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Disaster management and emerging technologies: a performance-based perspective

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Abstract

Purpose – This paper aims to analyse how emerging technologies (ETs) impact on improving performance in disaster management (DM) processes and, concretely, their impact on the performance according to the different phases of the DM cycle (preparedness, response, recovery and mitigation).

Design/methodology/approach – The methodology is based on a systematic review of the literature. Scopus, ProQuest, EBSCO and Web of Science were used as data sources, and an initial sample of 373 scientific articles was collected. After abstracts and full texts were read and refinements to the search were made, a final corpus of 69 publications was analysed using VOSviewer software for text mining and cluster visualisation.

Findings – The results highlight how ETs foster the preparedness and resilience of specific systems when dealing with different phases of the DM cycle. Simulation and disaster risk reduction are the fields of major relevance in the application of ETs to DM.

Originality/value – This paper contributes to the literature by adding the lenses of performance measurement, management and accountability in analysing the impact of ETs on DM. It thus represents a starting point for scholars to develop future research on a rapidly and continuously developing topic.

Keywords Emerging technologies, Disaster management, Performance, Systematic literature review, VOSviewer, Emergency response

Paper type Research paper

1. Introduction

Despite the rising number of catastrophic events occurring in recent years, disaster management (DM) has received little attention from the interdisciplinary accounting community (Lai *et al.*, 2014; Sargiacomo *et al.*, 2014; Walker, 2014; Sciulli, 2018; Perkiss and Moerman, 2020; Sargiacomo and Walker, 2020).

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A key aspect of DM theory and practices is related to the information systems used to support decision-making and to measure, manage and report the performance of the whole DM cycle (see, amongst others, Carreño *et al.*, 2007). Information systems have widely supported disaster practitioners in recent decades, providing an increasing volume of data gathered through emerging technologies (ETs), such as big data, Internet of Things (IoT) (Yang *et al.*, 2013; Shah *et al.*, 2019), machine learning, artificial intelligence (AI), remote sensing, cloud computing, social media communication (Alexander, 2014) and blockchain.

ETs are science-based innovations which provide great transformative potential for an industry, in an "early phase of development" (Boon and Moors, 2008) and can lead to "radical innovations" (Day and Schoemaker, 2000) and/or allow an evolutionary process of technical, institutional and social change; however, they bring risks of uncertainty in terms of network effects, costs and social and ethical concerns (Halaweh, 2013).

All these technologies are spreading their value in a growing variety of domains, effectively contributing to the planning, decision-making, accounting and auditing process of public and private organisations (Ndou *et al.*, 2018; Bonsón and Bednárová, 2019; Lamboglia *et al.*, 2020; Lombardi and Secundo, 2020; Rodríguez-Bolívar *et al.*, 2021; Tingey-Holyoak *et al.*, 2021; De Santis and D'Onza, 2021; Lombardi *et al.*, 2021).

Indeed, the implementation of digital technologies are becoming increasingly relevant for corporate and performance management (Oliver, 2018; Marrone and Hazelton, 2019; Wang *et al.*, 2020a, 2020b; Chatterjee *et al.*, 2021; Jun *et al.*, 2021), and especially ETs have demonstrated in the last years to be particularly supportive in fostering these issues in health care (Spanò and Ginesti, 2021), transportation (Chhabra *et al.*, 2021), manufacturing (Rezaei *et al.*, 2017) and so on.

With specific regards to DM, extant studies have mainly focused on how technology could support data gathering and visualisation (Fajardo and Oppus, 2010) as well as knowledge management (Inan *et al.*, 2018; Raman *et al.*, 2018; Oktari *et al.*, 2020). Conversely, literature reviews have focused on how specific technologies influence DM (Kankanamge *et al.*, 2019), how they support supply chain management (Ivanov *et al.*, 2019) or how they can be applied to deal with risks in small- and medium-sized enterprises (Verbano and Venturini, 2013).

To date, various streams of research across different disciplines, such as information science, computer science and engineering, have focused on the impact of ETs on disaster and emergency response.

However, to the authors' knowledge, limited attention has been devoted to understanding how ETs could support performance measurement, management and accountability in the specific setting of DM processes. To fill this gap, this study develops a systematic literature review (SLR) analysing how ETs impact on improving performance in DM, altering and changing DM processes to enhance resilience according to the different phases of the DM cycle (preparedness, response, recovery and mitigation). We used Scopus, ISI Web of Science, ProQuest and EBSCO as the data sources. We selected academic journal articles within the business, management and accounting categories.

The paper is structured as follows. Section 2 presents a theoretical background that links literature on DM, ETs and performance. Section 3 explains the methodology and clarifies the research question, and Section 4 presents the results of the SLR. Finally, the discussion and conclusions are presented.

2. Theoretical background

2.1 An overview of disaster management

The frequency and magnitude with which natural disasters (earthquakes, floods, landslides, droughts, storms, etc.) have occurred in recent decades are alarming. According to EM-DAT [1], over the last 20 years, disasters have claimed approximately 1.23 million lives and affected a total of over 4 billion people, leading to US$2.97tn in economic losses worldwide. During the same timeframe, a total of 7,348 disasters related to natural hazards have occurred worldwide.

The concept of disasters is extremely complex and multidimensional in nature; it can be discussed by drawing on several connected fields of research (Quarantelli, 1998).

According to the definition proposed by the United Nations Office for Disaster Risk Reduction, a disaster is:

> [. . .] a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts [2].

DM refers to the organisation, planning and application of measures aimed at preparing for, responding to and recovering from disasters. This topic has been widely discussed in the academic literature in recent decades through different perspectives (Faulkner, 2001; Pearce, 2003; Lettieri *et al.*, 2009) and, most recently, with a specific focus on how firms (Kraus *et al.*, 2020; Ferrigno and Cucino, 2021) and public institutions (Steen and Brandsen, 2020) have reacted to the COVID-19 pandemic. Social scientists frame disasters from three different perspectives: the *hazard*, the *vulnerability* and the *holistic view* (Berg and De Majo, 2017).

