since 2013 and are still the focus of relevant studies. The research fever of infectious disease has continued from 2010 to 2018, which shows that infectious diseases are an important part of PHE research. However, the term became less frequent in related articles after 2018. We found that, after 2018, scholars more commonly used “pandemic” to summarize the characteristics of major PHE, particularly evident in the COVID-19 infectious pneumonia pandemic (e.g., [57–59]). As countries become more closely connected, the consequences of PHE often become global health issues, so “global health” has also been a concern in recent years. The COVID-19 infectious pneumonia outbreak will push forward this trend.

There are also some keywords that have received widespread attention in certain time periods. For example, Ebola virus disease, Ebola and Africa. After the emergence of the Ebola virus from Guinea in 2014, it quickly spread to other countries and continued to do so up to the end of 2016. In 2018, Ebola appeared in Africa again, and “Africa” became an emerging keyword during this period. Combined with the analysis of the polio eradication initiative in Section 3.2, this shows that global PHEs have large sphere of influence and will draw scholars to pay close attention to them. However, after the incident is over, the enthusiasm of scholars will also decline.

4. Features and Gaps of EMPHE Research

On the basis of the above bibliometric results, this work further summarized features and gaps of EMPHE research through extensive reading of the related literature, WHO reports and other official materials. By comparing public reports and media disclosures with the current research, several feasible countermeasures have been put forward.

4.1. Agility of Emergency Response

Emergency response is a key research paradigm in the EMPHE field. It is considered an important part of the PHE management system [45]. In 2018, the WHO released a report on integrated scientific interventions to respond to PHE response in epidemics and pandemics, which states the importance of emergency preparedness by emergency departments and community involvement in the emergency response to PHEs, and highlights the agility of the emergency response as a key factor. Agility, in this sense, means swift and effective. Due to the public characteristics of PHE, it is necessary to consider the participation rights and responsiveness of multiple actors, to maximize the public interest and thus maintain social stability [60]. Gillespie et al. [61] takes the Ebola pandemic as an example to confirm that it is necessary to include community participation and social mobilization into the PHE response system to promote the flexibility of the emergency response and better adapt to actual local needs. Lurie et al. [46] emphasized multiple levels of preparedness activities to achieve agility in coping with the uncertainty of PHE, including community participation, abnormal situation surveillance and detection and effective deployment by emergency departments. Based on the above analysis, emergency preparedness, community participation and social mobilization form the basis for ensuring the agility of emergency response to PHE. However, by further digging into the bibliometric results and extensive reading of the related literature, two weak points have been found in this area. This paper tries to meet the challenges with feasible countermeasures.

First of all, we are concerned that current studies on the agility of emergency response are mostly based on qualitative research related to textual analysis or case study analysis to describe the status quo and reasons for this. Their recommendations are often too narrow or too broad to be extensively
applied—for example, Gillespie et al. [61] analyzed the Ebola outbreak in Guinea, Liberia and Sierra Leone, and it is hard to apply the conclusions obtained to other countries or other PHEs; Lurie et al. [46] reviewed the challenges of 10 PHE cases to identify key elements of emergency response measures and designed a PHE response system based on this; however, the construction of such an emergency response system is too broad, resulting in less feasibility. Thus, the advancing methodology should take a noteworthy direction when the related research is conducted. Applying quantitative and qualitative approaches in one study can achieve complementary advantages, and qualitative analysis based on quantitative description can reveal and explain more profound reasons. Therefore, it is necessary to combine quantitative and qualitative research in future research to explore the improvement of emergency response to PHE. Mathematical function-based modeling and simulation tools may be the focus of attention in the future. Such technology can better ensure the stability and practicability of the emergency response system for PHE. For example, the $\beta$-distribution model is capable of modelling and simulating the risk perception of social public opinion, and it has been applied in machine learning and mathematical statistics [62]. It refers to a set of continuous probability distribution density functions defined in (0,1), which can be used to represent the posterior probability distribution of binary events. The $\beta$-distribution model provides a reliable mathematical basis for confirming the credibility of information feedback, and further make a better emergency response in the early stage of PHE.

