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ORIGINAL RESEARCH

Resource management in disaster relief: a bibliometric and content-analysis-based literature review

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Abstract
Disasters cause huge economic losses, affect the lives of many people, and severely damage the environment. Effective resource management during disaster preparedness and response phases improves distribution efforts and service levels and, hence, accelerates the disaster relief operations. Resource management in response to catastrophe has received increasing research attention in recent years, but no review paper focuses on this specific topic. Thus, the main purpose of this paper is to review the existing literature on resource management for disaster relief published in English in peer-reviewed journals in order to fill the gap. We apply bibliometric, network, and content analyses in our review to identify popular research topics, classify the literature into research clusters, and analyze the interrelationships between these research clusters. The second purpose of this paper is to identify gaps and trends in existing research. Finally, we propose six future research directions that provide a roadmap for resource management research for disaster relief.

Keywords Disaster management · Emergency resource · Literature review · Network analysis · Content analysis · Bibliometric

1 Introduction

During the 2000–2019 period, it was estimated that worldwide disasters caused 1.23 million deaths and 4.03 billion injuries (UNDRR, 2020). The economic loss was 2.97 trillion USD, an increase of 1.82 times in the past 20 years (Ajibade & Siders, 2021). Efficient resource management can play an important role in reducing the impact of disasters. This can be achieved

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by pre-deploying emergency resources at appropriate locations, allocating an appropriate number of emergency resources during the preparedness phase, and optimizing the allocation of emergency resources during the response phase. Adapting resources to the demands of the affected areas is a crucial step in the disaster management (DM) process (FEMA, 2021). The emergency resources include rescue supplies (e.g., water, food, and medicine), transportation means (e.g., vehicles, boats, and unmanned aerial vehicles (UAVs)) (Gao et al., 2021; Ozkapici et al., 2016; Rottondi et al., 2021), emergency facilities (e.g., shelters, distribution centers, and warehouses), personnel (e.g., paramedics), and rescue teams (FEMA, 2021). Therefore, resource management plays a vital role in disaster operations management. Although there are some literature review papers on disaster operations (Akter & Wamba, 2017; Behl & Dutta, 2019), to the best of our knowledge, none of them pay specific attention to resource management in natural disasters.

The main objective of DM is to find ways to prevent and reduce risks (Coppola et al., 2013). DM can be divided into four stages: mitigation, preparedness, response, and recovery (Boonmee et al., 2017; Farahani et al., 2020). *Mitigation* requires active measures to reduce or eliminate the impact of disasters. *Preparedness* includes the organization and preparation of appropriate actions in case of disasters. At this time, tactical preparations such as deploying rescue operations, establishing communication channels, and allocating responsibility need to be completed. *Response* includes the use of emergency resources and emergency procedures as planned, participation in the protection of life, property and environment, and the transportation of materials in the affected area. *Recovery* is a long-term activity to restore the affected areas to their pre-disaster status. Although each stage has its objectives and irreplaceable importance, eliminating negative consequences largely depends on the quality of the decision-making process in the preparedness phase and the efficiency of operations management in the response phase. Therefore, the focus of this paper is on the review of the resource management literature in the disaster preparedness and response phases.

1.1 Resource management in DM

The International Federation of Red Cross and Red Crescent Societies (IFRC) describes disasters as sudden catastrophic events that seriously undermine the function of communities, with various adverse consequences (e.g., life-threatening situations, economic, and environmental losses), which the community cannot cope with alone (IFRC, 2015). We adopt Galindo and Batta's (2013) definition which suggest a disaster as an event that causes severe damage to people, materials, the economy, communities, society, and the environment that local agencies cannot manage through standard procedures. Therefore, DM contains a series of successive phases to reduce human and economic losses, personal suffering, and return to pre-disaster conditions rapidly (Gama et al., 2015). Disasters can be divided into natural and man-made disasters. In this study, we do not consider the daily response of ambulances, police forces, and fire departments to routine emergency calls (Altay & Green, 2006) and man-made disasters.

The Disaster Management Handbook defines resource management as 'Resource management defines standardized mechanisms and requirements to inventory, mobilize, dispatch, track, and then recover assets over the course of an incident' (Pinkowski, 2008). Hence, it is a critical component that bridges the gap between disaster preparedness and response (Altay & Green, 2006). Its objective is to manage limited emergency resources (i.e., personnel, teams, facilities, equipment, and supplies) effectively and efficiently to reduce the impact of disasters, including human suffering and social and economic disruptions (FEMA, 2021).

Resource management requires complex, interdisciplinary, and interagency efforts. It may require many organizations and coordination of managers and operators, including engineers, scientists, and medical personnel from governmental, public, private, and non-profit institutions, working in unpredictable, time-limited, and subject to budgetary constraints. The focus of this paper is resource management during the preparedness and response phases of natural disasters. The typical activities include emergency planning, constructing emergency facilities, maintaining emergency supplies, budgeting for and procuring equipment, recruiting personnel for emergency services in the preparedness phase and evacuating affected populations, opening emergency service facilities, providing rescue and medical care, and casualty management in the response phase (FEMA, 2021).

1.2 Related reviews and motivation

A list of relevant review literature relating to different phases, optimization methods, and relief operations of DM is shown in Table 1. The scope of each paper is given in the subject area of the column. Some reviews cover a wide range of Operations Research/Management Science (OR/MS) methods (Altay & Green, 2006; Galindo & Batta, 2013). Other reviews focus on specific OR/MS methods such as mathematical modeling (Baxter et al., 2019; Boonmee et al., 2017; Burkart et al., 2017; Caunhye et al., 2012; Özdamar & Ertem, 2015), game theory (Seaberg et al., 2017), stochastic modeling (Hoyos et al., 2015) and simulation modeling (Mishra et al., 2018). A more detailed analysis of the methodologies for cost assessment of disasters is carried out by Eckhardt et al. (2019). The search scope in some reviews covers broad DM research (Altay & Green, 2006; Galindo & Batta, 2013; Goldschmidt & Kumar, 2016; Gutjahr & Nolz, 2016; Mishra et al., 2018; Özdamar & Ertem, 2015; Simpson & Hancock, 2009) and a wide range of research methods related to DM in natural disasters (Behl & Dutta, 2019; Jabbour et al., 2019). Others analyze specific resource management decisions, such as assets and supplies prepositioning (Sabbaghtorkan et al., 2020), relief distribution network planning (Anaya-Arenas et al., 2014), shelter location and evacuation routing (Amideo et al., 2018), emergency healthcare workers' perceived preparedness (Almukhlifi et al., 2021), and mass casualty management (Farahani et al., 2020).

In terms of the review analysis method, most review papers use content analysis (Anaya-Arenas et al., 2014; Boonmee et al., 2017; Caunhye et al., 2012; Kaveh et al., 2020; Sabbaghtorkan et al., 2020). Only a few papers use bibliometric analysis (Akter & Wamba, 2017; Jabbour et al., 2019; Liu et al., 2021; Wamba, 2022) of those papers, some provide relatively straightforward descriptive analysis such as the number of papers and research topics (Akter & Wamba, 2017; Behl & Dutta, 2019; Wamba, 2022). However, there is a lack of review that combines both content analysis and bibliometric analysis.