Under the *hazard* paradigm, disasters are considered extreme physical events with accidental causes and no human or cultural influence on their origin and scope; therefore, DM is mainly focused on *post-disaster short-term measures,* such as recovery, relief and humanitarian aid for those who need help (Alexander, 1997).

This traditional view has been replaced by the *vulnerability* paradigm, rooted in development studies, in which disasters are considered the results of natural causes related to the vulnerability of the surrounding social, economic and political environment (Cutter, 1996; McEntire, 2005; Buckle, 2005; Adger, 2006). Natural disasters, rather than being only uncontrollable events, greatly depend on some structural constraints of the population hit by catastrophic events (Wisner *et al.*, 2004).

Assuming this renewed approach, Gilbert (1998) stated that a "disaster is no longer experienced as a reaction; it can be seen as an action, a result, and more precisely, a social consequence." This broader perspective sheds light on how human activity, social order and development paths characterise the breadth and severity of natural disasters over time. According to Perry (1998), "vulnerability is socially produced," but it "may be also related to the state of technology," as information systems and ETs play a supportive role and have a key relevance within the various phases of DM (Von Lubitz *et al.*, 2008).

The increase in the occurrence of natural disasters sheds light on the inadequacy of traditional DM processes and practices around the globe. To tackle the wickedness (Rittel and Webber, 1973; Head and Alford, 2015; Pesch and Vermaas, 2020) of such problems and reduce their intrinsic complexity, scholars have highlighted the importance of collaborative networks amongst public institutions (Waugh and Streib, 2006; Ansell *et al.*, 2010; Comfort *et al.*, 2012; Kapucu and Garayev, 2016), coordination mechanisms to respond and react to the emergence of problems (Moynihan, 2008; Boin *et al.*, 2013; Kuipers *et al.*, 2015), competencies and leadership behaviours (Rosenthal and Kouzmin, 1997; Van Wart and Kapucu, 2011) and capacity building and community awareness (Kitagawa, 2021). All these aspects are important in disaster and emergency situations characterised by complexity, urgency and uncertainty (Kapucu and Van Wart, 2008).

The multiple threats posed by disasters suggest the adoption of a holistic view of DM with a more strategic focus on the actions and tools targeted to reduce exposure and vulnerability to disasters (Berg and De Majo, 2017). The holistic view marks a paradigm shift from responsive to proactive management of natural hazards based on the principles of resilience and disaster risk reduction (Manyena, 2006; Demiroz and Haase, 2019). The key phases of the DM cycle can be summarised in Figure 1.

DM requires and generates a huge amount of data coming from different sources, which must be reliable, accurate and real time. Through these data, DM practitioners can gather information on the features, locations and prospective impacts of threats, providing essential inputs for managing all the phases of the disaster cycle in a timely and effective way (Yu *et al.*, 2019). ETs have, to date, offered opportunities to improve the management of several fields. Table 1 shows the main applications discussed in the academic literature.

These technologies are considered to have a high impact on each of the phases displayed in Table 2, although all of them are valuable for the whole DM cycle.

2.2 Performance in the disaster management context

Performance is one of the most explored topics by business and public administration scholars in the last half century. It is a broad concept discussed by different streams of literature, which range from the measurement of performance to management accounting and control, behavioural economics and so on (Moynihan, 2008; Ferreira and Otley, 2009; Bititci *et al.*, 2012).

The literature usually focuses on performance by adopting three lenses that are strongly connected: performance measurement (Bititci *et al.*, 2012), performance management (Ferreira and Otley, 2009) and accountability (Roberts, 1991; Gray, 1992).

Performance measurement is the activity of collecting data, defining indicators and computing such indicators to evaluate the ability of a certain entity to achieve strategic goals (Eccles, 1991; Hudson *et al.*, 2001).

If performance measurement is concerned with what and how to measure, performance management is instead focused on the utilisation of such information in decision-making processes (Ferreira and Otley, 2009; Bititci *et al.*, 2012). In this sense, performance management could be defined as the process of creating the context for performance (Lebas, 1995). Performance management comprehends the whole process starting from the