Secondly, as outlined above, emergency preparedness by emergency departments and community involvement have been growing in importance in more and more countries, while the quality and ability of emergency department officials and community workers in many countries have not yet reached the level to make agile judgments about PHE situations [63,64]. It can be understood that if the relevant staff lack the expertise and ability related to EMPHE, it is difficult for them to play their part in EMPHE, and may even lead to unnecessary losses due to human errors, which may lead to risk and unnecessary loss. However, there are no keywords that relate to human error in the high-frequency keywords (Table 1) and time zone, indicating insufficient attention paid to this aspect. A preventive risk management tool based on the principles of Hazard Analysis and Critical Control Points (HACCPs) should be a way to reduce the probability of human error and, furthermore, to prevent the outbreak of PHE. Although the principles of HACCPs were originally created for the food industry, they have been successfully applied to risk management in a large number of disciplines [65]. They contribute to confirming the desired workflow and avoiding possible troubles that may lead to avoidable risks [66]. Designing a specific and reliable EMPHE process can make it easy to do the right thing and hard to do the wrong thing [67] through clarifying responsibilities and the EMPHE operating process, thus reducing human-caused risks. The HACCP should be developed by the WHO, who employ the top experts from around the world. Therefore, the most professional advice possible can be proposed and the different EMPHE strategies can be developed according to the actual situations of different countries. The WHO also has the responsibility of contributing to avoiding the spreading of PHE around the world. Some scholars have proposed that, in normal periods, attention should be paid to the training of emergency management departments and community workers, and carrying out regular assessments [68].

4.2. Timeliness of Protective Treatment

There is no doubt that protective measures are necessary to protect public health in PHE. The current research has been mainly carried out from the perspective of clinical medicine and medical staff management.

Although vaccines are the fundamental way to resolve many PHEs, it is difficult to develop specific vaccines for many diseases. Taking COVID-19 infectious pneumonia as an example, the current main means of prevention and control are cutting off the route of transmission. However, such methods are very costly, need to find close contacts through various channels, and may lead to large numbers of people being isolated, even posing risks of global economic downturn, devaluation of the currencies of many countries, and high mortality rates. Countries should establish a multi-national expert research
& design (R&D) cooperation network and work together to jointly develop effective vaccines and other treatment medicines to jointly cope with COVID-19.

In addition, Gao et al. [69] found that there are problems, such as irregular sample collection and processing, different test reagent quality, and high false negative rates in monitoring results, making the prevention and control of PHE a serious hidden danger. Therefore, it is necessary to formulate strict standards before the onset of PHE and reserve qualified sample detection tools, so that after the onset of PHE, the source of infection can be identified in time and effective protection and treatment can be employed.

Finally, from the analysis of the time zone, was found that scholars are more enthusiastic about the timely PHEs. With the end of a PHE, the enthusiasm of scholars also diminishes. However, the end of a PHE does not mean the completion of scientific research—for example, after the end of the Ebola pandemic in 2016, studies on Ebola have rapidly declined, but the Ebola pandemic made a comeback in 2019, causing more than 2000 deaths in the Republic of Congo alone, demonstrating the necessity for continuous scientific research on a pandemic, rather than only deeming pandemic as short-term incidents. In actual fact, there is a valuable common experience that can be summarized from different PHEs. For instance, Liu and Cao [70] designed countermeasures for the COVID-19 infectious pneumonia pandemic from the experience of malaria prevention and treatment. Richards [71] proposed how to scientifically reduce the mortality rate of contact infectious diseases through a long-term study on the Ebola pandemic in West Africa. These studies will provide references for the study and handling of other infectious diseases. Thus, past experience is still valuable for coping with PHEs. Hope [52] classified PHE into three different types according to their causes, namely weather events, influenza pandemics and bioterrorism events, which provide a reference for further research on the relationship between different PHEs. It is necessary to carry out detailed research on the characteristics and nature of these types of PHEs to find some rules and laws from the pandemic phenomenon.