1.3 Research contributions

Despite the significant development and the importance of resource management research in DM, we cannot find any review paper that focuses solely on resource management during the disaster preparedness and response phases. Resource management is critical in DM to increase capabilities to respond to and recover from a disaster (FEMA, 2021). Hence, the main contribution of this paper is to review resource management in DM literature in detail combined with bibliometric, network, and content analyses (Feng et al., 2017). The statistical classification we provide includes contributions from journals and the number of related papers published per year. Network analysis is used to identify established and emerging

Table 1 Review literature review related to disaster relief

Reference	Subject area	Phase				Period	Number of Papers
		Mitigation	Preparedness	Response	Recovery		
Altay and Green (2006)	Disaster operations management	√	√	√	√	1972–2004	109
Galindo and Batta (2013)	Disaster operations management	√	√	√	√	2005–2010	155
Hoyos et al. (2015)	Disaster operations management	√	√	√	√	2006–2012	101
Eckhardt et al. (2019)	Disaster risk management	√	√	√	√	1997–2018	36
Kovacs and Moshtari (2018)	Humanitarian operations	√	√	√	√	2006–2018	43
Goldschmidt and Kumar (2016)	Humanitarian operations and crisis management	√	√	√	√	1980–2015	1276
Simpson and Hancock (2009)	Emergency service	—	—	√	—	1965–2007	361
Caunhye et al. (2012)	Emergency logistics	√	√	√	—	1976–2011	74
Kaveh et al. (2020)	Emergency management systems	√	√	√	√	1929–2020	150
Mishra et al. (2018)	Disaster management	√	√	√	√	2000–2016	100
Akter and Wamba (2017)	Disaster management	√	√	√	√	2010–2017	76
Seaberg et al. (2017)	Disaster management	√	√	√	√	2006–2016	57
Baxter et al. (2019)	Disaster management	√	√	√	√	1998–2019	99
Jabbour et al. (2019)	Humanitarian logistics and supply chain management	√	√	√	√	1992–2017	87
Behl and Dutta (2019)	Humanitarian supply chain management	√	√	√	√	2011–2017	362

Table 1 (continued)

Reference	Subject area	Phase				Period	Number of Papers
		Mitigation	Preparedness	Response	Recovery		
Wamba (2022)	Humanitarian supply chain	√	√	√	√	1967–2020	1152
Özdamar and Ertem (2015)	Humanitarian logistics	—	—	√	√	1998–2014	126
Gutjahr and Nolz (2016)	Humanitarian aid	√	√	√	√	2007–2015	89
Sabbaghtorkan et al. (2020)	Disaster operations management	—	√	√	—	2000–2018	74
Boonmee et al. (2017)	Facility location	—	√	√	—	1950–2016	84
Anaya-Arenas et al. (2014)	Relief distribution networks	—	√	√	—	1990–2013	83
Amideo et al. (2018)	Shelter location and evacuation routing	—	—	√	—	2012–2017	92
Liu et al. (2021)	Crowd evacuation	√	√	√	√	1999–2019	1190
Farahani et al. (2020)	Mass casualty management	—	—	√	—	1977–2019	88
Almukhlifi et al. (2021)	Emergency healthcare workers	—	√	—	—	2005–2020	27
Our research	Resource management	—	√	√	—	1971–2021	460

clusters of the subject area. The content analysis is used to draw insights from the identified clusters to provide a knowledge structure for resource management research in DM and to propose ideas for future research. The differences between our review paper and the existing review papers are summarized in the last row in Table 1.

The rest of this paper is organized as follows. Section 2 introduces the literature review methodology. Section 3 provides the results of bibliometric analysis and network analysis. We critically carry out content analysis in Sect. 4. The gaps are identified and discussed in Sect. 5. Finally, Sect. 6 summarizes and highlights the limitations of this study.

2 Research methods

A literature review aims to map and evaluate the main body of literature and ensure access to research on the subject without prejudice to identify potential research gaps and highlight knowledge boundaries (Tranfield et al., 2003). The review steps are summarized as follows: (1) determine the reviewed content; (2) identify the samples of potentially relevant works; (3) select relevant articles; (4) summarize the evidence; (5) report results and findings (Durach et al., 2017; Tranfield et al., 2003). In this study, we follow the above steps to determine the most influential research and existing thematic research areas and provide information on future research directions.

We follow a conservative search and filtering methodology shown in Fig. 1 to ensure that all relevant papers are included. We search the Scopus and Web of Science databases for "title, abstract, and keywords". We limit the search field to journal papers written in English using the terms given in Fig. 1. The start time includes as many articles as possible before 2021. This search results in more than 45,000 papers. To manage the number of papers, we further limit our search to papers published in the 2020 Scientific Journal Rankings (JCR 2020). The JCR list is used because it is adopted by research institutes worldwide. The next step is to read the titles and abstracts and exclude papers outside the scope of this review. The scope of this review must be related in whole or in part to resource management in the natural disaster preparedness and response phases. For example, the allocation of evacuees and the treatment of casualties can be relevant as far as they improve rescue efficiency by integrating emergency resources. We exclude papers that address routine emergencies or man-made disasters. We also remove the overlap between the two databases. When we are in doubt, we conservatively leave the paper to the next step for more careful examination among the co-authors. We repeat the same exclusion criteria in the final stage but based on the full text, which leaves 460 papers for our bibliometric, network, and content analyses.

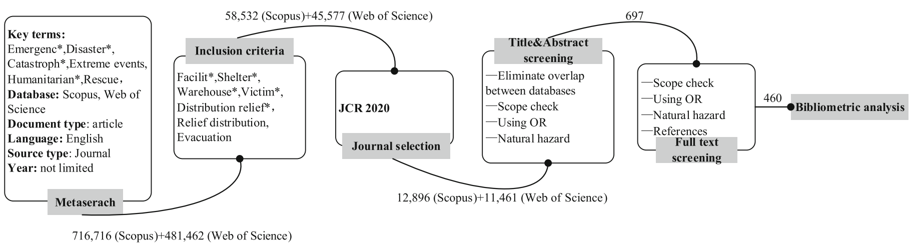

Fig. 1 Search and filter methods

3 Bibliometric and network analyses

This section presents the bibliometric and network analyses results' outcomes based on the literature search in Sect. 2. We use BibExcel for bibliometric analysis because it has the functionality to import and combine data from Scopus and Web of Science and a good interface with Gephi (Wehbe et al., 2016) which is used for network analysis.

3.1 Bibliometric analysis

460 papers are published in more than 130 journals, of which 253 (55%) are published in 10 journals, as shown in Fig. 2. As expected, most resource management research articles are published in operational research and operations management journals. Figure 3 provides information on the number of papers and the type of natural disasters dealt with in these papers. The first relevant paper was Toregas et al. (1971). Since 2010, the number of papers began to rise, probably because climate change became one of the attention hotspots around that time. Furthermore, the news coverage on high-profile natural disasters (e.g., the 2008 Sichuan earthquake, the 2008 cyclone Nargis, and the 2004 Boxing Day tsunami) has motivated more researchers to investigate humanitarian relief operations during natural disasters. A more interesting insight is that most papers (79%) state that the proposed methods are meant to be applicable to all types of natural disasters, as shown by the disaster type "general" (shown in green in Fig. 3). There are differences in the demand for emergency resources between different natural disaster types. For example, victims of drought urgently need food and drinking water while, for earthquakes, medical rescue has a higher priority (IFRC, 2000). One aim of humanitarian operations research is to propose an appropriate way for each type of disaster according to specific characteristics (Gupta et al., 2016; Kovacs & Moshtari, 2018). Hence, in resource management, the ability to support decisions for specific disasters is important. The other bibliometric analyses are given in the Appendix. They are the related top authors (Table 5), top institutions (Table 6), and top countries Table 7).