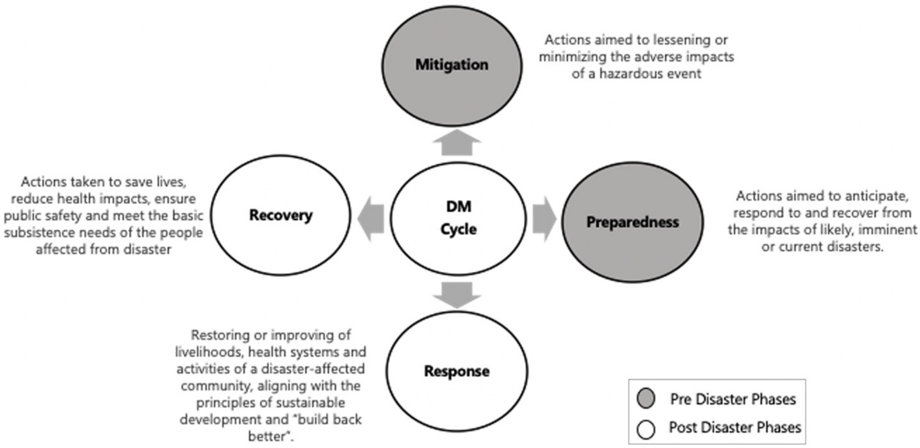

Figure 1.
Disaster risk management cycle. Our elaboration

Technology	Description	Main applications	Main applications in DM
Internet of things (IoT)	IoT refers to the networking of physical objects using embedded sensors and other devices that collect and transmit information about real-time activity within the network (Harbet, 2017)	Location finding Big data processing Mobility management (Asghari *et al.*, 2019)	Response
Artificial intelligence (AI)	AI is the ability of a machine to learn from experience, adjust to new inputs and perform human-like tasks. AI systems can be used either to support/assist human decision-makers or to replace them (Duan *et al.*, 2019)	Process automation to perform specific tasks Cognitive insights using machine learning algorithms to detect patterns in vast volumes of data and interpret their meaning Cognitive engagement using natural language processing tools to provide prompt response to specific needs (Davenport and Ronanki, 2018)	Mitigation/ prevention
Big data analytics (BDA)	BDA management involves the processing of huge amounts of data coming from different sources in different formats to acquire intelligence from the data. BDA can be viewed as a sub-process in the overall process of insight extraction from big data (Gandomi and Haider, 2015)	Data management Data analytics, e.g. modelling, analysis and interpretation of results	Emergency response/recovery
Remote sensing (RS)	RS provides observation of some physical parameters in a mapping frame at a given time or period (Toth and Jozkow, 2016)	Image and spatial data acquisition for topographic mapping Remote platform control, e.g. satellite or unmanned aerial systems or vehicles like drones	Preparedness/ response
Geospatial data (GIS)	GIS provides the geographic and location information of different data objects connected with a specific place or location, which can then be mapped (Barcevičius *et al.*, 2019)	Earth observation (Breunig *et al.*, 2020)	Mitigation/recovery
Robotics and automation (RA)	RA technologies automate repetitive, routine, rule-based human tasks, aiming to bring benefits to organisations (Ivancic *et al.*, 2019)	Industry 4.0 Health-care industry Emergency management Smart city applications (Macrorie *et al.*, 2019)	Response/recovery
Social media	Social media is an umbrella term and a revolutionary trend which refers to online blogs, micro-blogs, social networking, forums, collaborative projects and the sharing of photos and videos (Xu *et al.*, 2019)	Crowdsourcing Communication during emergency and disaster management (Harrison and Johson, 2016; Mehta *et al.*, 2017a, 2019 b)	Response
Blockchain	BC is a distributed peer-to-peer ledger that provides a way for information to be recorded, aggregated and shared within a heterogeneous community of participants (Felin and Lakhani, 2018)	BC has been so far applied, amongst others, in the financial sector, logistics and supply chain, health care, food safety, art market and agriculture	Relief–recovery

Table 1. Suitable emerging technologies in the DM field

definition of performance, the identification of related targets and the evaluation ex-post of the results obtained (Lebas, 1995; Ferreira and Otley, 2009).

Lastly, performance accountability is a broad concept which covers activities such as reporting performance, communicating the results achieved to stakeholders and the broader community and guaranteeing transparency (Roberts, 1991; Gray, 1992). It is a concept which

Table 2.
Search criteria

"Criteria	Description
Field of knowledge	Business, management and accounting
Literature type	Research article
Literature language	English
Period	2000–2021
Search query	"emerging technolog*" OR "big data" OR "artificial intelligence" OR "AI" OR "IoT" OR "Internet of Things" OR "predictive analytics" OR "machine learning" OR "geospatial data" OR "robotics and automation" OR "social media" OR "cloud computing" OR "quantum computing" OR "drones" OR "blockchain" AND "disaster*" OR "risk management"
Screening I	Article title, abstract, keywords
Screening II	Text mining

has been widely explored in the literature on both public and private sector organisations (Kassel, 2008; Kaur and Lodhia, 2019).

Because of increasingly complex changes in society and the environment, performance studies have rapidly evolved in recent decades. Whilst the first management scholars mainly focused on financial performance, today, the literature agrees that researchers should focus on different performance dimensions, such as social, competitive and environmental (Kaplan and Norton, 1996; Bititci *et al.*, 2012; Khalid *et al.*, 2019). Moreover, the evolution of the discipline has made scholars shift their focus to the inter-organisational level, as in the case of supply chains, strategic alliances or governance networks (Dekker, 2016; Nuti *et al.*, 2018; Dell'Era *et al.*, 2020; Ferrigno *et al.*, 2021).

DM is amongst the fields of application of management which, more than others, present degrees of social complexity derived from a large set of stakeholders, multiple objectives and goals and the difficulty of measuring many of these because of the high uncertainty given by the unprecedented scenarios characterising every disaster (Comfort *et al.*, 2004).

The introduction and adoption of ETs are of great support to researchers and practitioners as they cope with the complexities of measuring, managing and reporting performance. According to many authors, information and digital technologies are indeed pivotal to the design and implementation of performance management and accountability systems (Marr and Neely, 2001; Nudurupati and Bititci, 2005; Rodríguez-Bolívar *et al.*, 2006; Buys, 2008; Marrone and Hazelton, 2019; Lombardi and Secundo, 2020).

New technologies may support performance in multiple ways. First, they assist in the measurement of performance (Nudurupati and Bititci, 2005; Cockcroft and Russell, 2018). Some technologies, such as big data or AI, allow managers to both have access to new sources of information and improve their ability to manage and analyse related data (Sardi *et al.*, 2020). This may enable the creation of new measures and performance targets. As such, in the case of DM, decision-makers may have access to new forms of information coming from social networks, satellites or sensors.

The second pivotal contribution of ETs is related to the real-time availability of new information, which improves performance management processes (Marr and Neely, 2001; Nudurupati and Bititci, 2005). This is of particular interest in the response phase of DM. Having the possibility to promptly react based on real-time reliable information can make a difference in emergency contexts (Laituri and Kodrich, 2008; Ragini *et al.*, 2018; Imran *et al.*, 2020).

Third, ETs as applied to performance have shown great potential for understanding concerns related to reporting and internal and external accountability (Marrone and Hazelton, 2019; Lombardi and Secundo, 2020). For example, new forms of data visualisation are being largely used to inform the community about the results achieved by the institutions in charge. What is peculiar in performance accountability in DM is its double directions, i.e. downward in an *accountability to the other*, in which the focus is on the intrinsic value of the suffering community, and upward in an *accounting for itself*, in which the focus is on market value (Sargiacomo *et al.*, 2014).