4.3. Guarantee of Necessary Supplies

The guarantee of necessary supplies can be reflected in two aspects, which are respectively medical supplies and living supplies. Medical supplies provide important guarantees for the effectiveness of protective treatment, while living supplies are the basis for ensuring people’s livelihoods. Some scholars think about the guarantee of necessary supplies from the perspective of supply chain optimization. For example, Ajrawat et al. [72] describes the development of decision support tools to assist the Center for Disease Control and Prevention’s Strategic National Reserve Division to ensure the timely supply of necessary supplies. Clausonc et al. [73] suggests further strengthening the block chain technology to increase the efficiency of the necessary supplies for EMPHE. Although scholars have examined the role of the supply chain, it is only one factor related to the guarantee of necessary supplies. The supply reserve, supply capacity and price stabilization in an emergency should also be attached importance by examining theoretical developments and practice improvements in related fields.

On the one hand, the theoretical development should be fully considered. The guarantee of necessary supplies is essentially a reflection of the government’s supply capability. In 2015, the Academy of Management Journal (an authoritative journal in the management field) published an article that called for the reconstruction of risk management theory from the perspective of resilience [74], to cope with the complexity and uncertainty of PHE risks, and improve our ability to respond to emergent public events. Some scholars have used resilience thinking combined with supply chains to study the flexibility of material supply, internal and external resource integration, and risk management (e.g., [75]). Some scholars also described the use of social media to increase the resilience of communities in the EMPHE field from the perspective of community resilience [76]. After extensive reading, this study finds that the current research on the resilience mechanisms of risk management mainly focuses on natural hazards such as floods, forest fires and hurricanes (e.g., [77–79]) or management of public risks against emergent human factor-induced hazards such as chemical spills (e.g., [80]). Some scholars have demonstrated the significance of resilience mechanisms in risk management in improving
EMPHE plans in small-scale areas through sample experiments [81]. In view of the above, the idea of incorporating the resilience mechanisms of risk management into EMPHE shows promise.

On the other hand, the practice still has large scope for improvement. Given the lack of effective vaccines for many PHEs [69], quarantine is one of the common approaches for stopping the spread of a virus. How to coordinate supply and demand during quarantine periods is a key point to be considered in the practice of EMPHE. Understandably, both medical supplies and living supplies may be in short supply to some extent in the initial days of quarantine. Governments should pay attention to supervise the market and stabilize prices. Donations from diverse sources can be managed through online cloud platforms. Some internet giants (such as Alibaba, Tencent, and Jingdong) can operate such platforms.

4.4. Effectiveness of Public Psychological Intervention

As mentioned earlier, the keyword “public health” should include public psychological health and physical health. Bibliometric analysis indicated insufficient attention to public psychological health and psychological intervention in PHE. According to the definition of a PHE, it also requires the timeliness, publicity, and the communication of relevant information [1]. Scholars have widely discussed the mental health problems of medical staff and put forward corresponding countermeasures [82,83], but there is lack of exploration of public psychology. However, in the sensitive context of PHE, the public require information, and the government information disclosure system has become an important tool for reducing public panic and anxiety [47]. In particular, the development of the all-media era has facilitated the dissemination of misleading and prejudicial information [84,85]. The public often lacks the ability to think rationally, and is easily misled by misinformation. This will further deteriorate the psychological problems such as anxiety and panic in PHE. Thus, managers of EMPHE should pay attention to public psychological interventions and the following suggestions are proposed.

Firstly, the psychological problems of the public, such as anxiety and panic, may be caused by inadequate knowledge about a PHE. Timely information disclosure and public opinion guidance by the mainstream media are important to effectively intervene in the psychological problems of the public [47]. With the development of network communication, the channels for the public to receive relevant information sources have been expanded. In the case, it is necessary for the government to establish multiple information communication channels and online health guidance to better publicize the relevant knowledge of PHE in time, so as to avoid unnecessary panic, and make the pandemic information more transparent.

Secondly, public psychological health has not been valued in many countries. Hu et al. [63] pointed out that, due to the defects of emergency management mechanisms and policy, governments cannot effectively deal with public psychological problems during PHEs, especially in the rural areas of developing countries. It is necessary to establish permanent emergency management institutions with public psychological health management functions. In normal times, such departments can carry out the popularization of EMPHE knowledge to promote the participation of the public; in emergency times, such departments can be devoted to coping with public psychological problems during PHE to minimize social anxiety. Furthermore, it is meaningful to establish network communication mechanisms involving governments, volunteers, community managers and experts to communicate with the public during PHE, so as to mobilize all available social resources to effectively solve the public’s psychological obstacles. Society as a whole also needs to increase support for psychological health, consulting the industry and calling on the public to pay attention to psychological health.