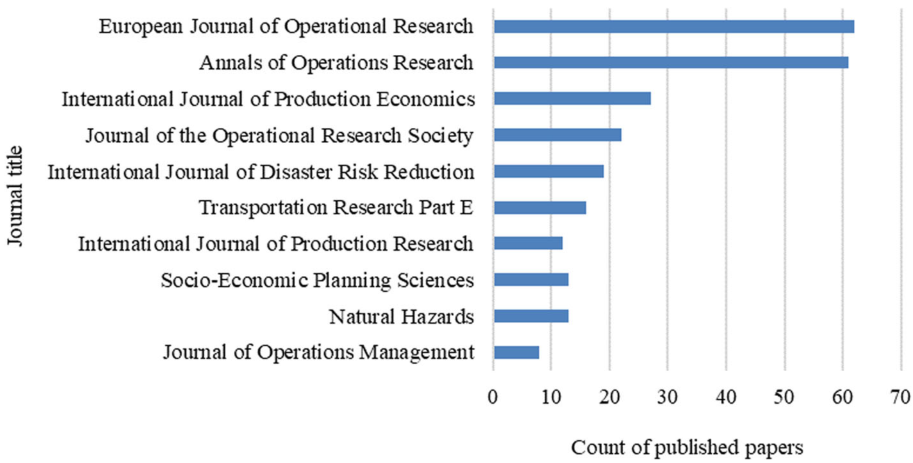

Fig. 2 The top 10 publishing journals (N = 460)

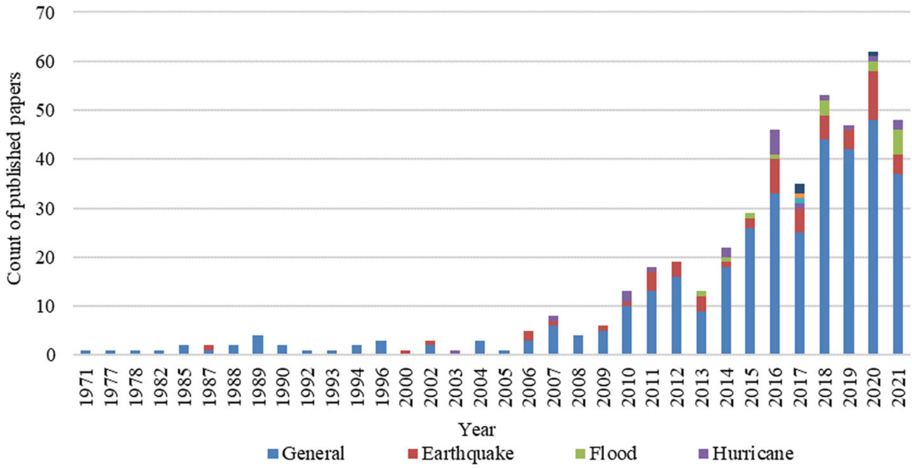

Fig. 3 Trends in papers published over time and the type of disaster considered (N = 460)

Table 2 The top 20 most commonly used words in paper titles and keywords

Rank	Words in the title	Occurrences in the title	Words in keywords	Occurrences in keywords
1	Disaster	138	Disaster	93
2	Emergency	107	Model	75
3	Model	87	Optimization	68
4	Relief	83	Facility location	61
5	Humanitarian	66	Disaster prevention	58
6	Network	60	Earthquakes	57
7	Supply Chain	50	Disaster management	48
8	Optimization	49	Emergency services	46
9	Location	48	Humanitarian logistics	44
10	Planning	47	Disaster relief	43
11	Uncertainty	42	Network	40
12	Distribution	42	Algorithm	32
13	Response	39	Operations	31
14	Logistics	39	Systems	30
15	Earthquake	37	Location	27
16	Stochastic	33	Uncertainty	26
17	Routing	31	Supply chain	24
18	Operations	31	Allocation	23
19	Decision	30	Stochastic models	23
20	Case	28	Humanitarian relief	22

The next insight is drawn from the words used in the titles and keywords (listed in Table 2). The top three words in the title are "Disaster, Emergency, and Model", which suggests that the literature on resource management is dominated by modeling work, particularly optimization. A comparison between words of the title and keywords indicates that, in most cases, the use of keywords in the title and keywords list is consistent. The words "Optimization, Operations, Supply chain, Relief, Location, and Uncertainty" may illustrate the challenges faced in the preparedness and response phases. Not only are humanitarian organizations expected to develop models and frameworks, but they should also optimize their emergency resources to assist all those in need in different locations in a highly uncertain environment.

3.2 Network analysis

Network analysis is often used to analyze the relationship between authors using co-citation network. Figure 5 in the Appendix shows the co-citation network of authors whose citation frequency is more than 30. It shows that there are three groups. The first group represents authors who are working on facility location, resource allocation, and scheduling. The second group includes authors who are working on resilience in the humanitarian supply chain. The third group represents authors who are focusing on the evacuation and treatment of victims. In this section, we focus more on the network analysis for the identification of the areas of research focus (using co-citation analysis and clustering) and the development of the areas over time (using dynamic co-citation analysis).

3.2.1 Co-citation analysis and clustering

A single subject term cannot identify specific research topics and content. Therefore, this paper applies cluster analysis to the co-occurrence and co-citation network. The links between two keywords in the co-occurrence network indicate that at least one article uses these two keywords. In a co-citation network, two or more papers are co-cited if they are cited by the same paper. Papers frequently cited together by other papers are probably more relevant and belong to similar research areas (Hjorland, 2013). Clusters can be identified in the network in such a way that papers in the same cluster have limited connections to papers in other clusters. In other words, the papers in the cluster have a strong co-citation relationship. The content analysis of a group of papers can reveal the research focus area of that cluster (Clauset et al., 2004; Radicchi et al., 2004). Using Gephi (Cherven, 2015), we find that the papers form five clusters listed in Table 3. The clusters can be seen visually using the corresponding co-occurrence network of keywords as shown in the Appendix Fig. 6, where the keywords of similar research topics are grouped using the same color. To determine the focus of each cluster, we use content analysis on the top 10 papers according to the PageRank score in each cluster. A highly-quoted paper may not necessarily be a prestige paper, although in some cases, there may be a strong positive correlation between the two indicators (Ding & Cronin, 2011; Fahimnia et al., 2015). We introduce the PageRank algorithm (Brin & Page, 1998) to solve the disadvantage of the impact factor that only considers the number of citations and ignores the quality of citations (Yin, 2012). Its core idea is that a paper cited by highly cited papers is likely to be important. For this reason, we use PageRank in the network analysis (Chen et al., 2007). From the content of these papers, we determine the focus of each cluster. The detailed content analysis is discussed in Sect. 4. Those five clusters indicate that different researchers have covered facility location, vehicle routing, humanitarian supply network flow,