In light of this theoretical premise, this paper aims at covering a potential gap in understanding how ETs impact on improving performance in DM processes and, concretely, their impact on the performance according to the different phases of the DM cycle (preparedness, response, recovery and mitigation).

3. Data collection and methods

To achieve the research aim, this study conducts an SLR to identify the impact of ETs on performance measurement, management and accountability (Kraus *et al.*, 2020; Snyder, 2019). This methodology has already been applied both in relation to the applications of ETs (i.e. Martinez-Rojas *et al.*, 2018) and to DM (i.e. Lettieri *et al.*, 2009; Akter and Fosso Wamba, 2019).

An SLR is a systematic process aimed at defining the research question, identifying relevant studies and evaluating their features, quality and impact on the field. The last phase of an SLR summarises the findings qualitatively and/or quantitatively, reporting evidence to clarify what is and is not known with respect to the object of investigation (Denyer and Tranfield, 2009).

To ensure that the analysis conducted is transparent, auditable and replicable, the study uses an iterative process consisting of the following phases (Lombardi and Secundo, 2020; Dumay and Cai, 2015; Thorpe *et al.*, 2005):

- definition of the research questions;
- development of the research protocol;
- identification of documents for analysis;
- development of a coding framework; and
- execution of in-depth analyses.

The first phase consisted of defining the research question of the study, which focuses on understanding how ETs contribute to improving DM processes. Consistent with the theme of the special issue, the research question is also explored from the perspective of the emerging issues related to the dimensions of performance and, more specifically, the impact of ETs in terms of management, measurement and accountability within the DM cycle.

In the second phase of the SLR, we define the research protocol to support evidence-based practices and ensure objectivity (Tranfield *et al.*, 2003). In this phase, the focus of the study, the research strategy, the data sources and the inclusion/exclusion criteria used for the review are specified in accordance with the research question (Petticrew and Roberts, 2008). The background of this study has been created by adopting a wide perspective of analysis, selecting the most relevant articles in the business, management and accounting fields. Later on, we opted for a longitudinal study to collect literature from different scientific databases.

The third phase aims to identify the papers to be added to the literature review, defining the research string to use. We managed to collect research articles via title–abstract–keyword field codes using Boolean operators (AND, OR) as connectors.

Following the parameters, the search strategy was applied in the business, management and accounting areas, referring to the Scopus and JCR lists. A description is reported in Table 2.

The search query was entered in the ISI Web of Knowledge, Scopus, EBSCO Host and ABI/INFORM (ProQuest) databases, and it allowed us to obtain a total of 101, 172, 184 and 280 articles, respectively, for a total of 737 articles. We first eliminated redundant and non-English articles (Petticrew and Roberts, 2008), which were few and not very significant with respect to the research question. We also restricted the collection to scientific articles only (Zheng *et al.*, 2020; Lombardi and Secundo, 2020) because during the review process, these papers were tested with high-quality standards; the purpose was to ensure the quality of knowledge they provided (Light and Pillemer, 1984).

The timeframe covered the period from 2000 to February 2021. Although few studies have devoted their attention to the potential capabilities and limitations of digital technologies in DM at the end of the last century (amongst others, Wallace and De Balogh, 1985; Waugh, 1995; Stephenson and Anderson, 1997; Barth and Arnold, 1999; Chengalur-Smith *et al.*, 1999), the choice of the period was made in light of the growing interest in ETs and their impact in society and the public sector starting from the early 2000s, as confirmed by the academic literature (Day and Schoemaker, 2000; Rotolo *et al.*, 2015).

From a careful reading of the abstracts, we eliminated papers of a specific technical nature, in which the connection between ETs and DM was only mentioned but not developed. Double counting of papers was avoided by including only those that were different across the databases. These processes allowed us to obtain a valid sample of 127 articles. We checked through the full-text articles to further evaluate the quality and eligibility of the studies (Xiao and Watson, 2019). Carrying out a thorough reading of the papers, we selected those relevant to our research question, obtaining a final corpus of 69 papers (Figure 2).

Then, we defined the coding framework, selecting the following parameters: time of publication, distribution of papers amongst journals, author citations and keyword co-occurrence. In this phase, a double analysis was carried out on the final sample: descriptive analysis and clustering. The descriptive analysis aimed to highlight the main characteristics of the articles, indicating their number, evolution over time and distribution amongst journals.

Data analysis was conducted using VOSviewer software (Van Eck and Waltman, 2017). As in other descriptive bibliometric analyses (Secundo *et al.*, 2020), we analysed keyword co-occurrence and document citations; then, we performed a cluster analysis to capture the focal points and connections between the main topics considered in our study.

We developed the co-occurrence analysis by selecting *keywords* as a single entity for analysis, as a meaningful description of an article's content (Lamboglia *et al.*, 2020) and as an endpoint to add a paper with a minimum number of two occurrences of a keyword. Using this technique, we obtained a twofold visualisation – network and overlay.

The last phase of the SLR aims to carry out a critical and comprehensive analysis of the selected articles. Finally, we clustered the results using VOSviewer. The main findings derived from the SLR are reported in Section 4.