5. EMPHE Knowledge System Construction

The construction of knowledge systems usually involves fields of information management and artificial intelligence. The former regards the knowledge base as a digital storage carrier for knowledge such as studies and patents from the perspective of knowledge resources and their organization, focusing on mechanisms and strategies of knowledge retrieval and institutional knowledge base
construction. The latter focuses on study of key technical issues related to knowledge representation methods, knowledge inference engines and multi-knowledge fusion [8].

This paper draws on and develops the research results of Shi and Liu [16], constructing the EMPHE knowledge system from three aspects: EMPHE knowledge base, EMPHE knowledge domain and EMPHE knowledge evolution, in order to discover the important issues in the current research, and to navigate future research interests in the field of EMPHE.

Because high-frequency keywords are the basis of a series of issues such as the spatial and temporal distribution characteristics, research status, cutting-edge research and future development directions (e.g., [12,14,16]), this work firstly uses the keyword co-occurrence analysis function of the CiteSpace software to find high-frequency keywords in the EMPHE field for building an EMPHE knowledge base. Then, we use CiteSpace’s literature clustering analysis to reveal the main research paradigm of EMPHE, so as to make the theoretical focus clearer, and thus construct the EMPHE knowledge domain. It is a visual description of the current research status, exploring the key research categories that have been studied. Exploring the EMPHE knowledge domain can help to understand the research experience and research results of EMPHE, providing reliable support for EMPHE knowledge evolution analysis. After that, according to the results of the EMPHE knowledge base and EMPHE knowledge domain, this work uses the time zone map function of CiteSpace to obtain the EMPHE knowledge evolution. The core of this step is to help analyze the changes in emerging research terminology. The visualized EMPHE knowledge evolution can provide researchers with valuable information and references.

Figure 5 provides an outline of the constructed knowledge system, covering the abovementioned features of EMPHE research, and the knowledge base, knowledge domain and knowledge evolution.
It should be noted that the knowledge system in the field of EMPHE is rapidly developing with evolving research topics. Therefore, the knowledge base, knowledge domain and knowledge evolution may also change in the future. The bibliometrics of EMPHE should be constantly updated with changes over time in order to provide a valuable reference to guide academic frontier research.

6. Conclusions

The COVID-19 infectious pneumonia pandemic highlights the importance of EMPHE. This work screens out 1467 articles about the theme of EMPHE in the SCI and SSCI database in WoS. With the help of the visualization bibliometrics software of CiteSpace, this paper builds an EMPHE knowledge map based on 62 high-frequency keywords, contributing to seeking out the relevance between topics. Afterwards, based on cluster analysis, this work clarifies six main categories of EMPHE research: disaster, public health, response, hospitals, polio eradication initiative and emergencies. The research foci have been analyzed in detail, a process which plays a vital role in understanding the current status of EMPHE research. This work identifies the research frontier in this field in relation to the time zone, to provide references for readers to identify emerging hotspots in this field. The findings of the time zone further confirm the results of the cluster analysis, showing that the research foci of EMPHE evolve in relation to the abovementioned topics. This work further summarizes four features EMPHE research: the agility of emergency response, the timeliness of protective treatment, the guarantee of necessary supplies and the effectiveness of public psychological intervention. These features are the summary of current trends in the EMPHE field and also imply that there are research gaps in this field, leading to possible opportunities for future research. An outline of the knowledge system of EMPHE is finally built, including a knowledge base, knowledge domain and knowledge evolution. This is the combination of knowledge system modeling and visualization, contributing to the better presentation of the main knowledge points of EMPHE research.

This work clarifies the research foci within the large number of studies on EMPHE and provides inspiration for extensive research related to EMPHE in the context of the COVID-19 pandemic. This work has implications for both academics and participators in the EMPHE area. Considering the rapid progress of the related knowledge about EMPHE, it is necessary to incorporate new knowledge to improve the analytical results. Gaining more knowledge by other methods, such as grounded theory, content analysis and epidemiological analysis, is an important focus for future work.

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