Table 3 The primary research cluster and top 10 papers in the identified five clusters according to the co-citation Pageranks

Cluster 1 location of resources (81 papers)	Cluster 2 moving resources (66 papers)	Cluster 3 resource risk management (64 papers)
Özdamar et al. (2004)	Hong et al. (2015)	Paul and MacDonald (2016)
Holguín-Veras et al. (2013)	Mete and Zabinsky (2010)	Campbell and Jones (2011)
Barbarosoğlu and Arda (2004)	Özdamar and Demir (2012)	Oloruntoba (2010)
Vitoriano et al. (2011)	Huang et al. (2012)	Nolz et al. (2011)
Campbell et al. (2008)	Döyen et al. (2012)	Görmez et al. (2011)
Ransikarbum and Mason (2016)	Turkes et al. (2019)	Sahebjamnia et al. (2017)
Zhang et al. (2012)	Davis et al. (2013)	Noyan (2012)
Toregas et al. (1971)	Fahimnia et al. (2017)	Elluru et al. (2017)
Duhamel et al. (2016)	Sheu and Pan (2014)	Zhang et al. (2019)
Aly and White (1978)	Rodriguez-Espindola et al. (2018)	Chapman and Mitchell (2018)
Cluster 4 shelter management (31 papers)	**Cluster 5 resource allocation for mass casualty (48 papers)**	
Saadatseresht et al. (2009)	Yi and Özdamar (2007)	
Li et al. (2011)	Jia et al. (2007)	
Sabouhi et al. (2018)	Zhu et al. (2019)	
Yahyaei and Bozorgi-Amiri (2018)	Krasko and Rebennack (2017)	
Kilci et al. (2015)	Haghi et al. (2017)	
Alçada-Almeida et al. (2009)	Jin et al. (2015)	
Trivedi and Singh (2017)	Gao (2019)	
Li et al. (2012)	Salehi et al. (2019)	
Knay et al. (2018)	Toro-Diaz et al. (2015)	
Goerigk et al. (2014)	Zhang and Li (2015)	

location routing, and supply chain management (Rennemo et al., 2014). The demands and rescue of victims have also received attention.

3.2.2 Dynamic co-citation analysis

To understand the development of clusters and their relationship with time, we plot the co-citation network over time in Fig. 4. The size of a node represents the PageRank score

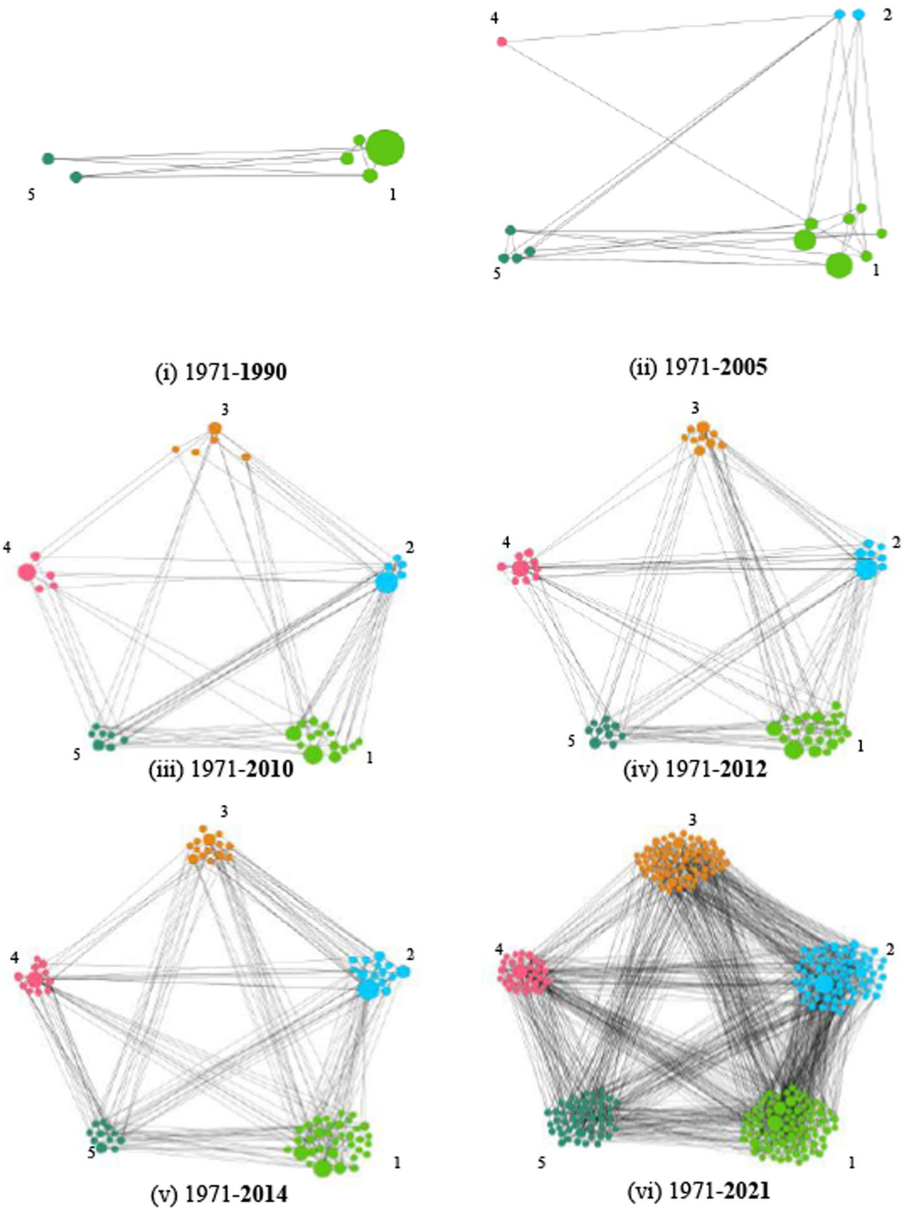

Fig. 4 The evolution of different research fields over time (accumulated from 1971)

of the paper. The figure shows that the resource management research in DM began with location of resources (cluster one). This cluster has dominated the early research in resource management. In fact, this cluster has sustained interest from researchers to the present day. As for cluster five (resource allocation for mass casualty), the first two papers appeared in 1989 and 1990, respectively. This cluster quickly evolved to become the next dominant research focus until 2015. In the early development of resource management research in DM, papers in clusters one and five have played a central role.

Since 2010 the number of papers in clusters two, three, and four has increased more rapidly than in clusters one and five. This shows the increasing need to focus on the more integrated solutions to DM (cluster two) and the more robust rescue plan (cluster three). Cluster two integrates the location of resources problem in cluster one with the inventory and transportation problem. Cluster three focuses on the resource risk management. There is also a greater emphasis on the demand-side, acknowledging the importance of fairness, demand coverage, and unsatisfied demands (clusters four and five). By 2021, all clusters have become heavily interconnected and play an almost equally significant role. This suggests that resource management research in DM has grown to be a developed research topic comprising five areas of focus which further justifies the need to review the literature on this topic.

4 Content analysis of the five clusters

The bibliographic and network analyses have helped us to identify the five research clusters quantitatively. In this section, we use the content analysis of the papers representing each cluster listed in Table 3 to conduct a more in-depth analysis of each cluster.