4. Findings

4.1 Characteristics of sample selection

As shown in Figure 3, the number of articles that investigate the relationship between ETs and DM in accordance with our research question was narrowed until 2016, with an average

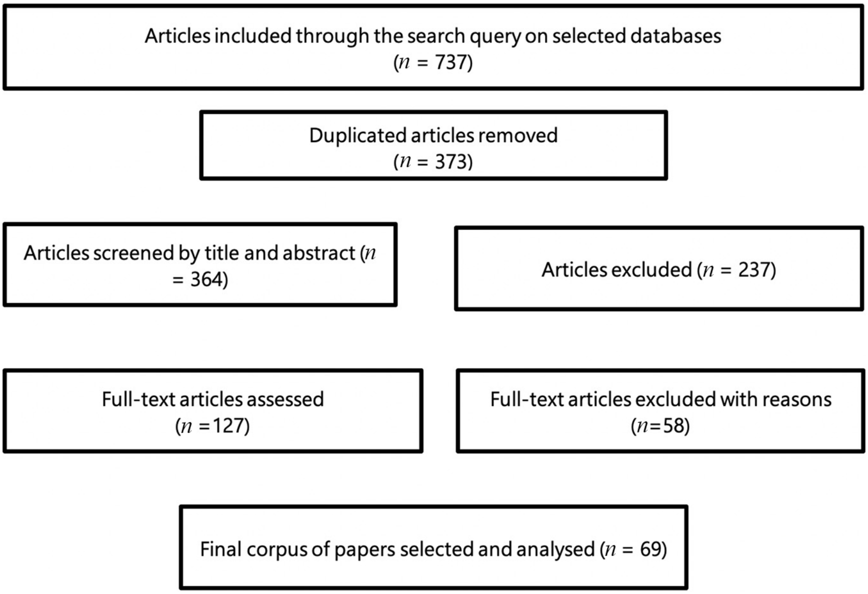

Figure 2.
Selection, screening, eligibility and inclusion process of articles

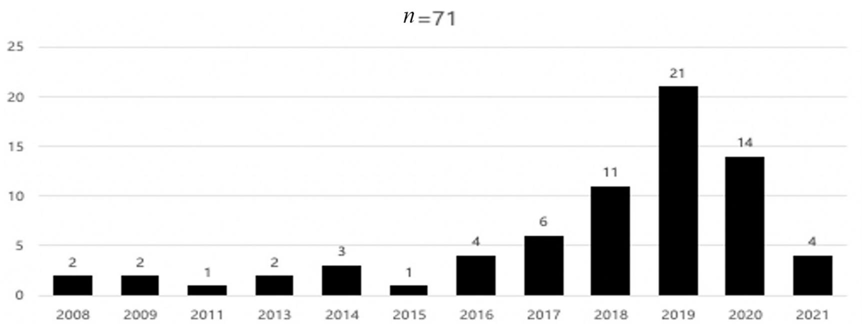

Figure 3.
Documents per year

of three articles per year. The 2018–2020 period seems to be the most prolific, covering almost 65% of the total, with 2019 marking the highest number of publications per year (21).

The descriptive analysis indicates the source titles in which the topic of our research has been mainly discussed. The following table lists the journals with the highest number of published articles concerning the subject of our research question (Table 3).

Source citation indicates that the *Journal of Cleaner Production* is the source with the highest number of citations for a single article included in the sample (Papadopoulos *et al.*, 2017), followed by *Annals of Operation Research* (185), *International Journal of Production Economics* (138) and *Technological Forecasting and Social Change* (129).

For article citation counting, we used the Scopus Field-Weighted Citation Impact to compare each paper citation with the average number of citations received by all similar documents over a three-year window. This choice was assumed with the aim of maximising the relevance of our sample, refusing the adoption of an arbitrary cut-off point for citation counting (Keupp *et al.*, 2012). This way, newer articles were not at a disadvantage compared with older ones. Table 4 lists the top 15 articles with the highest citations within the selected timeframe.

An analysis of documents by country shows that the USA has the highest number of both papers (20) and citations (785), followed by India (14 papers and 379 citations), the UK (13 papers and 632 citations) and France (9 papers and 452 citations). The table also shows the number of citations by source.

4.2 Networking and clustering analysis

Then, we used the VOSviewer algorithm (Van Eck and Waltman, 2014, 2017) to perform the cluster analysis starting from the co-occurrence analysis, which expresses the relatedness of items based on the number of documents in which they occur together. As explained before, our unit of analysis is author keywords, with a threshold of two keywords. We obtained a total of 37 keywords, which fell into four different clusters (Table 5 and Figure 4).

Our analysis includes the overlay visualisation, which is presented in Figure 5. Keywords in red colour refer to the more recent topics discussed in the academic debate on ETs in DM.

Source title	Article counts
Annals of Operations Research	7
International Journal of Emergency Management	6
Disaster Prevention and Management	5
Decision Support Systems	5
International Journal of Recent Technology and Engineering	4
Sustainability (Switzerland)	4
Applied Geography	3
Information Processing and Management	3
International Journal of Production Economics	3
International Journal of Production Research	3

Table 3.
Top ten journals publishing papers regarding DM

Document	Citations	Publication year
Papadopoulos *et al.*	189	2017
Yang *et al.*	129	2013
Ragini *et al.*	85	2018
Abidi *et al.*	80	2014
Dubey *et al.*	69	2019
Chowdury *et al.*	69	2017
Dubey *et al.*	56	2018
Shavarani	42	2019
Hung *et al.*	42	2016
Singh *et al.*	37	2019
Dubey *et al.*	28	2020
Zahra *et al.*	23	2020
Fan *et al.*	13	2021
Karami *et al.*	8	2020
Rodríguez-Espíndola *et al.*	6	2020

Table 4.
Citation counting. Top 15 cited documents

Blue cluster	Red cluster	Green cluster	Yellow cluster
machine learning	disaster management	emergency services	simulation
data mining	disaster response	humanitarian operations	decision support
sentiment analysis	disaster recovery	humanitarian supply chain	risk management
social media	emergency response	performance measurement	resilience
social media crowdsourcing	Drone	disaster	artificial intelligence
text classification	path planning	predictive analytics	deep learning
data analysis	unmanned aerial vehicle (UAV)	blockchain	
natural disaster	damage assessment	big data	
	strategic values	big data analytics	
	Internet of Things	trust	
	volunteered geographic information (VGI)	confirmatory factor analysis	
	geospatial data (GIS)		