4.1 Cluster one: location of resources

Cluster one is the largest group with 81 papers. The first paper was published in 1971. Papers in this cluster address problems such as constructing or opening emergency facilities (Barzinpour & Esmaeili, 2014; Duhamel et al., 2016; Kim et al., 2019), distributing supplies (Aly & White, 1978; Özdamar et al., 2004; Ransikarbum & Mason, 2016; Sharma et al., 2017), and optimizing commodity flow (Vitoriano et al., 2011; Zhang et al., 2012). Facilities and supplies are the most prominent categories of emergency resources. The main assumption is that the quantity of supply and demand are known.

Most of these papers have traditional objectives, categorized into facility operation, relief transportation, and demand. The objectives related to facility operation include the number (or cost) of opening facilities (Kim et al., 2019), cost of maintaining and running facilities (Burkart et al., 2017), and personnel cost (Hale & Moberg, 2005). The objectives related to transporting materials include transport time (Holguín-Veras et al., 2013) and the distance between facilities and demand points (Campbell et al., 2008; Khare et al., 2020). Demand-related objectives include unsatisfied demands (Holguín-Veras et al., 2013), degrees of satisfaction (Khare et al., 2020), and area coverage (Toregas et al., 1971).

Some papers propose deterministic models to optimize the number and locations of facilities (Verma & Gaukler, 2015) or the type and quality of transportation means (Campbell et al., 2008; Kim et al., 2019). In the real world, the availability of emergency resources and the environment in which they operate, and the demand are dynamic and uncertain. Hence, some scholars construct stochastic programming models to solve the problems (Abualkhair et al., 2020; Aly & White, 1978; Barbarosoğlu & Arda, 2004). Some authors notice that existing solutions ignore the secondary disasters and propose a model to address such issue (Zhang et al., 2012).

Some authors apply a multi-criteria decision framework. Roh et al. (2015) analyze the preposition of warehouses for humanitarian organizations from both macro and micro perspectives. These authors use the Analytical Hierarchy Process (AHP) and fuzzy-TOPSIS to determine the relative importance of each criterion. Given that multiple humanitarian organizations may compete for emergency resources, game theory can accurately capture this competitive relationship to help humanitarian organizations choose appropriate suppliers (Nagurney et al., 2019).

4.2 Cluster two: moving resources

With 66 papers, this is the second-largest cluster, and the first paper was published in 2002. These papers integrate the problems in cluster one (such as constructing or opening emergency facilities, distributing supplies, and optimizing commodity flow) with vehicle routing and maintaining emergency supplies. The primary assumption in the early work was that the location of relief facilities was known (i.e., inventory problem) (Huang et al., 2012). However, the more recent work combines the facility location and supply repositioning, including the location inventory problem (Noham & Tzur, 2018; Rodriguez-Espindola et al., 2018) and the inventory routing problem (Alem et al., 2016; Mete & Zabinsky, 2010). The cost per number of open facilities (Noham & Tzur, 2018; Tofighi et al., 2016), inventory costs (Davis et al., 2013; Khalilpourazari & Khamseh, 2017; Tofighi et al., 2016), transportation costs (Garrido et al., 2015; Paul & Zhang, 2019), the unfulfilled demand, and oversupply (Alem et al., 2016) are the common objective functions that appear in almost all papers in this cluster. Rezaei-Malek et al. (2016) propose a rather different objective function, in which they define a level of utility of relief commodities provided to demand points and minimize the maximum difference of utility levels among demand points.

Most papers in this cluster use stochastic models that consider the parameter uncertainties, such as demand quantity and locations (Hong et al., 2015; Sheu & Pan, 2014), supplies quantity and availability (Turkes et al., 2019), post-disaster route availability (Alem et al., 2016; Özdamar & Demir, 2012), and disaster severity (Alem et al., 2016; Fahimnia et al., 2017; Mete & Zabinsky, 2010). They focus on a multi-level humanitarian supply chain network, determine the location of central warehouses and local distribution centers, and set prepositioned inventory levels of relief supplies. Relief allocation plans are then developed based on post-disaster uncertainty (e.g., Döyen et al., 2012; Tofighi et al., 2016).

In addition to using a single model, authors also apply a variety of optimization techniques. Lodree and Taskin (2008) present four variants of the newsvendor model to determine the appropriate inventory level. Adida et al. (2011) transform joint inventory storage into a non-cooperative strategic game and analyze the impact of public health policies on disaster planning.

4.3 Cluster three: resource risk management

Cluster three consists of 64 papers and the first of which was published in 2006. During the preparedness phase, this cluster provides various solutions to reduce the vulnerability of the humanitarian supply chain to better implement emergency plans. The objective functions include minimizing the cost of constructing or opening a facility (Campbell & Jones, 2011; Charles et al., 2016; Görmez et al., 2011; Paul & MacDonald, 2016), costs of supplies maintaining (Campbell & Jones, 2011; Noyan, 2012), distribution costs (Elluru et al., 2017), cost of equipment or personnel recruitment (Soltani-Sobh et al., 2016), uncovered demand (Sanci & Daskin, 2019), the Conditional-Value-at-Risk (CVaR) or Value-at-Risk (VaR) (Chapman & Mitchell, 2018; Condeixa et al., 2017; Noyan, 2012), and risk (Campbell & Jones, 2011; Elluru et al., 2017; Nolz et al., 2011).

The reliability of the humanitarian relief supply chain can be improved by increasing the budget or adapting the supply chain structure (Zhang et al., 2019). For example, Elluru et al. (2017) propose proactive and reactive versions of the location-routing problem with time windows. In a proactive approach, risk factors are considered as distribution network preventive measures caused by disasters. The model is further extended to a reactive approach by taking into account disruptions such as facility failures, route congestion, delays in delivery, and costly penalties. More details about risk measurement include road damage coefficient, road repair difficulty, repair time, and weather (Oloruntoba, 2010; Wang & Sun, 2021). As another example, when studying the location of disaster response and supply facilities for the expected earthquake in Istanbul, Görmez et al. (2011) analyze the vulnerability level of each candidate facility location and establish service level constraints related to the risk level to address the possible interruption of service after the earthquake. They also recommend the use of standby facilities to serve high-risk areas. For supply shortage risk, Chen et al. (2021) propose a combined entrusted reserve and options contract for procurement of supplies. Integrating non-profit humanitarian organizations and the supplier to jointly stockpile and deliver supplies is beneficial for sharing the risk of material shortage and increasing the storage quantity (Balcik & Ak, 2014; Chen et al., 2017). Additionally, UAVs are receiving increased attention from relief organizations (Rabta et al., 2018). They can be used to distribute supplies to cut-off regions in the early hours after an earthquake (Shao et al., 2020), support making a high-level route map for disaster response managers (Fu et al., 2021; Nedjati et al., 2016), and search and rescue victims to finish the field-based disaster damage assessment (Wang & Liu, 2021).

To deal with non-quantifiable risk assessment criteria, Malekpoor et al. (2019) propose the hybrid method of bi-objective integer linear programming and MCDM (VIKOR) to plan the power system of disaster relief camps. The VIKOR approach considers the risk of interruption caused by intermittent resource supply (Hooshangi & Alesheikh, 2017). In addition, the simulation-based decision support system (DSS) allows to reassess the risks of disruption and recreate and analyze the decision iteratively to manage project risks and risk interactions (Chao & Marie, 2012). Sahebjamnia et al. (2017) develop a DSS to optimize a three-level humanitarian relief chain. The optimal facility location, supply allocation, and distribution plan serve to assess the potential earthquake damage in urban fabrics based on three factors: the vulnerability of buildings, the size of houses in the block, and the width of the existing road network in urban blocks.

4.4 Cluster four: shelter management

With only 31 papers, this is the smallest cluster. The first paper appeared in 1988. The research in this cluster mainly addresses constructing or opening emergency shelters and evacuating affected populations taking into account facility capacity and distance to shelters (Kilci et al., 2015; Sabouhi et al., 2018). For example, GIS and a multi-objective model are combined to determine the location of shelters and promote evacuation planning (Saadatseresht et al., 2009; Alçada-Almeida, 2009). Yahyaei and Bozorgi-Amiri (2018) propose a mixed-integer programming model to solve the robust problem of humanitarian relief network planning. The multi-stage stochastic programming model can be used to find optimal shelter locations considering primary and secondary disasters to transfer victims to the nearest shelters (Ozbay et al., 2019). Kimms and Maiwald (2018) consider the uncertainties of route available in the model to reduce the risk exposure of evacuees.

The typical objective functions are evacuation distance (time, routing) (Goerigk et al., 2014; Kilci et al., 2015; Kimms & Maiwald, 2018; Li et al., 2012), evacuee risk (Bish et al., 2014), location and number of shelters to be opened (Kilci et al., 2015; Knay et al., 2018; Li et al., 2011; Saadatseresht et al., 2009), uncovered shelter demand (Yahyaei & Bozorgi-Amiri, 2018), satisfaction level of evacuees (Kilci et al., 2015), and shelter service quality (Pérez-Galarce et al., 2017; Trivedi & Singh, 2017).

The needs of victims also affect evacuation and resettlement activities (Bayram & Yaman, 2017). For example, evacuees may agree to choose a route that does not exceed the shortest way to the nearest shelter (Bayram et al., 2015), and they are free to select their preferred route (Li et al., 2012). In response to the multiple needs of victims, it is necessary to determine transfer points and shelter locations to transport evacuees to hospitals, and commodities can be distributed to evacuees optimally. For example, Sabouhi et al. (2019) develop a multi-objective robust optimization model to generate evacuation and relief distribution plans to minimize the total waiting time for evacuation and delivery time of materials.

4.5 Cluster five: resource allocation for mass casualty

This cluster comprises 48 papers. The earliest paper was published in 1987. This cluster focuses on decisions related to providing medical services to casualties who need first-aid assistance and medical attention. The objective is to save as many lives as possible, for example, by efficiently allocating medical supplies, personnel, and equipment (Jia et al., 2007; Jin et al., 2015; Salehi et al., 2019; Yi & Özdamar, 2007). The objective functions include unmet demand (Gao, 2019; Haghi et al., 2017; Zhang & Li, 2015), the expected cost of casualties and the time taken to discover casualties (Bravo et al., 2019), human suffering (Huang et al., 2015), and rescue time (Lee, 2011; Toro-Diaz et al., 2015). Effective casualty management can significantly improve the survival rate of casualties.

Mass casualty incidents often overwhelm emergency response capacities. Thus, it is critically important to set the correct priority for emergency medical resources, which is usually determined by a patient's criticality or the victims' chances of survival (Na & Banerjee, 2015; Sung & Lee, 2016). Complex disaster evacuation problems are characterized by multiple evacuation priorities, various types of vehicles, and various categories of emergency resources (Krasko & Rebennack, 2017; Na & Banerjee, 2015). The transportation strategy aiming at diverse injury degrees must be determined effectively and efficiently, particularly when the relief budget is limited (Zhu et al., 2019). Bravo et al. (2019) propose a partially observable Markov decision-making process to guide drones to search for injured people in affected areas. Their model is to set higher priorities in places with more casualties. Similarly, the optimization model based on the rolling horizon has been used to allocate relief commodities and injured populations to reduce the total non-satisfied demand (Liu et al., 2019). In the field of humanitarian assistance, emergency departments need to consider fairness and priority.

To save lives and provide safety, a variety of activities should be considered in DM. For example, Najafi et al. (2013) propose a robust multi-objective, multi-mode, multi-commodity, and multi-period stochastic model for transporting relief supplies and victims. They suggest transforming the model into three sub-samples and using three phases to optimize three objectives hierarchically. Similarly, Edrissi et al. (2013) define three sub-problems under budget constraints: reconstructing damaged and low-quality buildings, improving transport infrastructure, and positioning/allocating emergency resources. The results show a considerable improvement in the number of deaths.

5 Suggested future research directions

Based on the bibliometric and content analysis, we propose six future research directions for resource management in DM (Table 4).

5.1 More research on the impact of disaster characteristics and secondary disasters on resource management

There is a need for more research into specific types of natural disasters in the DM area. Our review shows that approximately 79% of the 460 papers indicate that their methods are suitable for natural disasters in general. This may not true for some decisions. From the resource management perspective, the type of disaster may affect the types of resources needed because different natural disasters have different characteristics and impacts. For instance, there is no sufficient warning time for earthquakes. However, for hurricanes, the wind speed, intensity, and path can be predicted so that there is ample time for the deployment of emergency resources. Moreover, the types of resources used and planned for each type of natural disaster may have different priorities. For example, relief teams and medical supplies are the top priorities for flood victims, while food and water are the top priorities for drought victims. Since the time, budget, and capacity are limited after disasters, setting the right priorities of resource supply can help national and local agencies organize rescue activities effectively to improve the wellbeing of the victims. Another issue is that demand triggered by possible secondary disasters poses more challenges in disaster relief operations. A few studies consider the impact of secondary disasters on resource management (Zhang et al., 2012). In

Table 4 Future research directions suggested for resource management in DM

Category	Existing research	Future research directions
Type of disaster	Disaster characteristics are not obvious	Analyzing the impact of disaster characteristics and secondary disasters on resource use
Model building	1. Existing assumptions are strict	1. Relaxing some assumptions and introducing new assumptions in resource planning and allocation
	2. Disaster situation is close to deterministic	2. Focusing on the mixed uncertainty in resource management
	3. Limited empirical data	3. Using actual data and archival data in resource allocation
Coordinated integration	Emergency resources are scattered	Developing resource coordination
Needs of victims	Lack of consideration for the needs of victims	Studying the psychological and sociological needs in resource management
	Few papers consider interruption risk	Studying risks in resource management
Resource reliability		
Emerging technologies	Focuses on describing the disaster situation and exploring the cause	Adopting emerging technologies in disaster resource management

reality, natural disasters may occur in sequence, such as a tsunami after an earthquake, which requires different materials and deployments to deal with different disasters. Hence, there is an urgent need for resource management research that considers specific disaster types and secondary disasters.