Table 5. VOSviewer cluster description

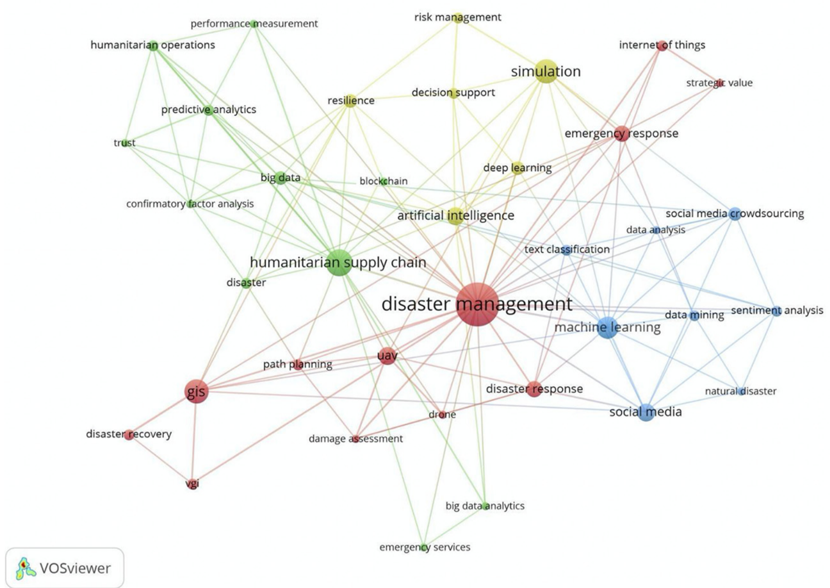

Figure 4. Network visualization

The following paragraph illustrates the findings of each cluster.

4.2.1 Yellow cluster. Papers included in the yellow cluster are mainly focused on the support that simulation approaches mainly provide to the preparedness phase of DM and to performance measurement.

In the broad management field, the value of simulation is highly recognised when experimentation in the real world is not feasible because of time, cost or ethical constraints (Davis *et al.*, 2007; Sterman, 2014; Noto and Cosenz, 2021). These kinds of situations characterise the contexts in which DM operates. In fact, experimenting with a disaster in the real world is never feasible or acceptable. As such, simulated environments are the only way

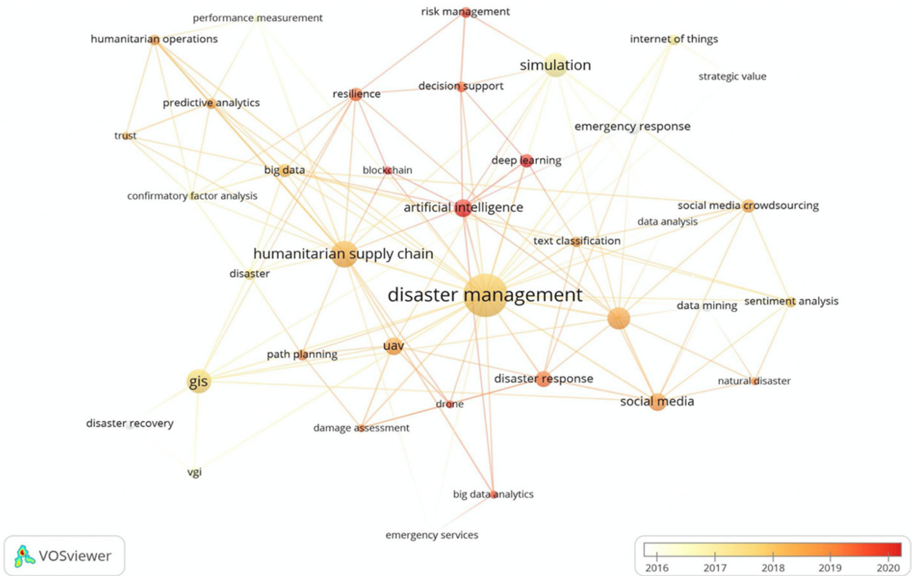

Figure 5.
Overlay visualization

we can discover how DM works and where high leverage points may lie to foster performance.

Simulation in DM studies has been explored in depth by Mishra *et al.* (2019), who conducted a literature review of the key approaches adopted by scholars in the field. These authors focused on system dynamics (SD), Monte Carlo simulation (MCS), agent-based modelling (ABM) and discrete event simulation (DES).

MCS has been mainly adopted for risk modelling, SD has been proposed as an effective tool for prevention. ABM has shown effectiveness in considering the behaviour of the multiple agents involved in the DM cycle. Less adopted, according to Mishra *et al.*'s (2019) study, was the DES, which is mainly used when modelling for large-scale disasters.

Whilst the literature on performance is already combined with simulation (Bianchi, 2016), with a few exceptions (Wang *et al.*, 2020a, 2020b), the resulting frameworks have not been applied to DM studies. However, in the analysed articles, simulation is mainly examined from the performance point of view. For example, Gul *et al.* (2020) used DES to assess the preparedness of an emergency department during an earthquake by using length of stay and utilisation of medical staff as measures of performance. Sahebjamnia *et al.* (2017) used coverage, cost and response time as performance measures in a decision support system for managing humanitarian relief chains. Lee and Lee (2021) focused on disaster response performance in a multi-agent environment. Fan *et al.* (2021) emphasised how ETs, such as AI algorithms and deep learning architectures, significantly contribute to disaster preparedness at the city level where, through the combination of multiple sources of data (geospatial, sensors, social media, crowdsourcing) and the interactions amongst different entities, the inefficiencies induced by their complex relationships can be easily explored. Moreover, the authors pointed out how temporal information recorded in the Disaster City Digital Twin enables monitoring, analysing and predicting the dynamic structures of the networks involved and their potential effects on the efficiency of relief and response actions.

In all the above-mentioned cases, scenario analysis through simulation was used to explore the preparedness and resilience of a specific system when dealing with different phases of the DM cycle by observing how the measures of performance identified may evolve under different environmental conditions.