5.2 More realistic models for resource management

As the ultimate goal of resource management research is to improve management decision-making in the real world, scholars need to consider the following aspects in their models:

(1) *There is a need for more realistic assumptions*. Overly strict assumptions help reduce the complexity of problems. However, this approach may reduce the applicability of the solution in the real world. This is particularly true for resource management. For instance, most papers on emergency resources allocation and evacuation assume that drivers or victims have complete information about the evacuation network and traffic conditions (Rodriguez-Espindola et al., 2018; Sung & Lee, 2016). Krasko and Rebennack (2017) consider the increased travel time due to road damage during the process of transporting casualties using vehicles. In reality, such information is not available immediately. Furthermore, Bayram and Yaman (2017) find that not all evacuees comply with the guidance from the central authority. Hence, a better understanding of how the behavior of actors, including victims, affects disaster response operations is needed. Special emergency rules could be introduced, such as allocating medical staff to hospitals other than the ones they usually work in before the disaster to help victims with serious injuries (Shavarani et al., 2019). In the relief distribution process, some papers do not set a deadline (Campbell et al., 2008; Ransikarbum & Mason, 2016; Rawls & Turnquist, 2010). In fact, the high priority demand needs to be delivered within a certain period (Zhu et al., 2019). Sabouhi et al. (2018) suggest that future research should consider time window constraints. These examples show the need for more realistic assumptions in resource management models used in DM.

(2) *There is a need to consider mixed uncertainty in the model*. Our review shows that "stochastic" is in the top 20 most often used words in the title and keywords. Hence, there has been significant work on this topic. Most studies dealing with this issue are based on stochastic programming methods (Barbarosoğlu & Arda, 2004; Noyan et al., 2016; Torabi et al., 2018). However, uncertainty is still one of the main challenges in resource management. The uncertainty mainly comes from random disaster scenarios (e.g., the time, location, and severity of the disaster), fuzzy scenario parameters in a typical disaster setting (e.g., travel time, cost of relief distribution, and demand) in disaster operations, and behavioral uncertainty of the actors (e.g., conformance to plans, coordination between agencies). Hence, more innovative methods that are realistic and practical are needed. For example, Nagurney and Nagurney (2016) present a mean–variance mode for the disaster relief chain to reduce risk under uncertain costs and demand. To consider different decision-makers and the lack of information at the beginning of the disaster, Nagurney et al. (2020) propose a model of game theory for disaster relief decisions under uncertainty. The sources for uncertainty include demand, the price of relief materials purchased from different suppliers, and logistics costs caused by damage to the infrastructure. The UAV helicopters can also be utilized to support the supplies distribution to victims who are located in collapsed or inaccessible areas in potential random scenarios (Golabi et al., 2017).

(3) *The use of real-world resource supply and demand data is preferable to make a model more realistic*. Our review shows that only 45% of literature use real-world data. Using real-world data can increase the recognition of decision-makers. The data sources include

personal interviews (Roh et al., 2015), surveys (Charles et al., 2016), relief organizations' archive data (Salehi et al., 2019), past literature, and online data (Paul & MacDonald, 2016). Some papers use HAZUS, a disaster simulation tool developed by the Federal Emergency Agency (FEMA), to assess the impact of natural disasters, which can be used to create real-world data sets (Mills et al., 2018; Ransikarbum & Mason, 2016). The literature survey carried out by Amideo et al. (2018) points out that authors should also be transparent on how data are collected. Past data also help to reliably predict short-term demand to improve the current relief distribution network (Charles et al., 2016).

5.3 The need for more integrated models in resource coordination

Good coordination between organizations that manage emergency resources is important for disaster relief operations. Most papers address the coordination issue by proposing models that integrate various emergency resources such as facilities, transportation, supplies, and relief personnel. For instance, Rodriguez-Espindola et al. (2018) incorporate the location of facilities, inventory, and transportation decisions. This then coordinates the use of multiple emergency resources (shelter, distribution center, relief items, transportation means, and personnel) from various organizations. Sabouhi et al. (2018) build a model that integrates the network of vehicle depots, affected areas, shelters, and distribution centers. Yi and Özdamar (2007) develop an integrated location-distribution model to transport essential first-aid products and emergency personnel to the affected areas. Given the importance of good coordination, more integrated models are needed to help decision-makers coordinate the various emergency resources effectively.

5.4 More research that considers the social and psychological needs of the victims in resource management

Most of the reviewed papers regard penalty costs like uncovered demand for relief items, time delay, and loss of waiting time as demand objectives (Elluru et al., 2017; Mete & Zabinsky, 2010; Salmeron & Apte, 2010). While cost and unmet demand are direct and straightforward expressions, it is also essential to reflect the victims' social needs and psychological perception (Zhong, 2021), such as psychological assistance and fairness. Specifically, the public social needs and psychological perception can be determined by the time reference point, the actual arrival time of supplies, risk aversion, and preference (Chang et al., 2022; Pérez-Rodríguez & Holguín-Veras, 2016). For example, Holguín-Veras et al. (2013) use the social impact of natural disasters in preparedness activities to reduce the effects of disasters. Sheu and Pan (2014) integrate the psychological costs of victims into the objective function when designing a centralized emergency supply network. Chapman and Mitchell (2018) use the concept of fairness when discussing rescue operations. However, our literature review shows a lack of research to consider the social and psychological needs of the victims. Therefore, more research is needed in this area.

5.5 More research into risk factors affecting resource management in disaster

When dealing with natural disasters full of risks, the reliability of resource management is important. However, the issue surrounding the risk reduction and reliability of emergency resources has only recently been mentioned (Chapman & Mitchell, 2018; Kimms & Maiwald, 2018; Noyan, 2012). Due to the unpredictability of some natural disasters, there is a risk of damage to facilities, supplies, and transportation networks (Nagurney et al., 2019). Power outages and shortages in water, food, and medical supplies are the most critical problems that affect victims. The method commonly used to analyze the risk is based on the geographic locations of facilities. For example, Campbell and Jones (2011) set different probabilities of destroying supply points at different locations. Elluru et al. (2017) consider probabilistic risk factors of infrastructure damages when planning relief distribution operations. Several scholars use CVaR or VaR to balance the highest cost and average cost of relief distribution (Chapman & Mitchell, 2018; Noyan, 2012). Finally, risks among supply points may be relevant (Campbell & Jones, 2011). This would affect the choice of supply points and the inventory levels because of the potential risk-sharing benefits. Our review has found that papers addressing risk measures in resource management is still at an early stage. Future research is necessary to investigate how risks in emergency resources are related.

5.6 Impact of emerging technologies on disaster risk management

The impact of multiple high-tech devices and big data analysis cannot be ignored in resource management. Most of the data include spatial elements or facility locations (Görmez et al., 2011; Kilci et al., 2015), which provide an opportunity to make good use of GIS. GIS accurately presents the location, distribution, severity, and damage of facilities and road networks. For example, Rodriguez-Espindola et al. (2018) combine GIS and optimization functions. Drones (Kim et al., 2019), satellite networks, and remote sensing can also be used as tools for disaster relief data acquisition. Vizvári et al. (2019) propose a top-down method to design a disaster relief system combined with UAV technology to deliver supplies, inform the inhabitants of supply points, complete part of reconnaissance and patrolling. It is particularly useful during disaster response operations as data are hard to find from other sources. Real-time analytics can be important, too, particularly when the situation is dynamic and natural disasters may have a chain reaction (Zhang et al., 2012). For example, Suriyaphong et al. (2018) use real-time data from Twitter to formulate the optimum location of ambulance bases when a disaster occurs. The volume of research in using big data-driven crisis analytics platforms to enhance disaster response capabilities is limited (Akter & Wamba, 2017). When future research is systematically embedded in information technology-based decision-making procedures, these approaches can be effectively used for real-time optimization and what-if analysis for resource management in DM.

6 Conclusion

Resource management is an area that provides many opportunities for both researchers and practitioners, not only in optimization but also in other professional fields. With the help of bibliometric and network analysis tools, we analyze the literature on resource management published in peer-reviewed elite journals from 1971 to 2021, including facilities, rescue materials, and personnel, investigate the evolution of this research field, and identify five research groups. Based on the co-citation analysis, we perform an analysis of the contents of the papers published in JCR 2020 ranking journals and finally determine the future research directions.

Adopting different measures, we find that most papers in resource management were published in the past 10 years. Keyword statistics show that quantitative modeling becomes more important, among which stochasticity and uncertainty have attracted scholarly attention. At the same time, an increasing number of papers in this area use real case studies to verify the effectiveness of the proposed methods. In Sect. 5, we point out that these are fruitful and challenging research endeavors. We identify five clusters among the existing research and provide additional insights from the content analysis. Finally, we highlight and discuss the gaps we find by reviewing these papers to provide researchers with six future research directions. As far as we know, this paper discusses, for the first time, an analysis of resource management during preparedness and response phases of natural disasters. The combination of multiple literature review methods, including bibliometric, network, and content analyses, provides academic rigor and minimizes the shortcomings of the existing review methods. For academics, potential future research directions are provided to propose methods close to reality and applicable for future natural disasters. For practitioners, particularly disaster relief project managers, managerial insights are provided from the content analysis on resource management. This includes the importance of combining the impact of disaster characteristics and secondary disasters to provide emergency resources and proposing more realistic models. Specifically, constructing models can be improved in the following ways: relaxing assumptions and introducing new assumptions in resource support, focusing on the mixed uncertainty in resource management, and using actual and archival data in resource allocation. It is also essential to develop resource allocation for various emergency resources. Other challenging future research directions involve studying the psychological and sociological effects and risks in resource management and adopting emerging technologies.

Our research methods also have limits. In this paper, we select keywords according to the definition of resource management during the preparedness and response phases of natural disasters. Although we have searched two widely used databases (Scopus and Web of Science) and used conservative search methods, the results may not be exhaustive. Some papers that meet the criteria of inclusion and exclusion may be omitted because there are no phrases about natural disasters and resource management in their titles, keywords, and abstracts. Moreover, to manage the number of papers for content analysis, we select journals on JCR 2020 list, which exclude certain papers. Although we have tried our best to include the most relevant papers, different search phrases and journal selection criteria may influence the results, leading to different interpretations of research progress in this field.

Appendix 1

Figure 5 and 6

See Table 5 and 6

See Table 7

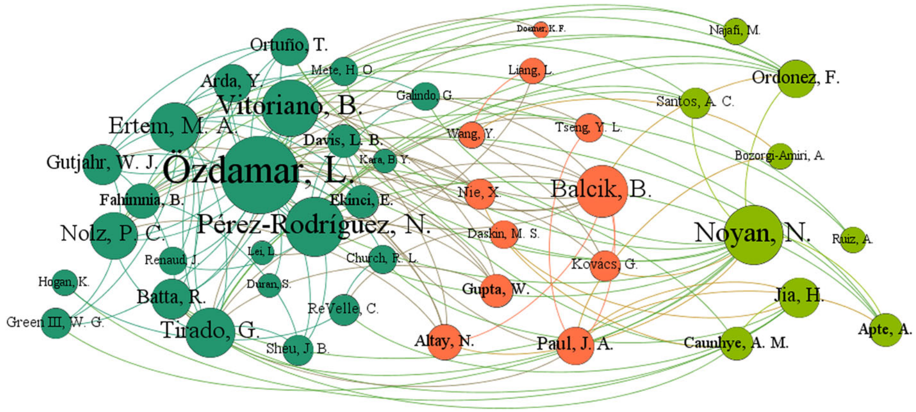

Fig. 5 Author co-citation network in resource management studies.

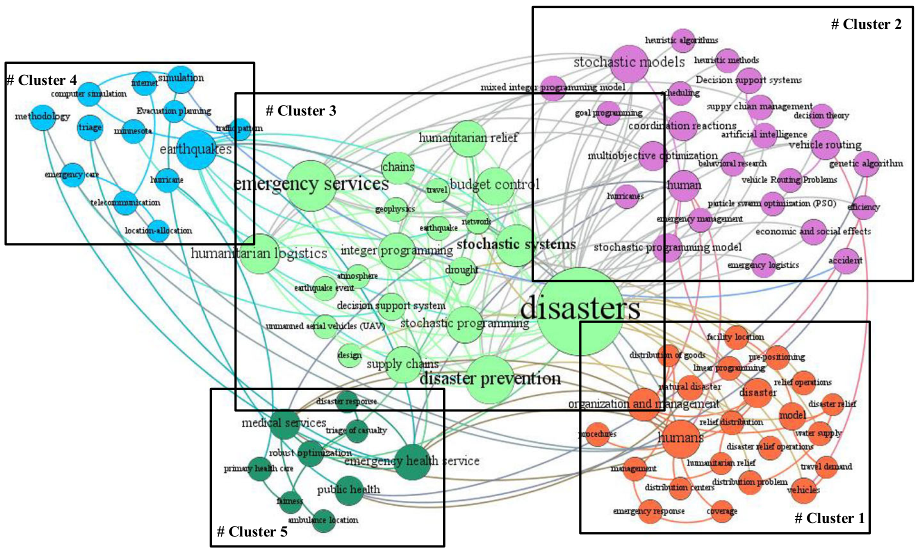

Fig. 6 Keyword co-occurrence network of articles in resource management studies.

Table 5 The top 10 most relevant authors and number of published papers.

Rank	Authors	Number of Articles
1	Liang Liang	8
2	Rajan Batta	7
3	Gregorio Tirado	7
4	M. Teresa Ortuño	7
5	Rajan Batta	7
6	Gregorio Tirado	7
7	Douglas Alem	6
8	Burcu Balcik	6
9	Begoña Vitoriano	6
10	Jomon A. Paul	6

Table 6 The top 10 most relevant institutions and number of published papers (note that papers with authors from different organizations may have been assigned to multiple organizations).

Rank	Organization	Location	Number of Articles
1	Iran University of Science and Technology	Iran	19
2	Rensselaer Polytechnic Institute	United States	17
3	University at Buffalo	United States	16
4	INSEAD	France	13
5	University of Science and Technology of China	China	9
6	Amirkabir University of Technology	Iran	6
7	University of North Carolina	United States	6
8	Hebei University	China	6
9	Sabanci University	Turkey	4
10	Northeastern University	United States	4

Table 7 The top 10 most relevant countries.

Rank	Country	Percentage contribution
1	United States	23.58%
2	Turkey	12.98%
3	China	8.91%
4	United Kingdom	5.24%
5	Iran	5.24%
6	India	4.67%
7	France	4.56%
8	Canada	4.44%
9	Brazil	3.30%
10	Austria	3.08%

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