4.2.2 Red cluster. Articles which fall into this cluster are mainly focused on the response phase of DM and provide interesting implications for what concern performance management. In light of our findings, the ETs which mostly support these phases are geospatial data (GIS), volunteered geographic information (VGI), IoT and robotics and automation (RA), such as drones and chatbots. Some scholars clearly described the complementary role of GIS and VGI in the provision of information, which can be helpful in coordinating response tasks amongst volunteer groups and official disaster agencies (Hung *et al.*, 2016; Contreras *et al.*, 2016; Schumann, 2018; Akter and Fosso Wamba, 2019; Sharma *et al.*, 2020). Other studies have shown the main challenges (digital divide, lack of resources, poor data quality) associated with their use in emergency response contexts (Haworth, 2016).

RA are effective tools for relief and response operations. To date, unmanned aerial vehicles (UAVs), which are a subcategory of RA, have been used in response to a wide range of disasters that have occurred in the last decade (Chowdhury *et al.*, 2017; Kim *et al.*, 2018), providing valuable support in searching the victims, mapping the affected zones, making structural inspections, estimating debris and assessing damage.

More recently, UAVs have become of key relevance in supplying emergency commodities in disaster-affected regions. In this regard, some scholars (Bravo *et al.*, 2019; Zwęgliński, 2020) stressed the impact of RA technologies in minimising the time and costs of disaster relief operations.

A further ET used in both the response and recovery phases of DM is IoT (Shahat *et al.*, 2020), which enables accurate and real-time accountability of resources and personnel allocated to emergency response operations.

Sinha *et al.* (2019) showed the role of IoT-based solutions in catering to the task requirements of the personnel involved in DM, specifically rescue operations. A critical aspect here is improper resource allocation, which slows down recovery efforts.

Performance measurement seems the main concern of the articles which fall into the red cluster. KPIs are mainly used to calculate the extent to which ETs might reduce time, distance covered, number of lives saved and relief provided. To some extent, ETs enhance the level of accountability of response operations, coping with the lack of visibility of resources available on the disaster scene or dispatched to other places prior to the event (Yang *et al.*, 2013).

4.2.3 Blue cluster. This cluster introduced an interesting topic concerning the contribution of data mining, machine learning and social media to performance measurement, management and accountability during disaster events. Data mining and machine learning algorithms are widely recognised tools to support decision making in many areas and, more specifically, along the DM cycle (Zagorecki *et al.*, 2013).

Machine learning is an umbrella term which sometimes overlaps with other concepts and applications, i.e. deep learning and AI. In any case, our findings show the high relatedness of this ET to the whole DM cycle, specifically to the emergency response phase (Chaudhuri and Bose, 2020).

The key role of social media in DM has been widely recognised in the literature (Xiao *et al.*, 2015). User generated content (UGC) from disaster-affected areas provides valuable information for emergency response when dealing with DM, as stated by Han *et al.* (2019). Nevertheless, this study points out the nature of UGC, which is huge, disordered and continuous. As a consequence, its exploitation has a direct impact on the effectiveness of response actions during disaster events.

On the one hand, the huge amount of data generated by social media – Twitter, Facebook, TikTok and other platforms – provides a big picture of the ongoing disaster situation in terms of location, temporal sequence and entity-related information (Hoang and Mothe, 2018; Singh *et al.*, 2019). On the other hand, the effective use of these tools raises critical issues in terms of text classification, data selection and validation, which are relevant when dealing with unpredictable and catastrophic events. More recently, sentiment analysis, topic modelling and other natural language processing tools have become promising techniques for assessing the reliability and accuracy of data gathered from social media during disasters (Thekdi and Chatterjee, 2019; Karami *et al.*, 2020). These ETs enable situational awareness in disaster response (Li *et al.*, 2018), especially through the analysis of crowdsourced data provided by the eyewitnesses of disaster events (Zahra *et al.*, 2020). From a performance-based view, it can be argued that the aforementioned ETs mainly support performance measurement through the real-time data gathered from social media. This result is coherent with our theoretical background. Moreover, social media are largely used by local and national authorities, as they show great potential for improving efficiency and widening the audience of information systems during disasters and for enhancing relations (e.g. improved transparency and accountability) between governments and the community affected by the event (Wehn and Evers, 2015).

4.2.4 Green cluster. The last cluster obtained from our bibliometric analysis consists of papers which focus on the post-disaster phase (i.e. recovery and mitigation), namely, the humanitarian relief and the related humanitarian supply chain (HSC) logistics. In this regard, the ETs linked with this phase mainly impact on performance management and accountability.

As is well known, humanitarian logistics refers to the mobilisation and management of resources (human and material) through which support for post-disaster response and rehabilitation operations is provided.

HSC management is crucial for the efficiency and effectiveness of DM systems. As observed by Rodríguez-Espíndola *et al.* (2020), the "duplication of efforts for data input, multiple formats, lack of control of budgets, absence of accountability, lack of integrity in procurement procedures, absence of a central database, and manual reporting and tracking" affect current DM systems.

The adoption of ETs, such as big data and predictive analytics (BDPA), provides valuable support to overcome the limitations in disaster relief operations. Indeed, scholars agree on the contribution that BDPA can offer when dealing with disasters (Ragini *et al.*, 2018). Akter and Fosso Wamba (2019) highlighted how BDPA can help address various challenges by providing critical recovery services in disasters. Considering the main properties of BD, such as volume (referring to the amount of data), velocity (referring to the frequency or speed by which data are generated and delivered), veracity (referring to data quality) and value (referring to the benefits from the analysis and use of big data), many authors have underlined how these help improve the visibility, coordination and sustainability of the HSC after a disaster (Papadopoulos *et al.*, 2017; Dubey *et al.*, 2018; Dubey *et al.*, 2019; Jeble *et al.*, 2019).

The subset of articles which fall into the green cluster gives relevance to some aspects related to both performance management and measurement. Abidi *et al.* (2014) analysed the state of the art of performance measurement, management and accountability in HSC. They pointed out some factors that determine reluctance to implement performance measurement in the humanitarian sector, such as a short-term perspective of disaster response actions, limited IT capacity and infrastructure and a chaotic environment.

Other scholars have underlined how ETs have enabled officials and non-government organisations involved in disaster relief and rehabilitation operations to reduce information asymmetry (Dubey *et al.*, 2018) and address the lack of trust amongst agents, volunteers and the affected community using blockchain technology (Dubey *et al.*, 2020); this has a critical role in enhancing collaboration and quickly building trust amongst various actors engaged in disaster relief operations.

5. Discussion and conclusions

This paper has sought to analyse how ETs impact on improving performance in DM processes, using a SLR as methodology of research and visualizing this impact with the VOSviewer software. The selected articles included in this review use different methodologies and focus on different phases of disasters, technologies and performance perspectives.

In many cases, we observed an inconsistent use of terms. This mainly happens in relation to the DM cycle. As mentioned in the theoretical background, DM can be framed into four phases: mitigation, preparedness, response and recovery. Many of the studies analysed, although focusing on specific phases, broadly refer to DM. This lack of specification poses challenges in the analysis and identification of the relationships between ETs and the DM phases. In some cases, DM is even used as a synonym for emergency management, resulting in a lack of clarity and confusion in the discipline. It is evident that ETs largely contribute to the management of disasters in each phase.

The complexity of DM often makes researchers and practitioners combine different technologies to improve the performance measurement, management and accountability of related activities. Although ETs may all be applied and successfully contribute to the different phases of the DM cycle, our analysis highlights some stronger linkages between some technologies, or features, and specific DM phases.

Many of the technologies considered rely on simulation features, which can be considered as a transversal tool supporting decision-makers at different levels in assessing the preparedness and resilience of a certain system prior to the occurrence of a natural disaster. Simulation enables experimentation with the consequences of a potential disaster in a virtual environment. This experimentation allows us to embrace the disaster risk reduction logic required to effectively tackle natural disasters. As such, simulation could be a valuable tool to improve preparedness. A simulated environment may foster the comprehension of the complex relationships characterizing disasters ex ante; thus, it may support the definition of consistent performance measures applicable to the preparedness phase.

Robotics and IoT are often associated with the improvement of operations in the response phase. ETs, such as drones or sensors, allow people to run activities that are not accessible to humans during disasters. These are valuable tools to monitor and manage performance during the response phases of the DM cycle.

Social media and related analytics tools have been widely used in two ways. On the one hand, they allow decision-makers to have access to a wider range of data sources (e.g. citizens, service users and other people involved in disasters) and to analyse this information through algorithms, such as topic modelling or sentiment analysis; this contribution is thus highly related to performance measurement. On the other hand, such tools foster performance accountability and disclosure towards the community.

In the following table, we highlighted the links between the performance perspectives here considered (measurement, management and accountability) and the main ETs identified by our review of the literature on DM (Table 6).

As emerges from the table above, all these ETs are key to the decision support systems in every DM phase as also emerged from the reviewed papers. However, it is evident that the ability to process the data obtained and to verify their reliability and quality requires much effort. This aspect is probably linked to the lack of performance-related aspects in many of the papers analysed here. In fact, although many of the papers in our sample focus on performance, few of them embrace a theoretical framework based on performance measurement, management or accountability.

In this paper, we attempted to frame existing literature on DM and ETs according to a performance-based perspective to orient future studies and to highlight how and which ET contributes to the different phases of DM cycle.

As a result of this literature review, it emerges that prior research has put emphasis on the usefulness of ETs for preventing and managing disasters as well as to provide channels for reducing the harmful consequences of these disasters. Our systematization of previous literature results may have important implications both for theory and practice. At the theoretical level, the paper provides a framework that links the key performance perspectives and DM phases with the implementation of ETs in the DM field; such a framework may represent a useful reference for studies aimed at deepening related aspect. Moreover, the study highlights that simulation and simulation-based tools allow scholars to explore and test the development of new theories and solutions to analyse performance in DM contexts (Davis *et al.*, 2007; Mishra *et al.*, 2019). At the practical level, the research suggests to the key involved actors (i.e. public administration, emergency managers, civil protection, experts and other stakeholders) to improve DM performance: analysing the importance of simulation tools to assess their preparedness; examining the ETs successfully used in the different DM phases (thus showing them how to invest in technologies); studying the importance to promote and enable citizens involvement as a new powerful source of data; and examining the need to invest in technologies to improve the ability to process, understand and use for decision-making purposes such data.

Despite its contributions, such as shedding light on the current state of the literature and providing future research directions about the theme addressed, this paper also has some limitations. Although frequently used in SLR, the criteria used to select our source of information – i.e. the exclusive focus on business, management and accounting categories;

Table 6.
Linking PM and ETs in DM cycle

Performance perspectives	Emerging technologies
Measurement	Simulation tools Big Data Analytics Artificial intelligence Social media
Management	Robotics and automation Remote sensing Internet of Things Artificial intelligence Big Data analytics Geospatial data
Accountability	Social media Blockchain

the exclusive focus on scientific articles in English language – may have excluded some valuable contributions. Future research could thus compare our results with other sources of information such as books and grey literature. Moreover, consistently with prior research, we have mainly analysed the implementation of ETs as "isolated islands." Nonetheless, future research could analyse integration processes of these ETs for managing all disasters in an efficient manner.

Finally, the study did not consider the question of technological acceptance by the users of the technologies. Verifying whether specific technologies or certain phases of the DM cycle are associated with greater reluctance on users' side could be interesting.

Notes

1. Centre for Research on the Epidemiology of Disasters – CRED. School of Public Health Université Catholique de Louvain.
2. www.undrr.org/terminology/disaster#:∼:text=A%20serious%20disruption%20of%20the,and%20environmental%20losses%20and%20impacts. Accessed on 1 February 2021.

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